be extremely polar in comparison with most of the organic liquids. The polar characteristics of the benzene derivatives are distributed much more over the whole molecule than is the case with the paraffin derivatives.

7. Attention should be called here to an error which is sometimes made in connection with the orientation theory, which is that the total surface energy, and the free surface energy, or the surface tension, are all due to the orientation of the molecules. This is just the opposite of the truth, since the surface energy is due to the stray surface field, and this field is decreased, and not increased, by the orientation. The general law for surfaces as presented by Harkins, Davies and Clark is: If we suppose the structure of the surface of a liquid to be at first the same as that of the interior of the liquid, then the actual surface is always formed by the orientation of the least active portion of the molecule toward the vapor phase, and at any surface or interface the change which occurs is such as to make the transition to the adjacent phase less abrupt. This last statement expresses a general law of which the adsorption law is only a special case. If the molecules are monatomic and symmetrical, then the orientation will consist in a displacement of the electromagnetic field of the atom. Since it is the *free* energy which is decreased by the orientation, thermodynamics tells us that the orientation will take place of itself.

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# THE RELATION BETWEEN THE TOTAL ACIDITY, THE CONCENTRATION OF THE HYDROGEN ION, AND THE TASTE OF ACID SOLUTIONS.

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In some determinations of the hydrogen ion concentrations of various fruits, including apples and tomatoes, the author found that sour varieties gave nearly the same value as did less sour varieties. The small variation in the hydrogen ion concentration of 30 varieties of tomatoes from $P_H$ 4.148 to 4.565 seems insufficient to account for the difference in taste. This suggested the question: "What do we taste in acid solutions, hydrogen ion concentration or total acidity?"

Opinions of various persons differs, but most seem to believe that the concentration of hydrogen ions is the important factor. Some work by

Kahlenberg[1] and Richards[2] indicates that there are factors of importance other than hydrogen ion concentration, but no definite relation of the factors is given. Crozier[3] suggests that the potentially ionizable hydrogen is a factor as well as the actual hydrogen ion concentration.

By making buffer solutions of different values of hydrogen ion concentration one can then obtain dilutions with the same hydrogen ion concentration but differing widely in total acidity. The same total acidities can also be produced at different hydrogen ion concentration values. The hydrogen ion concentration of an acetate-buffer mixture depends upon the ratio of acetic acid to sodium acetate, and not upon the total acetate ion present.

With the assistance of a number of persons in the Bureau of Plant industry, a comparison was made between the tastes of sodium acetate and acetic acid buffer mixtures at different hydrogen ion concentrations and at different total acidities for each hydrogen ion concentration. The range covered was from solutions almost too sour to be tolerated down to practical neutrality of taste. The acid taste of the buffer solutions was expressed in terms of the normality of hydrochloric acid of the same degree of sourness. For hydrochloric acid the dissociation into hydrogen and chlorine ions is practically complete for the dilutions which can be tasted without injury, 97% for $N$ 0.025$N$.[4]

The hydrogen ion concentration and total acidity of hydrogen chloride solution is, therefore, practically the same. Hydrochloric acid was selected on account of its almost complete dissociation, its lack of oxidizing or other disturbing properties possible in other acids. Some confusion was experienced by nearly all the experimenters on account of slight differences in flavor of the 2 different acid solutions. Hydrochloric acid has a faintly bitter taste while acetic acid tastes somewhat aromatic. This is evidently due to the negative radical and would be difficult to eliminate. This confusion was noticed mostly in the more acid solutions. The dilutions were made with redistilled water and this was found to be confusing in the higher dilutions on account of its insipid taste. Considerable difficulty was found in remembering the taste of a solution, but by repeated alternation 5 persons usually selected the same or nearly the same standard solution without knowing the dilutions given for the trial. It

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[1] Louis Kahlenberg, "The Action of Solutions on the Sense of Taste," *Bull. Univ. Wisconsin*, **25**; *Science Ser.*, **2**, No. 1, 1–31 (1898); "The Relation of Taste of Acid Salts to Their Degree of Dissociation," *J. Phys. Chem.*, **4**, 33 (1900); "The Relation of Taste of Acid Salts to Their Degree of Dissociation, II; *ibid.*, **4**, 533 (1900).

[2] T. W. Richards, "The Relation of the Taste of Acids to Their Degree of Dissociation," *Am. Chem. J.*, **20**, 121–126 (1898).

[3] W. J. Crozier, "Taste of Acids," *J. Exp. Neurology*, **26**, 453–462 (1916).

[4] *Landolt-Börnstein*, "Physikalisch-Chemische Tabellen."

was found that experience was gained so that one could more accurately estimate the acidity after a few trials.

The sourness of an acetate-buffer solution, measured as equivalent to a solution of hydrochloric acid in which the hydrogen ion concentration and total acidity are the same, is a function of 2 independent variables, the hydrogen ion concentration of the buffer solution and the total acidity of the buffer solution.

By plotting the negative logarithms of the various ion and total concentrations expressed in equivalents per liter, on logarithmic 3 dimensional Cartesian coördinates, the graph modeled in Fig. 1 was obtained, showing the relative values of the total acidity, the hydrogen-ion concentration, and the sourness of the solution.

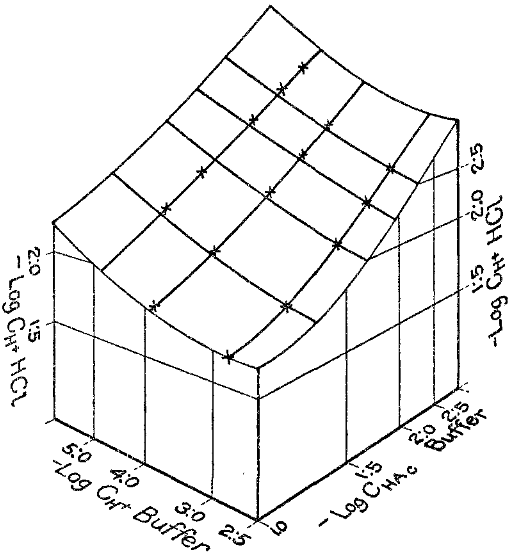

Fig. 1.

From these values it appears that the total-free acid of the solution is a factor as well as the hydrogen ion concentration. It is desirable, therefore, in determining the acidity of acid foods to give both of these values in order that their desirability as edible products can be determined.

In the ingestion of such acid foods as tomatoes or citrous fruits the tendency to produce hyperacidity is, therefore, dependent also upon the total acidity or quantity of acid ingested and not necessarily upon the hydrogen-ion concentration alone. Although it alters the taste, the addition of sugar changes neither the hydrogen-ion concentration nor the total acidity of a solution.

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