

XXXI.—*Contributions to the Knowledge of Citric and Aconitic Acids.*

By SIDNEY SKINNER, B.A., late Scholar of Christ's College, Cambridge,
and S. RUHEMANN, Ph.D., M.A.

THE compounds formed by the action of aniline on citric and aconitic acids have been carefully examined by Pebal (*Annalen*, **82**, 78; **98**, 67). In the first paper he deals with the direct action of aniline on citric acid, and describes several of the anilides and anils produced. The second paper gives an account of a substance which he calls "oxychlorocitronsäure" (chlorocitryl monochloride), from which he obtained an aconityl-derivative by the action of aniline.

In the course of some experiments, having occasion to prepare the chlorocitryl monochloride with the view of testing some results previously obtained by one of us, it seemed desirable to submit it to a more complete examination, and with this object we have reviewed the action of primary monamines on citric acid.

Pebal's directions for the preparation of the chlorocitryl monochloride were followed as closely as possible; three equivalents of phosphorus pentachloride mixed with one of citric acid (dried at 130°) were shaken together in a flask; the heat evolved in the

reaction caused the mass to become gradually pasty, and, on slightly warming, the mixture was transformed into a light-red liquid. Overheating on the water-bath must be avoided, or else the colour will become dark and decomposition begin. If the light-red liquid is poured off from the excess of pentachloride and mixed with dry carbon bisulphide, crystalline needles of the citric acid chloride separate out in a few minutes. These are collected on a filter, washed with dry carbon bisulphide until they are as free as possible from phosphorus oxychloride, pressed, and dried in a vacuum over caustic potash and sulphuric acid.

The chlorocitryl monochloride thus obtained is a hard, white substance, exhibiting no crystalline structure when dried, insoluble in carbon bisulphide, but readily soluble in benzene, and melting at about 100° . In moist air, it rapidly absorbs water with evolution of hydrogen chloride.

Pebal analysed the substance by an indirect method, and the results led him to the conclusion that the formula $C_{12}H_6O_{12}Cl_2$ ($C = 6$, $O = 8$) best represented its composition. This cannot, however, be reconciled with the present view of the constitution of citric acid or with the reactions which Pebal attributed to it. Its composition may, however, be expressed by the formula $C_6H_3O_6Cl_2$, which requires the percentage composition—

C_6	72	31.4
H_3	6	2.6
O_6	80	35.0
Cl_2	71	31.0
	<hr/>	<hr/>
	229	100.0

This agrees as well with Pebal's analyses as with ours. We have determined the chlorine in several specimens of the product with such varied results as 19.92, 21.72, 25.96 per cent., and in a specimen recrystallised from benzene without heating, and dried in a vacuum, we found 29.6 per cent. This still contained minute traces of phosphorus, but was decidedly the purest specimen, and agrees best with the assumption that the compound is a chlorocitryl monochloride. As the substance could not be obtained pure enough for ultimate analysis, it was evident that its composition could only be arrived at by the study of its reactions.

Action of Water on Chlorocitryl Monochloride.

On addition of water, it readily dissolves if impure, but after recrystallisation from benzene it is necessary to warm slightly before

it dissolves. An aqueous solution of the crude substance was evaporated to dryness on a water-bath, and the crystalline residue, which was found to be free from chlorine, was shaken with ether. The soluble portion left on evaporation of the ether was dissolved in alcohol and saturated with hydrogen chloride; on adding water, an oil separated, which boiled at about 294° . Analysis proved it to be ethyl citrate.

	Calculated for $C_{12}H_{20}O_7$.	Found.	
		I. B. p. 294° C. at ordinary pressure.	II. B. p. 218° C. at 75 mm. pressure.
C.....	52.1	52.1	51.6
H.....	7.2	7.24	7.2

The larger portion of the substance which was not taken up by ether was recrystallised from water. Analysis of these crystals dried in a vacuum gave numbers corresponding with those required for citric acid.

	Calculated for $C_6H_8O_7 + H_2O$.	Found.
C	34.28	34.6
H	4.76	5.1

Hence citric acid is the only product of the action of water on chlorocitryl monochloride.

Action of Heat on Chlorocitryl Monochloride.

The crude substance when heated to 125° melts and gives off hydrogen chloride. The resulting product was dissolved in water, the solution evaporated to dryness, and the crystalline residue shaken with dry ether. This extracted a crystalline acid, the silver salt of which gave on analysis 65.33 per cent. of silver. It is therefore silver aconitate, which requires 65.45 per cent. Ag. Hence the action of heat on chlorocitryl monochloride results in the formation of aconityl chloride, which under the influence of water is transformed into aconitic acid. The darkening which, as above mentioned, follows prolonged heating in the preparation of chlorocitryl monochloride, is undoubtedly due to a partial change into aconityl chloride, for aconitic acid may be readily obtained by the action of water on the darkened liquid.

Action of Aniline on Chlorocitryl Monochloride.

On the gradual addition of the finely powdered acid chloride to aniline, a violent reaction takes place, causing a considerable rise of temperature, and a resinous mass is produced, which melts on heating

238 SKINNER AND RUHEMANN: CITRIC AND ACONITIC ACIDS.

and only partially solidifies on cooling. This contains aconityl anil-anilide, which may be best extracted by first distilling with steam to remove the excess of aniline, and subsequently recrystallising the solid residue from methylated spirit. The anil-anilide forms small needles of a faintly yellow colour, insoluble in water and ether, and only slightly soluble in alcohol. It appears to suffer decomposition at about 200° , but for complete fusion requires a higher temperature, given as 250° by Michael (*Amer. Chem. J.*, **9**, 192), for a specimen prepared from aconitic acid.

The formula $C_{18}H_{14}N_2O_3 = C_6H_5 \cdot N < \begin{matrix} \text{CO} \cdot \text{CH} \\ \parallel \\ \text{CO} \cdot \text{C} \cdot \text{CH}_2 \cdot \text{CO} \cdot \text{NH} \cdot \text{C}_6\text{H}_5 \end{matrix}$ requires the following numbers:—

	Theory.		Found.			
			I.	II.	III.	IV.
C ₁₈	216	70.59	70.24	70.30	—	—
H ₁₄	14	4.57	4.99	5.23	—	—
N ₂	28	9.15	—	—	9.24	9.47
O ₃	48	15.69	—	—	—	—
	306	100.0				

This substance was described by Pebal, who prepared it from chlorocitryl monochloride, as well as from aconitic acid. It is evident that its formation from the former is due to removal of hydrogen chloride as aniline hydrochloride, with conversion of the citryl radicle into the aconityl radicle.

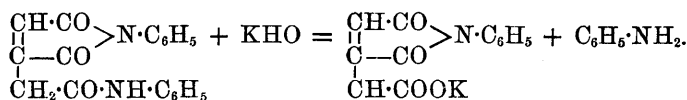
Action of Alkalis on Aconityl Anil-anilide.

Strong or dilute solutions of potassium hydroxide, and even of ammonia, decompose aconityl anil-anilide with formation of aniline and the salt of an acid. The anilide dissolves in the alkali after slight warming, forming a red liquid with a violet fluorescence. On addition of dilute mineral acids to the concentrated solution, a precipitate of the acid is thrown down; this may be purified by shaking with ether, in which it is only sparingly soluble. On evaporating the ether, the crystalline acid is left contaminated with a green viscous substance; the latter may, however, be readily got rid of by treatment with ether, in which it is very easily soluble. The acid crystallises from alcohol in rosettes of a faintly yellow colour, which melt at 250° with decomposition.

Analysis proved it to be aconitylanilcarboxylic acid. Its formula, $C_{12}H_9NO_4$, requires—

	Calculated.	Found.	
		I.	II.
N	6.06	6.83	6.27

and the following equation represents its formation—



Aconitylanilcarboxylic acid is but sparingly soluble in water. Its aqueous solution reddens litmus-paper, and the addition of alkali produces a violet fluorescence. With silver nitrate, the ammonium salt of the acid yields a silver salt, which is, however, very unstable, and on warming gently deposits a silver mirror. Dried in a vacuum, it gave on analysis 31.5 per cent. of silver, whilst $\text{C}_{12}\text{H}_9\text{AgNO}_4$ requires 31.9 per cent. Ag.

This acid is doubtless identical with the acid prepared by Pebal by the action of phosphorus pentachloride on citrylanilcarboxylic acid, for it has been shown that phosphorus trichloride when heated with ethyl citrate transforms it into ethyl aconitate (Conen, *Ber.*, 12, 1655). Aconitylanilcarboxylic acid is closely related to pyrrol, for when distilled with zinc-dust it readily yields a liquid which possesses the characteristic odour of pyrrol, and gives a bright scarlet colour to a pine-chip moistened with strong hydrochloric acid.

Action of Orthotoluidine on Chlorocitryl Monochloride.

By using orthotoluidine in place of aniline, we obtain a precisely analogous series of derivatives. Thus the product of their direct interaction is aconityltoluidtoluidide, a straw-yellow, crystalline substance melting at 214° , insoluble in water and ether and sparingly soluble in alcohol.

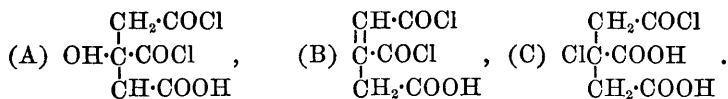
The formula $\text{CH}_3\cdot\text{C}_6\text{H}_4\cdot\text{N} < \begin{array}{c} \text{CO}\cdot\text{CH} \\ \parallel \\ \text{CO}\cdot\text{C}\cdot\text{CH}_2\cdot\text{CO}\cdot\text{NH}\cdot\text{C}_6\text{H}_4\cdot\text{CH}_3 \end{array}$ requires—

	Calculated.	Found.
N	8.38	8.67

Here again the chlorocitryl radicle has been transformed into the aconityl radicle by the removal of hydrogen chloride by the toluidine with formation of orthotoluidine hydrochloride, which was identified both by its reactions and by analysis. Boiling potassium hydroxide solution dissolves aconityltoluidtoluidide, producing a strong violet fluorescence. Orthotoluidine is eliminated, and the potassium salt of aconityltoluidcarboxylic acid is formed, from which the acid may be precipitated by dilute hydrochloric acid. The toluidcarboxylic acid is soluble in water, and the addition of alkalis to the solution produces a fluorescence similar to that of the corresponding salts of the anilcarboxylic acid.

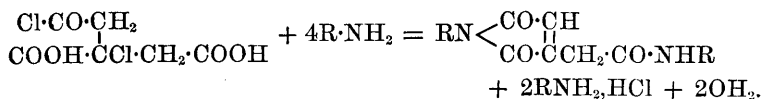
Constitution of Chlorocitryl Monochloride.

Taking into account the preparation of this substance, and the fact that analysis indicates that it contains two atoms of chlorine in its molecule, it would appear that its constitution might be represented by one of the three following formulæ:—



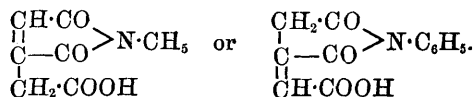
But the formula A, though accounting for the formation of citric acid by the action of water, would not readily explain the transformation into an aconityl-derivative, and on the other hand the formula B, though accounting for the latter fact, could not explain the former, as the conversion of aconitic into citric acid by the direct action of water has never been observed. Neither can the substance be a mixture of A and B, for then the action of water would give rise to both aconitic and citric acids, and that of aniline to both citryl and aconityl anil-anilides. The formula C alone expresses all the reactions that we have observed.

On heating to a temperature of 125° C., chlorocitryl monochloride splits into aconityl chloride and hydrogen chloride. From experiments made on the preparation of ethyl chlorocitrate, we have every reason to believe that this substance is formed by the interaction of equivalents of phosphorus pentachloride and ethyl citrate, but that on distillation in a vacuum it undergoes an analogous decomposition into ethyl aconitate and hydrogen chloride. We have, therefore, sufficient evidence that one of the chlorine-atoms of chlorocitryl monochloride is substituted for the alcoholic hydroxyl in citric acid, but it is not easy to ascertain which of the three acid hydroxyls is displaced by the other chlorine-atom. On treatment with aniline, the two unchanged carboxyl-groups first combine with it to form a salt which, however, readily loses water and gives rise to an anilide—a change which is very characteristic of aconitic, citraconic, itaconic, and maleic acids (Michael, *Amer. Chem. J.*, 9, 192). The equation representing the action of aniline and orthotoluidine on chlorocitryl monochloride may be given as follows:—

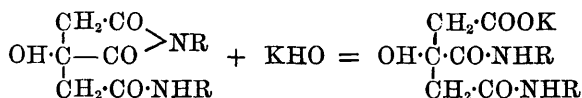


The fact of the formation of a pyrrol is a sufficient proof that the NR group unites with the carbon-atoms of adjacent carboxyls, for

if it united with those of the end carboxyls a pyridine-derivative would have been formed. Moreover, one of us has already proved (*Trans.*, **51**, 403) that the primary monamines such as methylamine cannot give rise by their action on ethyl acetyl citrate to substituted pyridines. The only question, therefore, remaining to be decided is whether the ethylene linking of the aconityl-group is within or without the pyrrol-ring. That is to say, which of the two following formulæ best represents aconityl anilcarboxylic acid :—

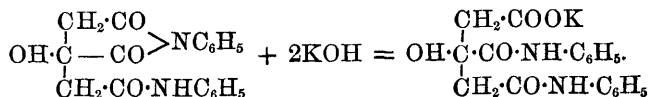


That the former is the correct one, results from the following considerations. The equation—

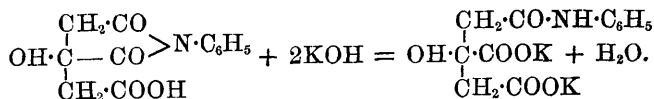


represents the general action of potassium hydroxide on citryl-derivatives of the formula $\text{NR} < \begin{array}{c} \text{CO}\cdot\text{CH}_2 \\ \text{CO}\cdot\text{C}(\text{OH})\cdot\text{CH}_2\cdot\text{CO}\cdot\text{NHR} \end{array}$.

Thus Pebal shows that citrylanil-anilide gives the potassium salt of citryldianilidocarboxylic acid :—



Analogous is the action of potassium hydroxide on the corresponding paratoluidine-compound (*Gill, Ber.*, **19**, 2352), on the α - and β -naphthylamine-derivatives (*Hecht, Ber.*, **19**, 2614), and on the ψ -cumidine-compound (*Schneider, Ber.*, **21**, 660). Different, however, is the behaviour of aconitylanil-anilide towards potassium hydroxide, for in this case aniline is eliminated, and there is formed the potassium salt of aconitylanilcarboxylic acid, whilst, as shown by Pebal, citrylanilcarboxylic acid yields, under the influence of potassium hydroxide, citrylanilidodicarboxylic acid,



This difference in behaviour can only be attributed to the ethylene linking of aconitic acid.

Ethyl aconitate has been shown by one of us (*Ber.*, **20**, 3367) to be transformed by ammonia into a pyridine-derivative. The above considerations render it probable that in this reaction the ammonium salt of an imido-acid is also formed. We are therefore reinvestigating this reaction.

University Laboratory, Cambridge.
