A STUDY OF THE STRUCTURE CHANGE OF WATER BY MEASURING THE SOUND VELOCITY

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ABSTRACT

The sound velocity has been measured in twice distilled water between 1-40°C with 0.5°C temperature intervals. The differences between the calculated velocities using a fifth degree polinom which was obtained by a computer and the measured velocities were plotted as a function temperature. It was noticed that at some temperatures this curve has not a random distribution character.

The investigations showed that, at same temperatures Qurashi and Ahsanullah observed a series of discrete jumps in the activation energy of viscous flow of water, and Ahsanullah found discontinuities in the thermal expansion of water.

The relationships among those three phenomens were investigated.
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Several sound velocity measurements in distilled water have been taken over a temperature range 1-39°C at temperature intervals of 1.5°C using phase change method Barlow and Yazgan (1966). To minimize the errors arise from the acoustic path and water, these measurements were repeated twice employing two different acoustic paths, and water samples with 1.5°C temperature intervals but shifted 0.5°C relative to the previous temperature values. The difference between the calculated velocities using the equation,

\[ V = 1400.7873 + 5.18999T - 6.394257 \times 10^{-2} T^2 + 4.4060241 \times 10^{-4} T^3 - 2.399801 \times 10^{-6} T^4 + 6.214865 \times 10^{-9} T^5 \text{ m.sec}^{-1} \]

Obtained by Barlow and Yazgan (1966), and the measured velocities at identical temperatures are plotted as a function of temperature in Fig (1.a). Although the deviation of the velocity differences are not more than ±0.05 m.sec\(^{-1}\) which is approximately equal to the experimental error, the averaged velocity difference curve (dotted line) shows some maximums and minimums. Several times these measurements were repeated, and each time similar velocity difference curves have been found.

Although the velocity of sound in liquids is not a fundamental factor regard to the structure of liquids, investigations on some physical properties of water encouraged to make a correlation between the observed maximums, minimums, and structure of water.

It is a well known phenomenon that the activation energy of an associated liquid decreases smoothly when the temperature increases, but Qurashi and Ahsanullah (1961, 1964) claim to have observed a series of discrete jumps in the activation energy of viscous flow of water, Fig (1.b) from very accurate differential viscosity measurements, and have concluded that at activation energy step,
a 30 to 50% change in the volume of the molecular aggregator or a corresponding change in the entropy of activation for the viscous flow, or a combination of these takes place. Furthermore it was shown that the amount of the change in the activation energy at the steps, corresponds to the necessary energy to break up for a hydrogen bond between the neighbouring molecules. Qurashi (1963) investigated the change of the second differential of thermal expansion of water Fig. (1.c) and observed some discontinuities which are in agreement with those found by Qurashi and Ahsanullah (1961), and has suggested that these two phenomena have the same physical basis of intermolecular aggregation, or re-arrangement.

Table (1) shows the temperatures which corresponds to sharp jumps in activation energy, \( \frac{\Delta \alpha}{\Delta T} \), and the minimums of the averaged velocity difference curve. It can be seen that eight of the given nine temperatures corresponding to three curves are in agreement within \( \pm 1.2^\circ \)C. At the fifth discontinuity point a maximum, and at 24\( ^\circ \)C a minimum, in the averaged velocity difference curve were apparent.

<table>
<thead>
<tr>
<th>No of Discontinuity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Fig. (1.a)</td>
<td>3</td>
<td>7.5</td>
<td>11.5</td>
<td>14.5</td>
<td>-</td>
<td>20</td>
<td>28</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>Fig. (1.b)</td>
<td>3</td>
<td>9.5</td>
<td>11.8</td>
<td>15.6</td>
<td>17.5</td>
<td>21.6</td>
<td>27.3</td>
<td>33.9</td>
<td>36.9</td>
</tr>
<tr>
<td>Fig. (1.c)</td>
<td>5.3</td>
<td>8.0</td>
<td>11.4</td>
<td>16.0</td>
<td>18.8</td>
<td>22.4</td>
<td>28.9</td>
<td>33.5</td>
<td>36.8</td>
</tr>
</tbody>
</table>

A minimum in the averaged difference velocity curve corresponds to a maximum in the true velocity of sound. In water, the association decreases with temperature and leads to a decrease in adiabatic compressibility and in density. Considering that the decrease in density due to a sudden decrease in association is very small (Qurashi, 1963) this sudden decrease in association will decrease the adiabatic compressibility and will lead to an increase in the velocity.
Consequently although it can not be said that a definite correlation exists between the fluctuations in velocity and any possible structural changes in water there is some evidence to support this hypothesis. Since eight of the nine discontinuities of the activation energy, $\Delta a^2/\Delta a^2$, and averaged velocity differences are in agreement within $1.2^\circ C$, the fluctuations in velocity probably have a physical basis which might be that of inter-molecular aggregation of re-arrangement as proposed by Qurashi and Ahsanullah (1961, 1964). In order to make a definite study the accuracy of the sound velocity measurements must be increased at least twice.
ACKNOWLEDGMENTS

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FIG. 1  DIFFERENCE VELOCITY (a),  ACTIVATION ENERGY (b),  AND $-4\Delta=\Delta T_{\times 10^5}$ (c) AS A FUNCTION OF TEMPERATURE.