

A STUDY OF THE VELOCITY OF SOUND IN SOLUTIONS

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Introduction. At the 1926 meeting of the Indiana Academy of Science, Dr. A. L. Foley reported on a unique phenomenon which he had observed while dissolving some sodium phosphate in a tumbler of water (1). He found that the pitch of the sound produced by striking a spoon on the tumbler lowered considerably at first, and after a few seconds returned to about the same as it had before the salt was added. The pitch was controlled by the depth, elasticity and density of the liquid phase, together with the characteristics of the tumbler. In the experiment, the properties of the tumbler remained the same. The change of pitch could not have been due to a change in depth or density, for it did not occur with all salts (chloride of tin, for instance), nor did it change when fine sand was stirred in the water. It would appear that the change was due to a transitory change in the elasticity of the liquid during the process of solution. Quoting from Dr. Foley's original report, we read: "Inasmuch as wave velocity depends on the elasticity of the medium in which the waves are traveling, one might expect a considerable change in the velocity of sound through a fluid in which a salt is dissolving, and possibly in any solution in which chemical action is taking place."

It was the purpose of this investigation to determine whether or not such a change in the velocity of sound through water while a salt is dissolving does exist, and to what extent the change takes place.

Description of apparatus. The scheme finally evolved for making the measurements will be discussed with the aid of the schematic dia-

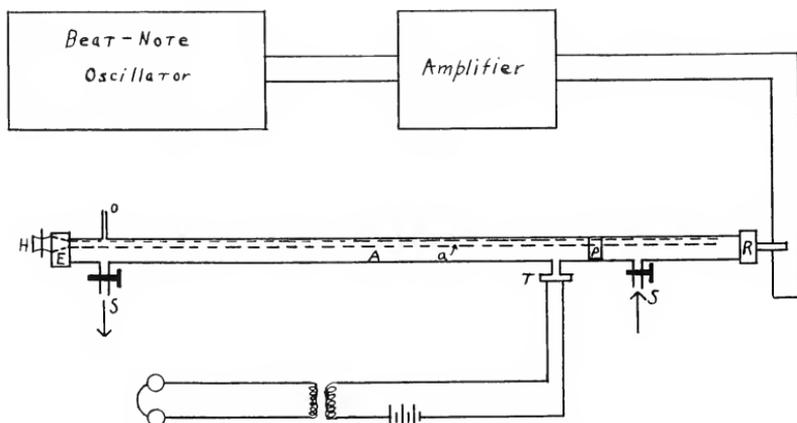


Fig. 1.

gram (Fig. 1). The method was essentially a resonance tube method employing a constant length tube with a source of sound of variable pitch. The pitch of the sound was controlled by a beat-note oscillator whose output was fed into an amplifier, and this in turn connected to a telephone receiver *R*, which was sealed with wax to the end of the resonance tube *A*. The frequency emitted by the beat-note oscillator was varied by changing the setting of a small vernier condenser. The instrument was calibrated so that the frequency could be determined with an accuracy of 20 vibrations per second. As the measurements were made at about 3,000 cycles per second, this represented an accuracy of about .7 per cent. The amplifier was a Sampson A. C. machine, type P-44. The source of sound was the magnet and diaphragm from a Stromberg-Carlson telephone receiver. The resonance tube proper was a brass tube six feet long and having a wall $\frac{3}{16}$ " in thickness and inside diameter of two inches. To allow the tube to be filled with water and to be drained and washed, two stopcocks *S*, were soldered to the bottom, one 28 cm. from the source of sound, the other, 8 cm. from the opposite end. It was necessary to add an opening *O*, to allow air to enter or leave the apparatus during the process of filling or draining.

The following method was devised to detect a condition of resonance: the tube was driven at the ninth harmonic, making nodes occur at the two ends and at intervals of 16 inches between the two ends. An opening was made two feet from the source of sound at which a node would occur if the tube was in resonance using the ninth harmonic. A telephone transmitter was screwed to a short tube, which was in turn soldered to the edge of the opening. A battery and telephone transformer were connected in series with the transmitter; the output of the transformer was connected to a pair of ordinary head phones. Since a transmitter responds to changes of pressure, and since a node is a position of maximum change in pressure, maximum response occurs when a node is opposite a transmitter. This occurs at resonance. This resonance condition was very sharp, being easily located to within ± 10 vibrations per second. Finally, it was necessary to devise a method of dropping the salt into the water at the right moment. For this purpose, to one end of a two mm. brass tube 180.5 cm. long, with an inside diameter of two cm., was fixed a thin brass disk completely closing the end; to the other end was soldered a handle arrangement *H*, similar to a stopcock, made to fit into a conical hole in the end piece *E*. A slit, nine mm. wide, was milled the total length of the tube. The tube was supported partially by the stopcock arrangement at the left end, and by a support *P* at the right end made of thin brass sheeting so placed as to obstruct the passage of sound down the tube as little as possible. Measurements were made in the following manner: the salt to be investigated was placed in the small tube and the small tube inserted, with the slit up, in the large tube. The large tube was then about three-fourths filled with water. The oscillator was started and the resonance frequency noted for pure water. The small tube was then inverted spilling the salt into the water and the resonance frequency was noted at minute intervals for about fifteen minutes.

Results. Data were obtained using sodium phosphate, tin chloride, sodium acetate, sodium carbonate, copper sulphate, zinc sulphate, sodium chloride, calcium chloride, and powdered quartz, as solutes. In general, the velocity rose from its initial value to a higher value. After a certain value was reached, the velocity remained constant. A set of data for tin chloride is included in this report, and is typical of all sets taken.

Time in min.	Frequency	Velocity in meters per sec.
0	2900	1179.3
1	2900	1179.3
2	2930	1191.5
3	2930	1191.5
4	2950	1199.7
5	2980	1211.7
6	2980	1211.7
7	2980	1211.7
8	3000	1220.0
9	3000	1220.0
10	3000	1220.0
11	3000	1220.0
12	3000	1220.0
13	3000	1220.0
14	2990	1215.9
15	3000	1220.0
16	3000	1220.0

This is shown in graphical form in Fig. 2, which also includes data for sodium carbonate and powdered quartz. It is to be noticed that the velocity as computed from the product of the frequency and wave length

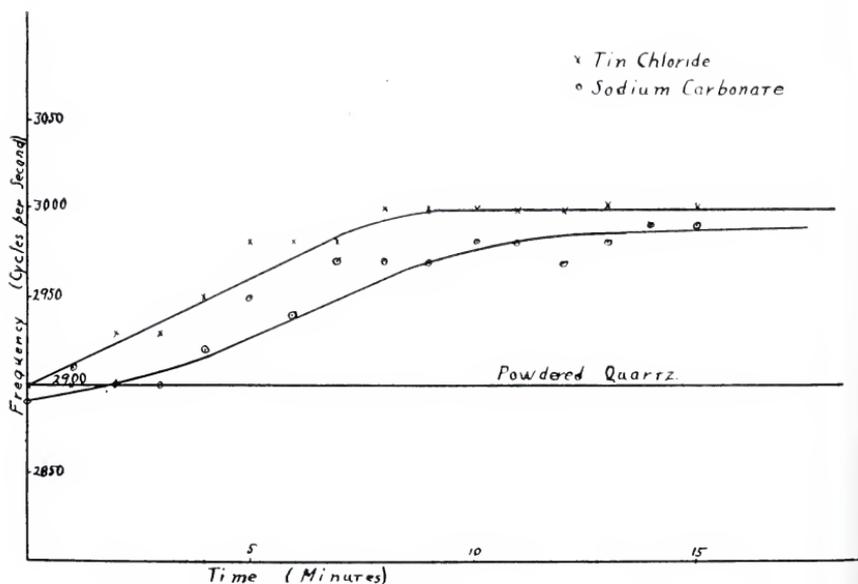


Fig. 2.

is below the accepted values for the velocity in the free fluid. This is due to the well known tube errors. The graphs are therefore frequency-time graphs which can be interpreted just as easily as velocity-time graphs. In the case of sodium chloride, the final solution was about 10 per cent NaCl. The tables give a change of 2.3 per cent between the velocity in pure water and in a 10 per cent NaCl solution. The observed rise was 2.34 per cent. It was concluded that the final value reached represented the velocity in the solution in a static condition. All solutions used were dilute and in no case were they stirred. The velocity of the process of solution was fairly slow. The conditions for this experiment were not the same as for the glass tumbler. It is impossible, therefore, from the results of this investigation to state an accurate reason why the pitch of a glass tumbler should fall while a salt is going into solution. More work on this same problem is being planned by the author.

Acknowledgments. In conclusion, I wish to express my thanks to Dr. Foley, for suggesting this problem and for his helpful advice from time to time. My thanks is due also the members of the Physics Department staff of Indiana University who gave aid in preparing the apparatus and many valuable suggestions.

Reference

- (1) Proc. Ind. Acad. of Science. 36:134. 1927.