observers then arise partly from differences in training but also quite probably from anomalies of various kinds in the binocular visual mechanism.

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Absorption of Sound in Aqueous Solutions of Electrolytes

A LARGE number of aqueous solutions of electrolytes have been investigated for frequency-, concentrationand temperature-dependence of their absorption of sound in the frequency-range 8 kc./s. to 15 Mc./s. It has been found that all uni-univalent salts investigated have no measurable sound absorption, that is, their excess absorption in concentrations up to 1 mole per litre is less than 10 per cent of the absorption of pure water. This proved to be the case also for a number of bi-univalent salts, except for high concentrations of sodium sulphate and magnesium chloride.



Absorption coefficient of a 0.02 N magnesium sulphate solution \times wave-length (2 α , λ) vs. frequency

 \bigcirc , Measured by resonance method ; \checkmark , measured by reverberation method ; \bigcirc , measured in progressive waves

The bi-bivalent sulphates examined (magnesium, manganese, copper, zinc, cobalt and nickel salts), on the contrary, showed very great absorption, which, from the slope of the frequency response, must be due to a relaxation process¹. For example, the frequency response of the absorption of a 0.02 N magnesium sulphate solution is given in the accompanying graph, where $2\alpha \lambda$ is plotted as a function of frequency. These parameters give a typical relaxation curve with a maximum at 120 kc./s. Other sulphates show similar curves, the relaxation frequencies of which are somewhat higher (for example, manganese, copper, zinc and cobalt sulphates), or lower (for example, nickel sulphate). The dependence on concentration from 0.002 to 0.2 mole per litre for magnesium sulphate proved to be linear within the limits of accuracy of measurement, that is, there is a constant absorption effect or absorption cross-section per molecule. Although this result is opposite to the expectation of Liebermann¹, who assumed an increase of the absorption cross-section proportional to the square root of the concentration, we believe that the relaxation process must be due to an interaction between the ions similar to that assumed by Liebermann. In favour of this are the changes of absorption observed in mixing different salts. In particular, we found the

following rule for mixtures of magnesium sulphate and sodium chloride. The decrease of absorption observed when sodium chloride is added to a magnesium sulphate solution can be explained by the loss of some of the ion-pairs of the magnesium sulphate through interaction with the sodium chloride, which therefore cause no absorption in this frequency-range. The remainder of the magnesium sulphate concentration still effective in absorption is given by :

$$C_{\rm eff} = [{
m MgSO_4}] \; {[{
m MgSO_4}] \over [{
m MgSO_4}] + f. \; [{
m NaCl}]} \; ; \; f = 1/5.$$

The factor f = 1/5 can be explained by the difference in interaction between 2-2- and 2-1-valent pairs of ions.

The further increase of absorption² above 5 Mc./s. is also remarkable. From its frequency response, it seems to be due to another relaxation process, caused by a change in the hydration shells of the reacting ions. The dependence of frequency response and the amount of absorption on concentration and temperature are in accord with this view.

The measurements were made with different methods in successive frequency-ranges, since any one method is only applicable in a limited frequencyrange of about 1 decade.

In the range 8-50 kc./s., the absorption of the solution was' determined from the decay constant of a single natural vibration of the solution in a spherical glass vessel with thin walls³. The losses of the walls were eliminated by comparison with the decay constant of pure water, measured at the same natural frequency. The absorption of pure water was assumed to be given by

$$2\alpha/f^2 = 50 \times 10^{-17}$$
 cm.⁻¹sec.²,

the value which is obtained at higher frequencies.

In the range from 50 kc./s. to 1 Mc./s., a statistical reverberation method according to Meyer and Skudrzyk⁴ has been applied, using a 100-litre aluminium vessel. With this method a mean value of the decay constants of many natural vibrations is measured, within a band-width of \pm 10 kc./s. The losses at the walls here, too, are eliminated by comparison with determinations using pure water.

In the frequency-range 3-15 Mc./s., the absorption was determined from the difference of level of the sound intensity in a plane progressive wave at two different distances from the source. This difference was obtained by photometrical comparison of the diffraction loss of the zero-order light of two beams of light crossing the sound field. The absorption determined for pure water by this method differs up to 10 per cent from the above-mentioned value. The excess absorption of magnesium sulphate as given in the graph is only of the same magnitude as the absorption of pure water in this frequencyrange.

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- ¹ Liebermann, L., Phys. Rev., 76, 1520 (1949).
- ² Smith, M. C., Barrett, R. E., and Beyer, R. T., J. Acous. Soc. Amer., 23, 71 (1951).
- ³ Cf. Leonard, L., J. Acous. Soc. Amer., 18, 252 (1946).
 ⁴ Skudrzyk, E., Oestr. Ing. Arch., 4, 408 (1950). Mulders, C. E., App. Sci. Res., B, 1, 341 (1949).