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ON THE ACTION OF CERTAIN VEGETABLE ACIDS ON LEAD AND TIN.

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The enormous and continually increasing use of canned goods—fruit, vegetables, meat, etc.—has led to the discussion, on sanitary grounds, of the possible injurious effect of the material of the can on its contents; and, among other chemical questions, is that of the effect of various vegetable acids upon the material of the cans, *i. e.* upon the can itself and upon the solder which may be exposed on the inside. The fear also has arisen lest the tin-plate itself of which the cans are made should, for the sake of greater cheapness, be made not with pure tin, but with an alloy of lead and tin.

The following paper contains the results of experiments on the action of certain acids on tin and on alloys of tin and lead, and also the results of some investigations as to the quality of the tin-plate and tin-foil in actual use as envelopes for food products.

On the Action of Vegetable Acids on Alloys of Lead and Tin.

One of the most important things to be considered in investigating the power of an alloy to resist corrosion is the electrical

relation of the metals which compose it. Lead and tin are so nearly alike in this respect that their relation to each other may be reversed in different liquids, or even in the same liquid under different circumstances. On this subject chemical literature contains many and quite discordant statements. It seems, however, to be fully established by the experiments of Weber¹ that ordinary vinegar will dissolve lead from an alloy of lead and tin containing only 5 per cent. of lead, and further, that from a dilute acidulated solution of acetate of lead, lead is precipitated by an alloy containing as little as 5 per cent. of tin.

In the following investigation I wished to ascertain quantitatively the action of several of the more common vegetable acids, all quantitative experiments that I had seen being made with acetic acid only.

To ascertain definitely the effect of alloying on the corrosion of the metals, the amount of lead or tin dissolved when pure must be compared with the amount dissolved, under the same conditions, from an alloy exposing the same surface of the metals in question. To make the experiment, as is usually done, with equal-sized pieces of pure metal and alloy is not fair, if we consider the action to be proportional to the surface of metal exposed, because then the united surface of the two pieces of pure metal is twice that of the alloy and the surface of either metal exposed in the alloy is less than that exposed by the piece of pure metal.

To overcome this difficulty I proposed to proportion the size of the pure metal plates according to the composition of the alloy. In order to proportion them more easily and to have them of a size readily comparable with one another, I took into account the specific gravity of the metals in making the alloys. Hence, barring the unequal contraction of the metals on alloying, I had alloys exposing a known surface of lead and tin. I could now expose an equal surface of pure metal to the same acid under the same conditions and compare the action, thus getting a fair idea of the effect of alloying the metals, as well as the action of the acid on a known surface of pure lead or tin.

I made after this plan three alloys—one with equal parts of lead and tin, one with an excess of lead, and one with an excess of tin. These were all that I had time to experiment with, but the researches

¹ *Dingl. pol. Jour.* 232, 153, 264; *Wagner Jahresb.* 1879, 196-207.

of Weber¹ show that, for acetic acid at least, the action on the alloys increases quite regularly as the proportion of lead increases, therefore the action on alloys containing lead and tin in different proportions than those I took can be inferred with fair accuracy by interpolation.

The alloys were made from pure lead and tin, well stirred when melted, then cast in thin sheets in iron moulds. Afterwards these sheets were rolled into thin strips and trimmed to the size desired. Strips of pure lead and tin were made at the same time. The tin used was Banca tin, containing 99.78 per cent. of tin, a trace of lead and a trace of copper.

For acids I used a solution of glacial acetic acid in distilled water, which, on titration with a standard solution of ammonia, proved to have a strength equal to 5.75 per cent. of acetic acid; also solutions of crystallized tartaric and citric acids, which neutralized the same amount of ammonia.

The tartaric and citric acids contained, as they always do, a trace of lead, but the amount was much too small to appreciably influence the results.

Strips of the alloys 1.2 inch wide and 12 inches long were cut out, exposing, therefore, counting both sides, 28.8 square inches or one-fifth of a square foot. Pieces of pure lead and tin were taken of the same width, but varying in length to suit the composition of the alloy to which each corresponded. These strips of metal were rubbed until perfectly bright, washed with a little dilute alcohol, heated in a drying closet, and when cool weighed. Immediately after weighing they were put into separate beakers each containing 200 cc. of acid. The long strips were coiled and kept off the bottom of the beaker by a \surd of glass rod. In each case the liquid covered the metal by more than an inch, so that the air did not take part directly in the action. Each beaker was covered with a watch-glass.

After standing for two weeks in a place where the temperature varied from 25° to 35° Centigrade, the contents of the several beakers were examined. The most notable change was that the acid containing the tin, as well as that containing the alloys, had a decided yellowish tint, while that containing the lead was perfectly clear and colorless. The metal in all cases was more or less tar-

¹ *Loc. cit.*

nished, but the tin much more noticeably so than the lead. Two of the alloys in the acetic acid were sprinkled with little black crystals. These crystals were evidently metallic; they were carefully collected, washed with alcohol, dried and analyzed. The result of the analysis is given later. The smallest of the pieces of lead in the tartaric acid was covered with small transparent crystals; these were set aside for further examination. The pieces of tin were covered with a dusty powder, but there was not enough of it to analyze.

When the contents of each beaker had been carefully examined, the strips of metal were lifted out, washed with a jet of water, dried with a soft towel, and, after remaining a while in a drying-closet, weighed. The loss of weight served as a rough check on the subsequent analysis of the solutions. Next, the metal in solution was precipitated by sulphuretted hydrogen. The lead caused dense black precipitates, much finer in the tartaric and citric acid than in the acetic. The tin in the acetic acid came down of a dark brown color, showing the stannous salt, while that in the tartaric acid gave, at first, merely a yellow coloration. After standing some time, however, a flocculent, apparently hydrated precipitate settled out. The same seemed to be the case with the citric acid solutions, but on closer examination an almost transparent precipitate could be seen, and it settled much quicker than in the case of the tartaric acid. These same peculiarities of the precipitates of sulphide of tin were noticed throughout the whole investigation. It was also invariably the case with the alloys that the precipitates in acetic acid were dark brown, while those in tartaric and citric acids were light-colored and flocculent.

After some experimenting I found the best way to separate the sulphides of lead and tin in the solutions was to carefully decant as much as possible of the liquid through a filter, neutralize what remained with ammonia water, add a little yellow ammonium sulphide, and heat; then collect the sulphide of lead on the filter used before. The tin was determined in the alkaline filtrate. The sulphide of lead was converted into the sulphate before weighing; the sulphide of tin into the oxide in the usual manner. In no case was either metal determined by difference.

The results obtained are given in the following tables. The first two columns of Table I give the amount of surface of each metal exposed both as pure metal and in the alloy.¹ The last two give the total weight of metal, lead and tin, dissolved from the alloy, and from an equal surface of the same metals exposed in the pure state. But although the surface exposed was the same, the unalloyed metals were exposed to twice as much acid, each being in a separate beaker with 200 cc. of the acid. This might have been righted by proportioning the acid to the surface exposed, but this did not occur to me until too late. It will be noticed how often the amount dissolved when unalloyed is equal to twice that dissolved from the alloy.

TABLE I.

| Kind of Acid. | Surface exposed, in sq. inches. | | Percentage composition. | | Loss of weight, in grams. | Found in solution, in grams. | | Percentage of dissolved metals. | | Total amount dissolved (in grams) from | |
|---------------|---------------------------------|------|-------------------------|-------|---------------------------|------------------------------|--------|---------------------------------|-------|--|--------------|
| | Lead | Tin. | Lead. | Tin. | | Lead. | Tin. | Lead. | Tin. | Alloys. | Pure Metals. |
| Acetic ... | 7.2 | ... | 100. | ... | 0.4320 | 0.4216 | ... | ... | ... | ... | ... |
| " ... | 7.2 | 21.6 | 34.1 | 65.9 | 0.4525 | 0.0432 | 0.3312 | 11.54 | 88.46 | 0.3744 | 0.7122 |
| " ... | ... | 21.6 | ... | 100. | ... | ... | 0.2906 | ... | ... | ... | ... |
| " ... | 14.4 | ... | 100. | ... | 0.5470 | 0.5444 | ... | ... | ... | ... | ... |
| " ... | 14.4 | 14.4 | 60.8 | 39.2 | 0.5145 | 0.0558 | 0.3552 | 13.57 | 86.42 | 0.4110 | 0.8242 |
| " ... | ... | 14.4 | ... | 100. | 0.2820 | ... | 0.2798 | ... | ... | ... | ... |
| " ... | 21.6 | ... | 100. | ... | 0.6195 | 0.6137 | ... | ... | ... | ... | ... |
| " ... | 21.6 | 7.2 | 80.84 | 19.16 | 0.6570 | 0.4887 | 0.1589 | 75.46 | 24.54 | 0.6476 | 0.8073 |
| " ... | ... | 7.2 | ... | 100. | 0.2135 | ... | 0.1936 | ... | ... | ... | ... |
| Tartaric. | 7.2 | ... | 100. | ... | ... | 0.0452 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0280 | 0.0029 | 0.0269 | 9.73 | 90.27 | 0.0298 | 0.0664 |
| " | ... | 21.6 | ... | 100. | 0.0210 | ... | 0.0212 | ... | ... | ... | ... |
| " | 14.4 | ... | 100. | ... | 0.6605 | 0.0586 | ... | ... | ... | ... | ... |
| " | 14.4 | 14.4 | 60.8 | 39.2 | 0.0385 | 0.0042 | 0.0332 | 11.23 | 88.77 | 0.0374 | 0.0750 |
| " | ... | 14.4 | ... | 100. | 0.0150 | ... | 0.0164 | ... | ... | ... | ... |
| " | 21.6 | ... | 100. | ... | 0.0655 | 0.0654 | ... | ... | ... | ... | ... |
| " | 21.6 | 7.2 | 80.84 | 19.16 | 0.0345 | 0.0080 | 0.0269 | 22.92 | 77.08 | 0.0349 | 0.0787 |
| " | ... | 7.2 | ... | 100. | 0.0115 | ... | 0.0113 | ... | ... | ... | ... |
| Citric ... | 7.2 | ... | 100. | ... | 0.3540 | 0.3521 | ... | ... | ... | ... | ... |
| " ... | 7.2 | 21.6 | 34.1 | 65.9 | 0.1690 | 0.0165 | 0.1461 | 10.15 | 89.85 | 0.1626 | 0.4785 |
| " ... | ... | 21.6 | ... | 100. | 0.1175 | ... | 0.1264 | ... | ... | ... | ... |
| " ... | 14.4 | ... | 100. | ... | 0.4355 | 0.4348 | ... | ... | ... | ... | ... |
| " ... | 14.4 | 14.4 | 60.8 | 39.2 | 0.1725 | 0.0210 | 0.1355 | 13.42 | 86.58 | 0.1565 | 0.5439 |
| " ... | ... | 14.4 | ... | 100. | 0.1080 | ... | 0.1111 | ... | ... | ... | ... |
| " ... | 21.6 | ... | 100. | ... | 0.4870 | 0.4875 | ... | ... | ... | ... | ... |
| " ... | 21.6 | 7.2 | 80.84 | 19.6 | 0.2305 | 0.0982 | 0.1221 | 44.58 | 55.42 | 0.2203 | 0.5946 |
| " ... | ... | 7.2 | ... | 100. | 0.1030 | ... | 0.1071 | ... | ... | ... | ... |

¹ See page 2.

The alloys Nos. 1 and 2 in the acetic acid were the ones on which the small black crystals before mentioned were found. The crystals on No. 1 weighed 0.0970 gram, and gave on analysis 0.0931 gram of lead, or 91.6 per cent. Those on No. 2 weighed 0.0620 gram, and gave 0.0586 gram of lead, or 94.45 per cent. They were evidently, therefore, crystals of lead. This amount of lead might have been considered as having been in solution, but it is not included in the amount given in the tables. Weber¹ noticed similar crystals in his experiments, and explained their presence by supposing that, at the surface of the liquid where the oxygen of the air and the acid both acted on the metal, so much lead was dissolved that it was precipitated again by the tin of the alloy below the surface. As, in my experiments, the metal was kept entirely covered by the acid, this could hardly have been the case.

The transparent crystals found on the smallest piece of lead in the tartaric acid were nearly, if not quite, insoluble in water. Under the microscope they appeared to be hexagonal and very much like small quartz crystals. They were found, on comparison, to have the same form as crystals of tartrate of lead. From this and from a few qualitative tests I decided that they must be tartrate of lead. The crystals adhered so firmly to the lead that they could not be removed, therefore the loss of weight, as well as the lead in them, could not be determined.

The results of the experiment agree in all essential points with those statements which I have found that have been supported by actual experiment. Those statements which would have us suppose that alloying with tin increased the corrosion of lead seem to be founded on the case of some stray tank or pipe, rather than on a well-conducted research. Moreover it does not appear, as is often supposed to be the case, that the alloy is more acted upon than either of the metals.

It was suggested that the galvanic action would influence more the rapidity of the corrosion than the total amount of metal dissolved; hence that the effect would be more clearly marked at the end of two days than at the end of two weeks, but experiment showed that this is not the case. For this experiment I used only one of the alloys, namely that containing the most tin: the results are recorded in Table II. While the amount of action is

¹ *Loc. cit.*

not exactly proportional to the time of exposure, it is not far from being so in the case of acetic acid, and in the case of citric and tartaric acids it is evident that the action is very slight at first and increases appreciably as time goes on.

TABLE II.

| Kind of Acid. | Surface exposed, in sq. inches. | | Percentage composition. | | Loss of weight, in grms. | Found in solution, in grams. | | Percentage of dissolved metals. | | Total amount dissolved (in grams) from | |
|---------------|---------------------------------|------|-------------------------|------|--------------------------|------------------------------|--------|---------------------------------|-------|--|--------------|
| | Lead. | Tin. | Lead. | Tin. | | Lead. | Tin. | Lead. | Tin. | Alloys. | Pure Metals. |
| Acetic | 7.2 | ... | 100. | ... | 0.0515 | 0.0497 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0460 | 0.0046 | 0.0387 | 10.62 | 89.38 | 0.0433 | 0.0896 |
| " | ... | 21.6 | ... | 100. | 0.0400 | ... | 0.0399 | ... | ... | ... | ... |
| Tart'c | 7.2 | ... | 100. | ... | 0.0400 | 0.0374 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0120 | 0.0012 | 0.0124 | 8.82 | 91.82 | 0.0136 | 0.0470 |
| " | ... | 21.6 | ... | 100. | 0.0255 | ... | 0.0096 | ... | ... | ... | ... |
| Citric | 7.2 | ... | 100. | ... | 0.0625 | 0.0599 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0215 | 0.0015 | 0.0218 | 6.44 | 93.56 | 0.0233 | 0.0817 |
| " | ... | 21.6 | ... | 100. | 0.0120 | ... | 0.0218 | ... | ... | ... | ... |

In these experiments, although the metal was covered with the acid and the beaker with a watch-glass, the air had more or less free access to the surface of the liquid. To see what effect the air had on the corrosion, and to approach more nearly the conditions of a sealed can, I took some glass-stoppered bottles and repeated the experiment in them. I weighed the strips of metal as before and placed them in the bottles, then heated the bottles on steam cups, and while hot filled them with the acid, also heated to boiling to expel any air. The bottles were at once tightly stoppered. As they cooled a few of them leaked a little, but as they were nearly full of liquid very little air could enter. They were put in the same place as in the former experiments and left for two weeks. On being examined at the end of this time there was evidently much less corrosion than in the case of the corresponding experiments in open beakers. There was no discoloration, and no crystals formed. That the air had been pretty well excluded could be seen from the way the stoppers stuck in the bottles even after they could be turned with ease. The same difference in the character of the precipitates of sulphide of tin was noticed as before.

The following table gives the results :

TABLE III.

| Kind of Acid. | Surface exposed, in sq. inches. | | Percentage composition. | | Loss of weight in grams. | Found in solution, in grams. | | Percentage of dissolved metals. | | Total amount dissolved (in grams) from | |
|---------------|---------------------------------|------|-------------------------|------|--------------------------|------------------------------|--------|---------------------------------|-------|--|--------------|
| | Lead. | Tin. | Lead. | Tin. | | Lead. | Tin. | Lead. | Tin. | Alloys. | Pure Metals. |
| Acetic | 7.2 | ... | 100. | ... | 0.0900 | 0.0886 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0365 | 0.0052 | 0.0289 | 15.25 | 84.74 | 0.0341 | 0.1332 |
| " | ... | 21.6 | ... | 100. | 0.0430 | ... | 0.0446 | ... | ... | ... | ... |
| Tart'c. | 7.2 | ... | 100. | ... | 0.0365 | 0.0343 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0085 | 0.0018 | 0.0084 | 17.65 | 82.35 | 0.0102 | 0.0400 |
| " | ... | 21.6 | ... | 100. | 0.0080 | ... | 0.0057 | ... | ... | ... | ... |
| Citric. | 7.2 | ... | 100. | ... | 0.0560 | 0.0510 | ... | ... | ... | ... | ... |
| " | 7.2 | 21.6 | 34.1 | 65.9 | 0.0250 | 0.0018 | 0.0249 | 6.74 | 93.25 | 0.0267 | 0.0644 |
| " | ... | 21.6 | ... | 100. | 0.0120 | ... | 0.0134 | ... | ... | ... | ... |

It will be noticed that the corrosion was considerably less. For convenience I give a table showing the comparative results obtained in open and in closed vessels.

TABLE IV.

| Dissolved from | By Acetic Acid. | | By Tartaric Acid. | | By Citric Acid. | |
|----------------|-----------------|---------|-------------------|---------|-----------------|---------|
| | Open. | Closed. | Open. | Closed. | Open. | Closed. |
| Lead | 0.4216 | 0.0886 | 0.0542 | 0.0343 | 0.3521 | 0.0510 |
| Alloy..... | 0.3744 | 0.0341 | 0.0298 | 0.0102 | 0.1628 | 0.0267 |
| Tin | 0.2906 | 0.0446 | 0.0212 | 0.0057 | 0.1264 | 0.0134 |

The acids used were of about the strength of good vinegar. It would naturally be supposed that less strong acids, such as usually occur in canned goods, would cause correspondingly less corrosion. This does not seem to be the case; an incomplete series of experiments seem to indicate that a dilute acid, if used in sufficient quantities, causes much more corrosion than would be inferred from its strength.

To try now the action on the cans themselves, and also the effect of the solder, I took three cans that had been emptied and put 200 cc. of acid into each—acetic acid in one, tartaric acid in another, and citric acid in the third. I covered these cans as well as I could by tying two thicknesses of paper over each, but of course they were practically open cans; moreover, the acid did not nearly fill them. They would represent, therefore, a can that had been partly emptied and set away, rather than a fresh one.

When examined at the end of two weeks, the tinning up as far as the acid reached was entirely taken off, except in the acetic acid. The citric acid had a yellowish color, and a quantity of white powder was deposited on the bottom of the can. I emptied the acid from the cans and added a few drops of chlorhydric acid, fearing that the organic acid was not sufficient to hold up the sulphide of iron. The addition of chlorhydric acid and a little warming dissolved the white powder in the citric acid, and at the same time destroyed the yellow color. On passing sulphuretted hydrogen through the solutions, a very large precipitate was obtained. This I filtered off, washed, and treated with ammonium sulphide; the residue was collected on a filter, dissolved in strong chlorhydric acid, and after evaporation the lead was precipitated as sulphate.

The tin was determined in the ammonium sulphide solution. The result was as follows:

| | | | | |
|-----------------------|--------|-----------------|--------|---------|
| Acetic acid dissolved | 0.4178 | gram of tin and | 0.0117 | of lead |
| Tartaric " " | 1.0430 | " " | 0.0873 | " " |
| Citric " " | 0.6828 | " " | 0.1559 | " " |

In addition to the lead and tin there was a good deal of iron dissolved.

This shows that corrosion takes place very rapidly after a can is opened, and that a can once opened should be emptied at once. One would have supposed that the acetic acid would have acted more than the others, and it probably would if the conditions in the different cans had been exactly the same. It is probable that more solder was exposed in the cans treated with tartaric and citric acids; at any rate the lead must have come from the solder, as the tin from which the cans were made proved, on being tested, to be free from lead.

On the Quality of Commercial Tin-plate.

Having seen the action of some of the more common vegetable acids on lead and tin, and the alloys of the same, we come to the tin-plate itself.

The tin-plate used in this country is entirely imported, most of it coming from England. The two principal kinds are "Bright plate" and "Terne plate." Bright plate is, or should be, tinned only with pure tin. It is divided into several grades, according to the thickness of the tinning and the quality and heaviness of the

iron which forms the basis, but in all these grades the tinning is supposed to be pure tin. Terne plate, on the other hand, is known to contain large quantities of lead, and is often called lead-plate, there being no attempt to pass it for tin, at least by respectable persons.

Tinware and fruit-cans are made from bright plate, while terne plate is used altogether for roofing. Of course the boundaries are sometimes overstepped; those who are very particular use bright plate for roofing, and those who are too avaricious may make tinware out of terne plate. This last, I think, however, is very seldom the case, and the heavy nature of terne plate unfits it for canning.

Knowing these divisions of tin-plate, the questions before us now are: Is bright plate, especially that used in canning, always tinned with pure tin? and how commonly is terne plate used where it will come in contact with food?

I procured some specimens of plate through the kindness of one of the largest importing houses in the city. These I tested by several methods. With the bright plate, taking small pieces, I could find no lead at all, and only after taking half a square foot did I find a trace. This was no more than would be found in most English bar-tin. I now tested a number of cans from various sources, as well as the worst-looking tinware from the so-called 5-cent stores, but not once did I find enough lead to show an intentional adulteration. Neither have I found any well instituted attack on the character of the tin-plate in this country. A good deal has been said and many suspicions thrown out, but the only statements of analyses that I have seen are in a Board of Health report of a Western State.¹ The author found lead so invariably in all tin articles that came into his hands that one cannot help suspecting that the methods of analysis were unreliable. He even observes that he found a considerable quantity of lead in what was sold for pure tin—a thing quite possible, it is true, but not likely to happen with dealers to whom a chemist would naturally go for pure supplies.

Even if the tin of the can is pure, there remains the solder, which always contains a large quantity of lead, and is used very freely. There remains, also, the fact that the vegetable acids act considerably upon tin itself. There are many published statements as to the presence of tin in canned goods, and the careful inspection of

¹ Mich. Board Health Rept. 1878,

the inside of a can which has contained an acid fruit shows quite clearly in many cases that corrosion has taken place. Moreover, although my experiments tend to show that the amount dissolved when the air is excluded is much less than when open, still it is an appreciable quantity; and if, as seems to be the case, the amount increases with the time, that dissolved from an old can must be considerable.¹

The terne plate, which is that most often used for roofing, cannot be considered quite harmless in cases where the water from the roof is used for household purposes. But as the tin roof as well as the whole house is generally covered with a paint containing far more lead than the terne plate itself, it would be absurd to complain while we use white lead to such an extent as at present.

I made a rough analysis of the tinning of terne plate by dissolving it off with chlorhydric acid, precipitating the lead and tin as sulphide and separating them with sulphide of ammonium. The result was as follows: One-fifth of a square foot gave 1.1650 gram of lead and 0.4469 gram of tin, which would make the tinning consist of 72.27 per cent. of lead and 27.73 per cent. of tin. Terne plate can be readily told by its dullness; it comes also in larger sheets than bright plate.

Although constantly on the watch for tinware made of terne plate, I have been able to find none. I am informed on good authority, however, that it is sometimes used for that purpose, but conclude that such use must be rare in this section of the country.

On Commercial Tin-foil.

Tin-foil is so much used now-a-days on chocolate, compressed yeast, cheese, and the like, that I thought the analysis of a few samples might not be amiss. Here at the outset we have a good proof of adulteration, from the fact that the price of most foil is but little more than half the price of pure bar tin.

I collected a number of samples from different importers and manufacturers. They varied greatly in thickness, coloring, and design, but I had reason to suppose that many were the same in composition. I took what I thought was a fair sample of them as regarded composition, and analyzed them.

The method used was that usually used for solders, the oxida-

¹ It is hardly to be supposed that the proportion indicated by the above experiments continues indefinitely.

tion with nitric acid. It was not thought necessary to correct for the trace of lead retained by the oxide of tin; neither were traces of copper or other metals sought for, which even if present would hardly influence the character of the foil, at least as far as sanitary purposes were concerned. The results of the analyses will be found in Table V. I give in the table the size of the piece of foil taken for analysis, its weight, and the weight of the lead and tin found in it, as well as the percentage composition. Only the first three foils were sold for pure tin. Some were sold as "composition foils," but generally, unless special inquiry was made, nothing was said of their composition.

TABLE V.

| No. | Amount taken | | Amount found in grams. | | Percentage. | |
|-----|-----------------|------------------|------------------------|--------|-------------|-------|
| | Size in sq. in. | Weight in grams. | Tin. | Lead. | Tin. | Lead. |
| 1 | 6 | 0.2285 | 0.2275 | ... | 99.53 | ... |
| 2 | 6 | 0.4260 | 0.4227 | ... | 99.23 | ... |
| 3 | 6 | 0.5950 | 0.5929 | ... | 99.65 | ... |
| 4 | 6 | 0.5150 | 0.1162 | 0.3945 | 22.56 | 76.60 |
| 5 | 6 | 0.9080 | 0.0902 | 0.8152 | 9.94 | 89.95 |
| 6 | 6 | 0.7140 | 0.1642 | 0.5464 | 23.00 | 76.41 |
| 7 | 6 | 2.0785 | 0.0839 | 1.9860 | 3.86 | 95.75 |
| 8 | 6 | 1.8580 | 0.1172 | 1.7360 | 6.31 | 93.43 |
| 9 | 6 | 0.3030 | 0.1125 | 0.1819 | 37.44 | 60.03 |
| 10 | 2.25 | 0.4720 | 0.1078 | 0.3678 | 22.84 | 77.94 |
| 11 | 3 | 0.8005 | 0.2004 | 0.5969 | 25.03 | 74.55 |
| 12 | 6 | 1.4940 | ... | 1.2240 | ... | 81.92 |

In order to see if I had had a fair sample of the foils in general use, and to see which of them were most used on articles of food, I took several foils that had been in actual use and analyzed them. The results appear in Table VI. It will be seen that each corresponds very nearly to some one in Table V. Nos. 21, 23 and 28 were on chocolate; Nos. 22 and 27 on different kinds of compressed yeast; Nos. 25 and 26 on "Neuchâtel" cheese; No. 24 on the outside of a box of troches. No. 23 was on a small cake of chocolate bought at a street stand, while No. 28 was an embossed foil and on a very fashionable cake of chocolate. No. 25 was very brittle and showed signs of being acted upon. The cheese was quite acid to litmus.¹

¹ The use of a foil containing about 75 per cent. of lead for wrapping the so-called Neuchâtel and other soft cheese is certainly reprehensible. Owing to the acid in, or developed in, the cheese the foil becomes crumbly, and even when the cheese is first covered with greased paper, particles of the oxidized foil are very likely to become attached to the cheese as it is used. Attention has been repeatedly called to this matter abroad, among others by Wittstein (Dingl. pol. Journ. 208, 341,) who found appreciable amounts of lead in cheese thus wrapped.

TABLE VI.

| No. | Size in sq. in. | Amount taken | Amount found in grams. | | Percentage. | |
|-----|--------------------|---------------------|---------------------------|--------|-------------|-------|
| | | Weight in grams. | Tin. | Lead. | Tin. | Lead. |
| 21 | 6 | 0.2650 | 0.2653 | ... | 100.10 | ... |
| 22 | 6 | 0.5145 | 0.5130 | ... | 99.70 | ... |
| 23 | 6 | 0.2560 | 0.2559 | ... | 99.96 | ... |
| 24 | 6 | 1.1175 | 0.1111 | 1.0040 | 9.94 | 89.87 |
| 25 | ... | 1.1600 | 0.2570 | 0.8733 | 22.15 | 75.27 |
| 26 | ... | 0.7915 | 0.1645 | 0.5793 | 20.77 | 73.19 |
| 27 | 6 | 0.4435 | 0.4419 | ... | 99.63 | ... |
| 28 | 2 | 0.4850 | 0.0938 | 0.3879 | 19.34 | 79.99 |

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