

# THE SURFACE-TENSIONS OF AQUEOUS SOLUTIONS OF ALKALINE CHLORIDES.

By C. E. LINEBARGER.

Received December 31 1898.

THE object of this investigation is to determine the surface-tensions of aqueous solutions of the chlorides of lithium, sodium, and potassium up to the limits of their solubility. The apparatus described in a previous number of this Journal<sup>1</sup> permits of the same degree of accuracy when the liquid is filled with suspended particles as when it is clear. The saturation of a liquid with a solid can accordingly be accomplished with the capillary tubes right in the mixture, and the surface-tension can be measured from time to time until the saturation is completed. The operations of determining the surface-tension of a saturated solution are as follows: The solution is saturated in a thermostat at the required temperature. A sample is then transferred to the tube of the apparatus and, the temperature being the same as before, several readings are made. Some of the powdered solid is then added and with frequent agitation readings are taken at intervals of thirty minutes or so for several hours. If the preliminary saturation has been total, these readings are the same.

The alkaline chlorides used were bought as chemically pure. Lithium chloride (Koenig's C. P.) was not subjected to further purification, but the chlorides of sodium and potassium were recrystallized a couple of times.

The solutions of potassium and of sodium chloride were prepared by weighing the well-dried salts and dissolving them in known weights of water. The solutions of lithium chloride were

<sup>1</sup> Vol. 18, No. 6, June, 1896. I have substituted for the compression bulb therein described the following simple arrangement. A large bottle filled with water is placed on a bench on the table so as to give an effective fall of water of about two feet. The water is siphoned over into a second bottle, the siphon-tube reaching to its bottom. This bottle is closed with a twice-perforated rubber stopper, through which pass the siphon-tube and an elbow-tube connected with the capillary tubes of the apparatus. The air forced from the second is passed through a piece of thermometer tubing to prevent too rapid a flow and a solid glass bead placed in the connecting rubber hose to act as a stop-cock. By pressing the hose around the head with the thumb and finger so as to form a channel alongside it, the flow of air can be regulated with great nicety.

made from weighed quantities of water and of a strong solution of the salt that had been analyzed for chlorine.

The specific gravities were determined with pycnometers of different styles and sizes, and are referred to water at 4°. Their accuracy is denoted by the number of decimal places retained.

The data are given in the following tables :

SURFACE-TENSIONS OF AQUEOUS SOLUTIONS OF LITHIUM CHLORIDE.

Temperature = 25°.

Per cent. of salt.	Mols. of salt per liter.	Specific gravity.	Apparatus constant.	Distance between tubes in $\frac{1}{16}$ inch.	Surface-tension in dynes per cm.
9.18	2.28	1.05023	1.259	54.50	73.17
18.06	4.70	1.10298	1.259	55.38	78.17
26.14	7.11	1.15468	1.259	56.50	83.39
40.49	12.02	1.25904	1.259	58.23	93.88

Lithium chloride is so soluble and prone to supersaturation that the surface-tension of its saturated solution was not measured. As a hydrate and not the pure salt crystallizes from its solution, it was not thought that this datum would present anything of especial interest. The strongest solution examined was very near to saturation.

SURFACE-TENSIONS OF AQUEOUS SOLUTIONS OF SODIUM CHLORIDE.

Temperature = 25°.

Per cent. of salt.	Mols. of salt per liter.	Specific gravity.	Apparatus constant.	Distance between tubes in $\frac{1}{16}$ inch.	Surface-tension in dynes per cm.
5.62	1.04	1.0370	2.366	29.29	71.59
10.87	2.06	1.0726	2.366	28.41	73.04
13.52	2.52	1.0944	1.259	52.63	73.71
15.72	3.04	1.1123	2.366	28.11	75.04

Temperature = 20°.

5.62	1.04	1.0388	2.366	29.01	72.38
10.87	2.06	1.0746	2.366	28.55	73.78
15.72	3.04	1.1146	2.366	28.30	75.87
26.19 <sup>1</sup>	5.38 <sup>1</sup>	1.20046	2.333	28.27	80.60

The surface-tension of a sodium chloride solution saturated at 25° was not determined. The determinations at 20° and 25° show such constant differences that its value may be calculated with no appreciable error by subtracting from the surface-tension of the solution saturated at 20° the average difference between

<sup>1</sup> Saturated solution.

the determinations made on the same solutions at the two temperatures, for the solubility of common salt varies very slightly with the temperature.

SURFACE-TENSIONS OF AQUEOUS SOLUTIONS OF POTASSIUM CHLORIDE.

Temperature = 25°.

Per cent. of salt.	Mols. of salt per liter.	Specific gravity.	Apparatus constant.	Distance between tubes in $\frac{1}{8}$ inch.	Surface-tension in dynes per cm.
9.09	1.29	1.0555	1.257	53.45	72.05
10.71	1.53	1.0665	1.278	52.26	72.33
16.67	2.48	1.1069	1.257	52.02	73.61
23.08	3.57	1.1526	1.257	51.11	75.39
26.44 <sup>1</sup>	4.18	1.17885	1.257	50.98	76.97

The data given in the preceding tables are plotted in Figs. 1 and 2; the ordinates of both are surface-tensions, and the abscissas concentrations, expressed in the first figure as percentages, and in the second as mols. per liter.

The percentage curves show that the surface-tensions are the

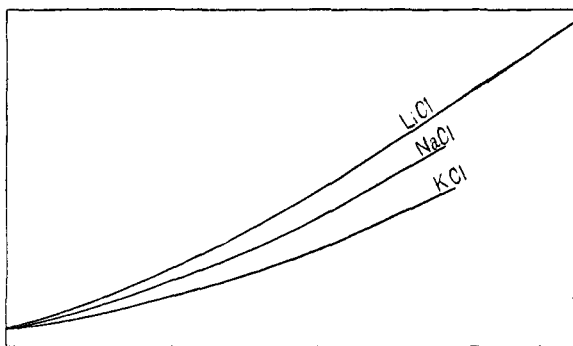


Fig. 1.

greater the smaller the molecular mass of the salt. Thus, the curve for sodium chloride lies about midway between those for lithium and potassium chloride. The surface-tension of these salt solutions is seen to be a function of their molecular masses. This is very plainly brought out by the curve in Fig. 2, where the concentrations are expressed in mols. per liter. It is seen that the surface-tensions of the solutions of the alkaline chlorides are the same, for the curve represents the behavior of each of the salts examined.

<sup>1</sup> Saturated solution.

As has already been found by Bulinginsk,<sup>1</sup> Valson,<sup>2</sup> Quincke,<sup>3</sup> Volkmann,<sup>4</sup> Rothier,<sup>5</sup> Traube,<sup>6</sup> and Dorsey,<sup>7</sup> the surface-tensions of the solutions of the salts increase with the concentration. The investigators named did not use very concentrated solutions, however, and assumed that the surface-tension was a linear function of the concentration. This conclusion is not justified when the surface-tension is measured throughout the

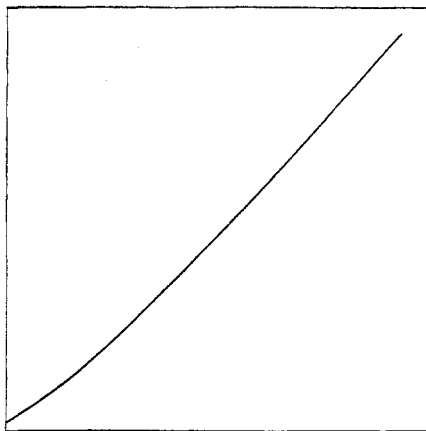


Fig. 2.

entire range of solubility of an alkaline chloride. The curve in Fig. 2 is slightly convex towards the axis of abscissas. It is, however, for small changes in concentration, practically a straight line, and for such concentration changes a formula of the form  $\gamma' = \gamma + ka$  may be applied, where  $\gamma'$  denotes the surface-tension of the solution,  $\gamma$  that of water,  $k$  a constant, and  $a$  the concentration expressed in mols. per liter. At 25° the surface-tension of pure water is 69.85 dynes per cm.<sup>8</sup> We accordingly may establish the following equations :

$$\begin{array}{l} \text{Between 0 and 1 mol. } \gamma' = 69.85 + 1.48 a, \\ \text{“ 1 “ 2 mols. } \gamma' = 69.85 + 1.55 a, \\ \text{“ 2 “ 3 “ } \gamma' = 69.85 + 1.62 a, \\ \text{“ 3 “ 4 “ } \gamma' = 69.85 + 1.70 a, \\ \text{“ 4 “ 5 “ } \gamma' = 69.85 + 1.78 a. \end{array}$$

<sup>1</sup> *Pogg. Ann.*, 134, 440 (1868).

<sup>3</sup> *Pogg. Ann.*, 337 and 560 (1877).

<sup>5</sup> *Ibid.*, 21, 576 (1884).

<sup>7</sup> *Phil. Mag.*, Nov. 1897, p. 369.

<sup>8</sup> Ramsay and Shields : *Ztschr. phys. Chem.*, 12, 432 (1893).

<sup>2</sup> *Ann. chim. phys.* (4), 20, 361 (1870).

<sup>4</sup> *Wied. Ann.*, 17, 353 (1882).

<sup>6</sup> *J. prakt. Chem.*, 31, 192 (1885).

There are too few data to permit of establishing the values of the constant  $k$  for concentrations greater than five mols. Still since the values of the " $k$ 's" increase by about 0.08 as the concentration increases by one mol., if it be legitimate to assume that this regularity continues, similar formulas may readily be found for greater concentrations.

---

## ESTIMATION OF THE LIME, POTASH, AND PHOSPHORIC ACID IN HAWAIIAN SOILS PROBABLY AVAILABLE FOR THE IMMEDIATE CROP.

BY WALTER MAXWELL.

Received January 11, 1899.

### ASPARTIC ACID METHOD.

1. The hypothetical principle of this method rests upon the assumption that the solvents used shall compare with the solvents that operate in the processes of soil disintegration, and plant-food preparation, in the field.<sup>1</sup>

2. The standards of control of this method are the ascertained results of the natural processes of soil decomposition in the field, under the conditions of climate and nature of the soils of the Hawaiian Islands, as indicated by the "results of cropping" and "the composition of the waters of discharge" flowing from the land into the sea.<sup>2</sup>

3. The sample is obtained by the mode given in previous publications; *viz.*, by the pipe, where this is practicable, otherwise by the spade. The calculation of available matter per acre is based upon the specific gravity (weight of the cubic foot) of the soil, and the depth to which the sample is taken. In thin soils the amount is less, in deep soils greater, than the amount found in one acre to a depth of one foot, upon which depth, calculations, so far, in the use of this method, have been based.

4. The solvent used in this method is aspartic acid. This acid was adopted because it was found that "aspartic acid dissolves phosphoric acid, lime, potash, and other bases (iron and alumina) out of the soil in almost the exact proportions that these ele-

<sup>1</sup> See the author's work on the "Lavas and Soils of the Hawaiian Islands;" also this Journal, 20, 107 (1898).

<sup>2</sup> See "Lavas and Soils of the Hawaiian Islands."