#### 754

## LXVII.—Resolution of Lactic Acid into its Optically Active Components.

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VAN'T HOFF relates, in the introduction to his *Chemistry in Space*, that the reflections which led him to his theory of the asymmetric carbon atom were suggested by the ideas of Wislicenus on the isomerism of lactic and sarcolactic acids, so that these acids may be said to have played a prominent part in the opening up of the new field of stereochemistry. It is noteworthy, in view of this fact, that only quite recently has experimental evidence been obtained that inactive lactic acid is actually composed of two oppositely active acids, as the theory referred to demands.

Lewkowitsch (Ber., 16, 2720) found that a solution of ammonium lactate became dextrogyrate under the action of *Penicillium glaucum*. Schardinger (Abstr., 1891, 666) obtained a lævolactic acid by the bacterial decomposition of cane sugar, the zinc salt of which crystallised with 2 mols.  $H_2O$ , like zinc sarcolactate, and showed that a mixture of these two salts in equal weights produced ordinary zinc lactate, which crystallises with 3 mols.  $H_2O$ .

While the work described in the present paper was being carried out, Linossier (*Ber.*, **24**, 660) published the results of a repetition and extension of Lewkowitsch's experiments on the action of *Penicillium glaucum* on lactic acid. Contrary to the experience of Lewkowitsch, he found that ammonium lactate became lævogyrate by the growth of the mould; from the ammonium salt he obtained a solution of a lævogyrate zinc salt, and from this a solution of a dextrogyrate acid.

These investigations, particularly that of Schardinger, prove conclusively that lactic acid consists of a dextro-acid, identical with sarcolactic acid, and of the lævogyrate isomeride, obtained as above from cane sugar. For the complete verification, however, of Van't Hoff and Le Bel's theory in the case of a common substance like lactic acid, it seemed to us desirable that direct analytical evidence of the composition of the acid should be supplied, and we therefore undertook the present investigation, the object of which was to resolve the substance in question into its constituent isomerides by the well-known methods discovered by Pasteur.

We find that the acid can, in fact, be decomposed into two oppositely active isomeric acids by means of the strychnine salt.

#### Preliminary Experiments.

Our first attempts were made with cinchonine. On dissolving this alkaloïd in an aqueous solution of lactic acid in the proportion requisite to form an acid salt, and evaporating, a jelly was formed which An aqueous solution of the acid in which refused to crystallise. cinchonine was dissolved to neutral reaction also left, on evaporation in a desiccator, a gelatinous residue, which did not crystallise from any of the usual solvents. On standing some days, however, radial bundles of fine prisms appeared, and ultimately the substance became a mass of minute crystals, imbedded in a viscid, dark-coloured gum. The crystals, being readily soluble in all the common solvents, were freed as far as possible from the uncrystallisable matter by pressure between folds of filter-paper. An aqueous solution of the substance, from which the cinchonine had been removed by precipitation with ammonia and then concentrated, gave a rotation of  $+0.3^{\circ}$  when examined by the polarimeter in a 220 mm. tube. It appears, therefore, that the cinchonine salt of lævogyrate lactic acid is more readily crystallisable than its dextrogyrate isomeride, and that this difference in properties might possibly be utilised for the decomposition of lactic acid into its constituents. The effectual separation of the cinchonine salts, however, presented so much difficulty that the method was abandoned.

Experiments were also made with narcotine, but a crystalline salt of this alkaloïd could not be obtained.

Experiments made on a small scale with strychnine gave a more promising result, of which the following will serve as an example :---25 grams of the alkaloïd were treated with just the quantity of aqueous lactic acid to effect solution. When the liquid, which was only faintly acid, was evaporated and cooled, it became a thick paste of minute, prismatic crystals, which, when separated from the syrupy mother liquor by means of a suction pump and air dried, weighed The substance was dissolved in water, decomposed by the 75 grams. cautious addition of ammonia, and filtered; the filtrate, after being evaporated to 20 c.c., was again tested with ammonia, and gave no further precipitate of strychnine. It gave a rotation of  $+1.07^{\circ}$  in a 220 mm. tube, whilst the mother liquor, containing the more soluble portion of the strychnine salt, when similarly treated, showed a rotation of  $-1.03^{\circ}$ . When sodium carbonate was used instead of ammonia to remove the alkaloid, the solutions of the sodium salts exhibited similar optical activity. When the ammonium salt solutions were digested with zinc oxide until ammonia was no longer evolved, much inactive zinc lactate crystallised out on cooling, but the remaining zinc salt solutions still showed dextro- and lævo-rotations respectively. On VOL. LXI. 3 G

evaporating the solution of dextrogyrate zinc lactate, a considerable quantity of zinc salt crystallised in needles, and the syrupy liquid then deposited comparatively large, well formed, transparent prisms, exhibiting also a dextrorotation. These crystals were found to contain both zinc and ammonia, and subsequent analysis proved them to be a zinc ammonium salt of definite composition. The concentrated solution of the lævogyrate zinc salt also deposited crystals exactly similar in appearance, mixed, however, with much larger quantities of inactive zinc lactate.

Further experiments showed that the amount of strychnine salt which crystallised depended only on the extent to which the solution was evaporated, and that when the salt which was first deposited was recrystallised, though reduced by the process to half its weight, it nevertheless yielded a more optically active liquid when decomposed. It thus appeared that the strychnine salts of both acids were crystallisable, that which yielded the lævogyrate salts (presumably sarcolactates) being, however, the more soluble of the two, and that, consequently, the solutions obtained from the strychnine salts were mixtures respectively of dextro- and lævo-, with probably larger quantities of inactive lactate. It was, therefore, evident that systematic crystallisation of the strychnine salt would be required in order to separate the two active acids.

The lactic acid used in our experiments was the syrup (sp. gr. When examined in the polarimeter in 1.21) prepared by Kahlbaum. the concentrated form, and also when diluted with an equal volume of water, no activity could be detected. By titration with standard alkali according to Wislicenus' method (Annalen, 164, 184), we found that the solution contained 55.9 per cent. of lactic acid and 31.1 per cent. of the monobasic anhydride. The quantity of strychnine required to make a neutral solution indicated that the anhydride was not decomposed into lactic acid by the alkaloïd. In order to avoid complications arising from this fact in the larger experiments to be described, we took the precaution of boiling the acid syrup after dilution with water to ten times its volume, until all the anhydride was converted into acid.

Wislicenus (Annalen, 164, 182, 196) showed that monobasic lactic anhydride is readily converted into lactic acid by alkalis, although it may be left for a long time in contact with water at the ordirary temperature without undergoing complete conversion. We find no precise data regarding the conditions under which the anhydride is converted into acid by heating with water, so the following results may be mentioned. A series of separate experiments showed that when the syrup, containing 31.1 per cent. by weight of the anhydride, was diluted to ten times its volume with water and boiled, using a

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reflux condenser, the quantity of anhydride, calculated on the weight of syrup taken, was reduced in half an hour to 23.6 per cent., in  $l\frac{1}{2}$ hours to 16.3 per cent., and, after six hours boiling was entirely converted into acid.

## Larger Experiments with Strychnine.

460 grams of strychnine were dissolved in just the quantity of lactic acid required for solution, namely, 1350 c.c. of a solution of the acid prepared as above. The solution was neutral, and the acid and alkaloïd, it was found on calculation, had acted in almost molecular proportion. The liquid was then subjected to systematic fractional crystallisation, the crystalline solid being in each case separated, as far as practicable, from the syrupy liquid with the aid of the suction pump, and pressed in folds of filter-paper. The compound readily gave off water when heated, and no definite melting point could be obtained; but with successive crystallisations the solubility of the separated substance decreased very decidedly. Ultimately three crops of crystals and seven mother liquors were obtained. The three crops of crystals,  $C_1$ ,  $C_2$ , and  $C_3$ , in order of increasing solubility, had been crystallised respectively five, six, and seven times, their respective weights, air dried, being 61.5, 22, and 31.5 grams. The crops of crystals were dissolved separately in water, and the strychnine was precipitated by the addition of ammonia in very slight excess. The filtrates were evaporated to a small bulk, again neutralised with ammonia, and allowed to stand, any small quantity of strychnine which separated being filtered off. The solution from C<sub>1</sub> was made up to 50 c.c., and the other two solutions to such volumes that all three were of the same concentration. The three solutions in order gave the following rotations in a 200 mm. tube:  $+5.46^{\circ}$ ,  $+4.83^{\circ}$ , and -1.33°.

### Lavolactic Acid.

The composition and chemical properties of this acid and its salts should from all analogy be identical with those of sarcolactic acid (dextrolactic acid). As among the few sarcolactates which have been investigated with any degree of accuracy, the zinc compound is the best known and best characterised, our experiments with the optically active lactic acids have been for the present chiefly confined to this salt. Besides the well-established difference in the amount of water of crystallisation of zinc sarcolactate and ordinary zinc lactate, the investigations of Wislicenus have shown that the former is about three times as soluble in water as the latter, and the same ought to hold true of course for zinc lævolactate. Zinc Lævolactate.—With the view of obtaining this salt, the dextrogyrate ammonium salt solution from  $C_1$  was boiled with zinc oxide until ammonia had almost ceased to be evolved, and then filtered and evaporated. Three crops of crystals were obtained weighing respectively 9.7, 5, and 1.1 grams; the first proved to be the approximately pure zinc salt of lævolactic acid, the second the same substance mixed with more inactive zinc lactate, and the third, which crystallised in large and well-defined crystals, a double zinc ammonium salt.

The zinc salt, weighing 9.7 grams, was recrystallised, dried between folds of filter-paper, and then subjected to analysis and examined by the polarimeter with the results which are appended below. The water of crystallisation was estimated by heating the salt in a platinum crucible at 105° until absolutely constant in weight; it was found that no further loss was undergone by heating it to 180°. The zinc was estimated by careful incineration.

- 0.6605 gram of substance heated at 105° lost 0.0875 gram, and yielded 0.1908 gram ZnO.
- II. 0.6943 gram of substance heated at 105° lost 0.0915 gram.
- III. 0.2998 gram of the residual salt from II gave on combustion in oxygen 0.1130 gram H<sub>2</sub>O, 0.3221 gram CO<sub>2</sub>, and 0.0994 gram ZnO.
- IV. 0.2955 gram of the residual salt from II gave on combustion in oxygen 0.1087 gram  $H_2O$  and 0.3180 gram  $CO_2$ .

	Found.	
Calculated for	ç^	 TT
$C_6H_{10}O_6Zn, 2H_2O.$	1.	10.10
$H_2O12.90$	13.25	13.18
Zn 23 <sup>·</sup> 30	23.18	
Calculated for	Found.	
$C_6H_{10}O_6Zn.$	ÍΠ.	IV.
C 29.63	29.30	29.35
H 4·12	4.19	4.09
Zn 26.75	26.61	

As a control experiment, a specimen of zinc salt was prepared from the original lactic acid by treating it with zinc oxide, and a portion of the salt was heated in the air-bath at 105° simultaneously with the optically active salt the analysis of which is given above.

0.7017 gram of the substance lost 0.1276 gram  $H_2O$ , and yielded on incineration 0.1918 gram ZnO.

Calcu	ulated for	
$U_6H_{10}U$	$b_6$ Zn, $3H_2O$ .	Found.
$H_2O$	18-18	18.18
Zn	21.89	21.93

In determining the specific rotation of the active zinc salt, 1.9240 gram was dissolved in water and the solution made up to 20.06 c.c., and the following results obtained :---

$$\alpha[11^{\circ}] = +1.08^{\circ}; l = 200 \text{ mm.}; C = 9.591; d 11^{\circ}/4^{\circ} = 1.0449;$$

hence

$$[\alpha]_{\rm D} = \frac{1.08 \times 100}{2 \times 9.591} = +5.63^{\circ}.$$

The zinc salt made direct from the original lactic acid was inactive. The polarimeter used throughout in our experiments was a half-shadow instrument of the Laurent form, admitting of readings to single minutes.

The analyses given show that the zinc levolactate has the same composition as zinc sarcolactate. The estimations of the water of crystallisation are slightly higher than the calculated numbers, and indicate that the substance was not free from inactive salt, which is also confirmed by the specific rotation. The specific rotation of zinc sarcolactate varies with the concentration; the number found by Wislicenus for this salt (*Annalen*, 167, 332) for a strength of solution approximating to that we used was  $-6\cdot36^\circ$ . If the quantity of inactive salt probably present be calculated from the estimation of water of crystallisation, and a corresponding allowance made, then the specific rotation would approach pretty closely to the number found by Wislicenus.

Owing to the facility with which the zinc lactates form supersaturated solutions, estimations of solubility vary within wide limits according to the length of time the solutions are allowed to stand. Wislicenus states (*loc. cit.*) that the solubilities of zinc lactate and sarcolactate at  $14-15^{\circ}$  may be taken respectively as about 1.7 and 5.7 parts hydrated salt in 100 parts of water. We made comparative experiments on the solubility of ordinary zinc lactate and the zinc lævolactate, described above, by dissolving 2 grams of each in 15 c.c. of water with the aid of heat, and then leaving the solutions to stand close together for about 6 weeks, the temperature varying from 10° to  $18^{\circ}$ . 6:2970 grams of the solution of the active salt left on evaporation and incineration of the residue 0:0878 gram ZnO, whilst 5:2733 grams of solution of the inactive salt gave 0:0229 gram ZnO; the solubilities of the hydrated salts are, therefore, 
 Inactive zinc lactate
 1.62 : 100

 Zinc lævolactate
 5.05 : 100

results which agree as closely with the numbers quoted above as could be expected. The solubility of zinc lævolactate, therefore, is the same as that of the sarcolactate.

As a determination of the water of crystallisation in the second crop of crystals, weighing 5 grams, gave the number 14 45 per cent., it evidently contained more inactive salt than the first crop, and it seemed, therefore, unlikely that a purer salt would be got by recrystallisation.

Zinc Ammonium Lævolactate.—We found this salt, as already stated, in the mother liquor of the zinc lævolactate, the boiling with zinc oxide not having sufficed to decompose the whole of the ammonium salt. As the substance formed comparatively large welldefined crystals, and no corresponding compound of inactive lactic acid seemed to have been observed, we prepared the salt with the view of procuring from it, if possible, a lævolactate free from inactive salt.

1.1 gram of the salt was got, as already stated, from the mother liquor of the zinc lævolactate, the analyses and specific rotations of which have been given. A second portion of 2.25 grams was obtained by decomposing with zinc oxide half of the ammonium salt from the crop of strychnine lactate  $C_2$ , and adding the zinc lævolactate thus obtained to the remaining half of the ammonium salt solution. A third portion of 3 grams was prepared by decomposing one half of the residue of the zinc lævolactate, the analyses of which have been given, with sulphuretted hydrogen, neutralising the resulting acid with ammonia, and adding this to the remaining half of the zinc salt.

These solutions were evaporated to a syrupy consistency without any zinc salt crystallising, but on adding a crystal of zinc ammonium salt, transparent, short, well-defined prisms were at once produced. The substance having been freed from adhering syrup by means of filter paper was subjected to analysis with the following results :---

- I. 0.7920 gram of substauce gave 0.1655 gram ZnO.
- II. 0.3157 gram of substance gave 0.1752 gram H<sub>2</sub>O, 0.3222 gram CO<sub>2</sub>, and 0.0668 gram ZnO.
- III. 0'2883 gram of substance gave 0'1582 gram H<sub>2</sub>O, 0'2955 gram CO<sub>2</sub>, and 0'0605 gram ZnO.
  - 0.2840 gram of substance gave by combustion 9.2 c.c. N. at 14° and 750.1 mm. bar.

Calculated for	Found.		
$C_9H_{15}O_9Zn\cdot NH_4, 2H_2O.$	ſ.	II.	<u> </u>
C 27.98		27.83	27.95
H 5.96		<b>6</b> ·0 <b>7</b>	<b>6</b> ·10
N 3.63			3.82
Zn 16.84	16.77	16.98	16.84

The substance is, therefore, a double lactate of zinc and ammonium crystallising with 2 mols.  $H_2O$ . A direct estimation of the water of crystallisation was not obtained, as ammonia was given off when the substance was heated. The salt is readily soluble in water, but cannot be recrystallised; on warming the solution, or even on evaporation at the ordinary temperature, it becomes acid from escape of ammonia, and zinc salt is gradually deposited. When excess of the animonium salt, however, is present, a supersaturated solution may be produced by evaporation without the separation of zinc salt taking place.

Determinations of the specific rotation gave the following results:---

I. 
$$\alpha[13^{\circ}] = +0.89^{\circ}; \ l = 200 \text{ mm.}; \ p = 7.7804; \ d \ 13^{\circ}/4^{\circ} = 1.0313; \text{ hence } [\alpha]_{\text{D}} = \frac{0.89 \times 100}{2 \times 7.7804 \times 1.0313} = +5.54^{\circ}.$$
  
II.  $\alpha[11^{\circ}] = +1.02^{\circ}; \ l = 200 \text{ mm.}; \ p = 8.6225; \ d \ 11^{\circ}/4^{\circ} = 1.0364; \text{ hence } [\alpha]_{\text{D}} = \frac{1.02 \times 100}{2 \times 8.6225 \times 1.0364} = +5.71^{\circ}.$   
III.  $\alpha[18^{\circ}] = +1.16^{\circ}; \ l = 200 \text{ mm.}; \ p = 8.6305; \ d \ 18^{\circ}/4^{\circ} = 1.0350; \text{ hence } [\alpha]_{\text{D}} = \frac{1.16 \times 100}{2 \times 8.6305 \times 1.0350} = +6.49^{\circ}.$   
 $\alpha[18^{\circ}] = +0.85^{\circ}; \ l = 200 \text{ mm.}; \ p = 5.8669; \ d \ 18^{\circ}/4^{\circ} = 1.0240; \text{ hence } [\alpha]_{\text{D}} = \frac{0.85 \times 100}{2 \times 5.8669 \times 1.0240} = +7.07^{\circ}.$ 

The specific rotations of I, II, and III were taken on different preparations of the salt. The two determinations on Preparation III, which was, no doubt, the purest, show that the specific rotation increases with decreasing concentration, as is the case with zinc sarcolactate. The specific rotations found for II and III indicate that these substances still contained some inactive salt, whether mixed or chemically combined with the active constituents, it is impossible to say. Inactive zinc and ammonium lactates do not seem to form any compound similar to that which has been described. The methods by which the active compound was prepared yielded no crystalline double salt when inactive salts were used. A dilute, hot solution of the latter deposits zinc lactate on cooling; a warm, concentrated solution of ammonium lactate will dissolve large quantities of zinc lactate, which the syrup still retains in solution on cooling, but on longer standing, or with stirring, zinc lactate separates.

The remaining portion of Preparation III of the zinc ammonium salt was converted into the zinc salt, with the view of obtaining a purer specimen of this substance. The zinc was removed as far as possible, by means of sulphuretted hydrogen, and the ammonia then driven off by heating the filtered solution with a slight excess of barium hydrate. Sulphuric acid was added in quantity nearly equivalent to the barium hydrate used, and the filtered solution evaporated to a syrup, and extracted with ether. After evaporating off the ether, the acid was dissolved in water, and converted into the zinc salt in the usual manner. A determination of the specific rotation is appended :---

$$\begin{aligned} \alpha [17^{\circ}] &= +0.88^{\circ}; \ l = 200 \text{ mm.}; \ p = 6.7510; \ d 17^{\circ}/4^{\circ} = \\ 1.0318; \text{ hence } [\alpha]_{\text{D}} &= \frac{100 \times 0.88}{2 \times 6.7510 \times 1.0318} = +6.32^{\circ}. \end{aligned}$$

This result is still considerably lower than that found by Wislicenus with solutions of zinc sarcolactate of similar concentration. An estimation of the water of crystallisation in another portion of the salt gave the result 13:30, the number calculated for  $2H_2O$  being 12:90.

Levolactic Acid.—The activity of sarcolactic acid is in the opposite sense to that of its salts. The same holds true for levolactic acid. A solution of zinc salt, which gave a rotation of  $+1.08^{\circ}$  in a 200 mm. tube, was decomposed with sulphuretted hydrogen, filtered, and made up to the same volume, when it was found to give a rotation of  $-0.27^{\circ}$ .

Like sarcolactic acid, lævolactic acid readily forms an anhydride, the activity of which is in the opposite sense to that of the acid. The solution just referred to was evaporated, and the acid separated from a small quantity of undecomposed zinc salt by extraction with ether. The syrup left from the ethereal extract was dissolved in water just sufficient to fill a 100 mm. tube; it was inactive. After standing three weeks, and being diluted so as to fill a 200 mm. tube, it gave the original rotation  $-0.27^{\circ}$ .

Dextrolactic Acid.—It has been already stated that of the three crops of crystals of strychnine salt, the first and second yielded a dextrogyrate, the third a lævogyrate ammonium salt. The weight of the first two crops together amounted only to about  $14\frac{1}{2}$  per cent. of the weight of acid and alkaloïd used, so it was evident that the mother liquors must contain, besides the salt of the dextro-acid, a

large quantity of the salt of the lavo-acid, the elimination of which was only to be effected by fractional crystallisation. As the process proved extremely tedious, and offered little promise of success, it was ultimately abandoned, and the various mother liquors, without further separation of the mixed salts, were decomposed separately by the addition of barium hydrate. The filtered solutions, from which the excess of barium hydrate had been removed by carbonic anhydride, were next concentrated to a small bulk, and, after standing, again filtered from small quantities of the alkaloïd, which separated. Each of the solutions gave, as was expected, a lævo-rotation. They were then mixed together, and treated with slightly less than the quantity of standard sulphuric acid requisite to precipitate the The filtered liquid was evaporated to a syrup, from which barium. the lactic acid was extracted with ether. The residue from the ethereal extract, after evaporation, was dissolved in water, and converted into a solution of the zinc salt in the usual manner, from which, on cooling, large quantities of inactive zinc lactate separated.

Zinc Dextrolactate.—By successive crystallisations of the liquid mentioned, and extraction of the more soluble part of the various crops of crystals, a solution was ultimately obtained which yielded two portions of crystals weighing  $2\frac{1}{2}$  grams and 1.9 grams respectively.

The following analyses and determinations of specific rotation showed them to consist mainly of zinc dextrolactate :----

0.4178 gram of the first crop, on heating at  $105^{\circ}$  till constant in weight, lost 0.0566 gram, and yielded 0.1209 gram ZnO, corresponding to 13.55 per cent. of water, and 23.22 per cent. of zinc, instead of the numbers 12.90 and 23.29 calculated for the salt containing  $2H_2O$ .

A determination of the specific rotation was made, with the following result: $\rightarrow$ 

$$\begin{aligned} &\alpha [16^{\circ}] = -1.01^{\circ}; \ l = 200 \text{ mm.}; \ p = 9.1351; \ d \ 16^{\circ}/4^{\circ} = \\ &1.0427; \text{ hence } [\alpha]_{\text{D}} = \frac{100 \times -1.01}{2 \times 9.1351 \times 1.0427} = -5.32^{\circ}. \end{aligned}$$

The second crop proved to be purer, as is shown by the specific rotation :---

$$\begin{aligned} \alpha [18^{\circ}] &= -1.08^{\circ}; \ l = 200 \text{ mm.}; \ p = 9.0823; \ d \ 18^{\circ}/4^{\circ} = \\ 1.0413; \text{ hence } [\alpha]_{\mathrm{D}} &= \frac{100 \times -1.08}{2 \times 9.0823 \times 1.0413} = -5.71^{\circ}. \end{aligned}$$

The specific rotation found for a solution of the dextrogyrate zinc salt of similar concentration was  $+5.63^{\circ}$ .

Zinc Ammonium Dextrolactate.—This salt was prepared by the same methods, which yielded the corresponding salt of the lævo-acid. It crystallised in the same manner from supersaturated solutions, and had the same chemical composition. An estimation of zinc gave 16.92 per cent., the calculated percentage being 16.84. The solution from which the salt was prepared was known to contain a considerable amount of inactive substance, and, as our experience with the corresponding salt of the lævo-acid led us to expect, the specific rotation was low. The number was  $-6.28^{\circ}$ , that for the purer lævolactate of similar concentration being  $+7.07^{\circ}$ .

Dextrolactic Acid.—The lævogyrate zinc salts, which have been described, yielded, as was expected, a dextrogyrate acid. The acid obtained from a lævogyrate barium salt solution made up to 13 c.c. gave a rotation of + 0.27°. When this acid was converted into zinc salt, and the solution made up to 25 c.c., it exhibited a rotation of  $-0.58^{\circ}$ .

## Confirmatory Experiments.

The following experiment was made to show that, when lactic acid is resolved into its optically active isomerides by means of their strychnine salts, the quantities of the latter which are separated from each other possess equal optical activity. 70 grams of lactic acid syrup were converted into a solution of strychnine salt, as already described, and from this a crop of crystals was obtained by evaporation. The crystalline strychnine salt and its mother liquor were converted into their barium salts by barium hydrate, and the liquids were shaken with chloroform to remove any strychnine which remained. As the solutions were too highly coloured for examination, they were diluted to 250 c.c. The rotations then exhibited in a 200 mm. tube were  $+0.45^{\circ}$  and  $-0.45^{\circ}$  respectively.

Our experiments show that inactive lactic acid can be resolved into two optically active isomeric acids, the zine salts of which both crystallise with 2 mols.  $H_2O$ . By mixing equal weights of these in solution, inactive zine lactate, crystallising with 3 mols.  $H_2O$ , should be produced. We find that this is in fact the case. We dissolved separately 1.2 gram each of the dextro- and lævo-gyrate zine salts from our purest preparations, of which the estimations of water and specific rotation have been given, in such quantities of water as to form saturated solutions. No salt separated from the liquids on standing some hours, or on stirring. But when the solutions were mixed at the ordinary temperature and stirred, the liquid became turbid almost instantaneously, and in a few minutes a heavy precipitate of crystalline needles subsided, which, on being separated and dried, weighed over 1 gram. A saturated solution of the crystals was found to be absolutely inactive, and the composition of the substance was identical with that of ordinary zinc lactate.

0.8925~gram lost at 105°  $0.1626~gram~H_{\rm 2}O,$  and yielded on incineration 0.2434~gram~ZnO.

	Calculated for	
	$C_6H_{10}O_6Zn, 3H_2O.$	Found.
$H_2O\ldots$	18.18	18.22
Zn	21.89	21.88

Our experiments show that fermentation lactic acid can be resolved into two oppositely active acids, one of which is identical with sarcolactic acid, the other with the lævorotatory acid produced, as already referred to, by the bacterial decomposition of cane sugar.