Ultrasonic Studies of the Hydration of Various Compounds in an Ethanol-Water Mixed Solvent. II. The Hydration of Organic Compounds

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In a previous paper,[1] it was reported that the degree of the hydration of inorganic electrolytes in a mixed solvent of ethanol and water can be determined by measuring the lowering of the ethanol concentration corresponding to the maximum point caused by the addition of the electrolytes in the plot of the sound velocity against the composition of the mixed solvent. A number of methods have been reported for the determination of the degree of hydration. Some of these methods are, however, applicable only to hydration of an electrostatic nature, and others, only to that of hydrogen bonding.

In the present study an attempt is made to determine, by the previous method, the degree of the hydration of such organic compounds as glucose, sucrose, glycine and gelatine.

1) T. Yasunaga, Y. Hirata, Y. Kawano and M. Miura, This Bulletin, 37, 867 (1964).

Experimental

Method. — The technique of measurement was similar to that reported in detail in the previous paper.[1]

Materials.—The materials described in Table I have been selected as examples of organic compounds. The solubilities of these compounds in

TABLE I. THE SOLUBILITIES OF ORGANIC COMPOUNDS IN ETHANOL

Compound	Solubility
Glucose	0.22 g./100 g. satd. solution (25°C)[2]
Sucrose	0.0 g./100 cc. ethanol (14°C)[3]
Glycine	0.029 g./100 cc. satd. solution (25°C)[2]
Gelatine	0.024 g./100 g. 99.69% ethanol (25°C)

2) A. Seidell, "Solubilities of Inorganic Compounds," 3rd ed., D. van Nostrand Company, New York (1941).

3) Landolt-Börnstein, Physikalisch-Chemische Tabellen, III (1923), p. 723.

ethanol are given in the table, together with the results measured for gelatine in our laboratory. They show that the mutual interaction between these compounds and ethanol is very small and may be disregarded without causing a serious error in the estimation of the hydration. Glucose, sucrose and glycine were guaranteed pure grade reagents and were used without further purification. Gelatine was purified by precipitation, with the addition of ethanol from its aqueous solution.

Results

The change in the velocity of sound when ethanol is added to the aqueous solutions of the compounds at various concentrations is presented graphically in Figs. 1—4. The amount of ethanol in the solution needed to give a maximum in the sound velocity decreases with the increasing concentration of the solute. The amount of hydration calculated from Eq. 1 in the previous paper[1] is shown in Fig. 5;

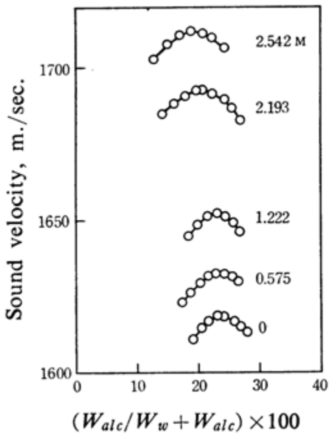

Fig. 1. Sound velocity in ethanol-water solution of glucose.

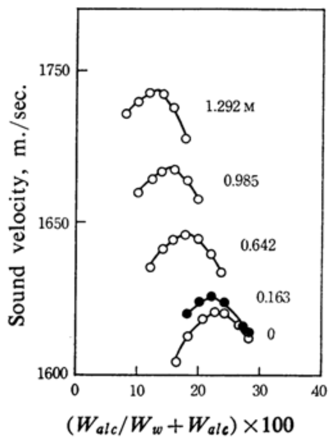

Fig. 2. Sound velocity in ethanol-water solution of sucrose.

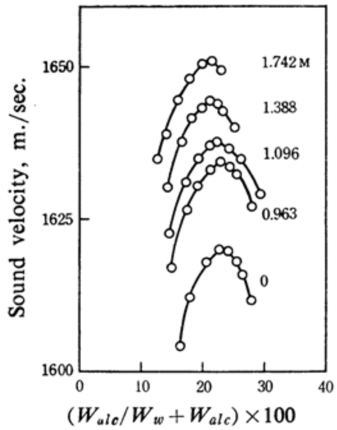

Fig. 3. Sound velocity in ethanol-water solution of glycine.

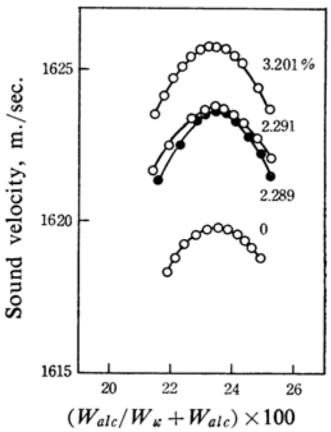

Fig. 4. Sound velocity in ethanol-water solution of gelatine.

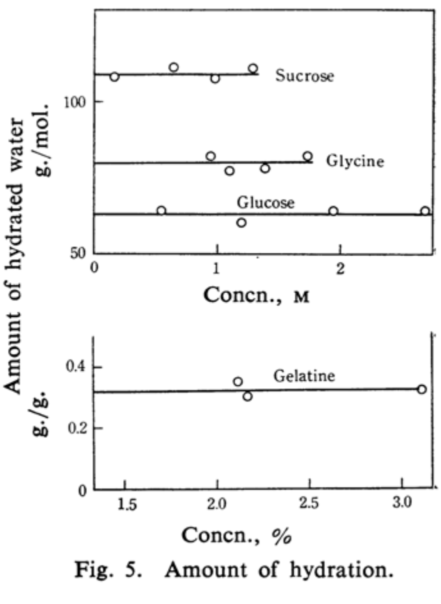

Fig. 5. Amount of hydration.

it is constant with respect to the concentration. The values for the degree of hydration at an infinite dilution, as calculated from Fig. 5, are given in Table II, together with those obtained by other experimental methods.

TABLE II. COMPARISON OF THE DEGREE OF HYDRATION

Compound	This method mol./mol.	Activity method[4] mol./mol.	Sound velocity[5] mol./mol.
Glucose	3.5	2.0	3.5
Sucrose	6.1	4.8	3.8
Glycine	4.4		2.9[6]
Gelatine	0.32 g./g.		0.27 g./g.[7]

Discussion

The degree of the hydration obtained in the present study is constant and is independent of the concentration for all the compounds. This result is in good accord with the expectation from the principle of the calculation of the degree of hydration proposed in this paper. The numerical value of the degree of hydration also agrees well with those obtained by other workers, as is shown in Table II. These facts indicate that the findings concerning the degree of hydration given in the table are quite reasonable, as has been discussed in the previous paper, and that an acoustical structure of the solution of ethanol and water at the maximum velocity of sound is not affected by the presence of inorganic electrolytes or organic compounds.

As can be seen in Table II in this paper and from Table III in the previous paper, various methods have been used to determine different types of the degree of hydration. As has been shown in the previous report, the hydration for inorganic compounds is caused by the electro-static interaction between ions and water molecules, whereas the hydration for organic compounds, as reported in this paper, is mainly caused by hydrogen bonding.

The results in these two papers lead us to the conclusion that the present experimental method can be used to determine the degree of hydration of both types, electrostatic and hydrogen-bonded. Therefore, further developement of this method will facilitate the study of the hydration of polymers which are soluble in water and insoluble in ethanol.

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4) Y. Miyahara, *Kagaku*, **29**, 365 (1959).
5) H. Shiio, *J. Am. Chem. Soc.*, **80**, 70 (1958).
6) Y. Miyahara, This Bulletin, **26**, 390 (1953).
7) H. Shiio, *J. Chem. Soc. Japan, Pure Chem. Sec.* (*Nippon Kagaku Zassi*), **74**, 203 (1953).