ULTRASONIC VELOCITY AND THE ADIABATIC COMPRESSIBILITY OF SOME LIQUIDS

BY S. BHAGAVANTAM AND CH. V. JOGA RAO
(From the Department of Physics, Andhra University, Waltair)

Received March 13, 1939

1. *Introduction*

NUMEROUS papers relating to the determination of ultrasonic velocities in liquids by the method of diffraction of light have recently appeared in the literature and no attempt will be made here to give exhaustive references. Adiabatic compressiblity is an important physical property that may be deduced from a knowledge of the sound velocity in the liquid. It may also be measured directly by applying a static compression and noting the change produced in a known volume of the liquid contained in a suitable type of piezometer. These two methods of obtaining the same physical property are entirely different and relate to different circumstances under which the liquid is compressed. It is thought that it would be of interest to study a few liquids using both these methods and the present paper describes the results obtained in the case of six liquids. Glycerine and cyclohexanol are chosen to represent the class of highly viscous liquids and benzene, carbon tetrachloride, etc., are chosen to represent the class of less viscous liquids.

2. *Experimental*

A single valve (D.O. 24–Mullard) in a Hartley type of circuit is adopted for generating the oscillations. A quartz crystal, the thickness of which is about 2 mm., is used for setting up the ultrasonic waves in the liquid. The fundamental frequency of the crystal is about 1·6 megacycles. The optical arrangements and other details are similar to those already described by other investigators. λ 5460 A.U. of the mercury arc is used as the optical source. A Philip's Heterodyne wavemeter capable of measuring frequencies correct to 0·2 % is used for measuring the frequency. For each setting, the frequency of the oscillator is measured afresh as there are small but appreciable variations caused by the small differences in the setting of the condenser, the temperature of the crystal, etc. The adiabatic compressibility is calculated with the help of the formula $\beta_\phi = \frac{1}{V^2\rho}$ where V is the ultrasonic velocity and ρ the density. The latter at the appropriate temperature is obtained from the *International Critical Tables*. The ultrasonic velocities for different frequencies and at different temperatures are also incidentally measured for some liquids. As only the first order diffraction spectra have been observed in the case of glycerine, measurements could not be taken over other orders. The results are therefore less reliable in this case than in other liquids where several orders of diffraction spectra have been obtained and measured. At the room temperature, glycerine had to be allowed to settle down for over a day in order to obtain clear fringes.

A glass piezometer suitable for studying the adiabatic compressibilities of ordinary as well as moderately viscous liquids has been developed in this laboratory[1] and this apparatus is used in the present investigation for determining directly the adiabatic compressibility. Reference may be made to earlier papers published in these *Proceedings* for a detailed description of this apparatus. The only point that need be mentioned here is that the movement of the mercury pellet is not instantaneous in the case of very viscous liquids and the results are accordingly less reliable. Nevertheless, attempts have been made to take a large number of readings and only the best representative values are included in this paper. Care is taken to use the same sample of liquid in both the experiments and the work is done at the same time and in the same room so that the temperature is nearly the same in both cases. Liquids are purified by distillation and only the middle fraction is employed, for these experiments.

3. *Results*

In Table I, the compressiblity obtained with the help of the piezometer for pressures ranging between 1 and 2 atmospheres is compared with the compressiblity calculated from the ultrasonic velocity at the same temperature for six different liquids.

TABLE I. *Adiabatic Compressibility*

Liquid	Temperature °C.	Density	Frequency in megacycles	Ultrasonic velocity met. sec.	Compressibility from column 5 (per atm. per c.c.) $\times 10^6$	Compressibility from piezometer (per atm. per c.c.) $\times 10^6$
Benzene	27·5	0·8708	4·35	1283	70·7	72·5
Carbon tetrachloride ..	27·5	1·5800	4·35	932	74·0	74·0
Carbon disulphide ..	27·3	1·2530	4·38	1139	62·3	61·7
Cyclohexanol ..	27·8	0·9416	4·38	1459	50·5	50·5
Acetic anhydride ..	30·0	1·0670	4·34	1249	60·9	58·6
Glycerine	28·5	1·2562	4·48	1957	21·1	21·0

[1] N. M. Philip, *Proc. Ind. Acad. Sci.*, 1939, **9**, 109.

In Table II, the ultrasonic velocities in CCl_4 at 27·5° C. for a range of frequencies are given.

TABLE II. *Ultrasonic Velocity in CCl_4 at 27·5° C.*

Frequency in megacycles	1·564	4·35	7·20	13·08
Velocity in metres per sec.	931	932	931	933

Tables III and IV show the dependence of the ultrasonic velocity in cyclohexanol and glycerine respectively on temperature. The density at different temperatures is obtained from the *I.C.T.* and the corresponding compressibilities are claculated.

TABLE III. *Ultrasonic Velocity in Cyclohexanol at Different Temperatures*

Temperature °C.	Density	Velocity in metres per sec.	Compressibility (per atm. per c.c.) $\times 10^6$
30	0·9399	1453	51·0
40	0·9324	1432	53·0
50	0·9248	1400	55·9
60	0·9172	1364	59·3
70	0·9096	1307	65·2
80	0·9020	1258	70·9

TABLE IV. *Ultrasonic Velocity in Glycerine at Different Temperatures*

Temperature °C.	Density	Velocity in metres per sec.	Compressibility (per atm. per c.c.) $\times 10^6$
28·5	1·2562	1957	21·1
40	1·2490	1926	21·9
50	1·2426	1895	22·7
60	1·2360	1862	23·6
70	1·2292	1840	24·3

4. *Discussion of Results*

The following conclusions may be drawn from the results presented in this paper. The adiabatic compressibility of a liquid determined by the method of ultrasonic diffraction agrees very closely with that determined directly by using a piezometer. This result holds good alike for all liquids irrespective of whether they are highly viscous or not. There is no dispersion of the ultrasonic velocity in the range 1 to 13 megacycles for carbon tetrachloride. Similar results obtained in certain liquids have already been published by other workers.[2] The absolute value obtained for the ultrasonic velocity in CCl_4 is however distinctly higher than the one recently published by Seifen.[3] Viscous liquids do not exhibit any abnormal temperature coefficient of the sound velocity at moderate temperatures. The gradient is about $-3 \cdot 0$ metres per sec. per degree and is more or less the same as that exhibited by the less viscous liquids like toluene and carbon tetrachlcride.

5. *Summary*

The ultrasonic velocity has been measured in benzene, carbon tetrachloride, carbon disulphide, cyclohexanol, acetic anhydride and glycerine and hence the adiabatic compressibility calculated. The latter has also been measured directly with a piezometer and good agreement is found to exist between the values obtained in the two methods for all the six liquids. No dispersion of the ultrasonic velocity has been found in carbon tetrachloride in the range 1 to 13 megacycles. The dependence of the ultrasonic velocity on temperature has been investigated in cyclohexanol and glycerine in the range 30° C. to 80° C.

---

[2] R. Bär, *Proc. Ind. Acad. Sci.*, 1938, **8**, 289.
Z. f. Phys., 1938, **108**, 681.