correctness of the above method[4] for determining the iso-electric points. The nitrogen determinations for both gliadin and glutenin show full agreement with the electrometric method.

Summary

The iso-electric points for gliadin and glutenin, respectively, have been determined, and have been found to be *P*H 6.5 for gliadin and *P*H 7.0 for glutenin.

MANHATTAN, KANSAS

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CINCINNATI]

SOME NEW HYDROXY-URETHANS AND CHROMO-ISOMERIC SILVER SALTS OF THEIR ACYL DERIVATIVES. II[1]

BY RALPH E. OESPER AND WALTER A. COOK

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A previous paper with the above title by L. W. Jones and one of us[2] contained an account of some preliminary studies of the white and yellow forms of the silver salts of benzoylated carbalkoxy-hydroxamic acids. It was suggested that these salts, which are reversibly transformable into each other, might correspond to the isomeric forms, I and II, or they might

$$\underset{\text{I}}{\text{Ag—N(—C(=O)—OR)—O—C(=O)—C}_6\text{H}_5} \rightleftharpoons \underset{\text{II}}{\text{Ag—O—C(—OR)=N—O—C(=O)—C}_6\text{H}_5}$$

I II

be polymers of either I or II. Molecular-weight determinations were inconclusive, while the evidence deduced from hydrolysis of the products obtained by replacing the silver atom by alkyl groups indicated that the yellow forms reacted as though they possessed Structure I. The behavior of the white forms under similar conditions was not studied in detail. This study has now been made, and the results lead to the conclusion that when direct replacement of the silver by alkyl occurs, both the yellow and white forms have Structure I. It has been pointed out by several investigators of similar cases[3] that this assumption is not always warranted and, furthermore, the media in which the reactions occurred may induce partial reversion of one form of the silver salt to the other until an equilibrium is reached, the latter condition then being disturbed by the interaction with the alkyl halide. No visible evidence of such transformation

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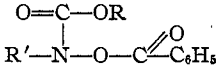
[4] Michaelis, "Wasserstoffionen Konzentration," Julius Springer, Berlin, **1914,** p. 40.

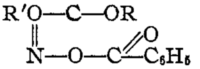
[1] This communication is an abstract of a thesis submitted by Walter A. Cook in partial fulfilment of the requirements for the degree of Doctor of Philosophy, at the University of Cincinnati.

[2] (a) Jones and Oesper, THIS JOURNAL, **36,** 2208 (1914); (b) **36,** 726 (1914).

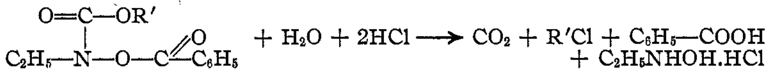
[3] Sidgwick, "Organic Chemistry of Nitrogen," Oxford Clarendon Press, **1910,** pp. 103, 81. Tafel and Enoch, *Ber.*, **23,** 1550 (1890). Comstock, *Am. Chem. J.*, **13,** 514 (1891). Lander, *J. Chem. Soc.*, **83,** 418 (1903).

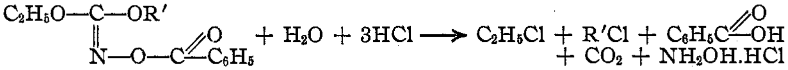
of the white to the yellow form appeared in any of the cases reported below, but the products, probably possessing Structure III without exception gave, on hydrolysis, β-substituted hydroxylamines.


$R'-N(-C(=O)-OR)-O-C(=O)-C_6H_5$ III


$R'O-C(-OR)=N-O-C(=O)-C_6H_5$ IV

The possibility that rearrangement may have taken place during the hydrolysis with concd. hydrochloric acid, was eliminated by preparation of benzoylated oximidocarbonic esters of the general formula IV. These were crystalline solids, as contrasted with the non-crystallizable oils of isomeric structure (III). The compounds IV yielded hydroxylamine on treatment with concd. hydrochloric acid. The hydrolyses may be represented as follows.


$$C_2H_5-N(-C(=O)-OR')-O-C(=O)-C_6H_5 + H_2O + 2HCl \longrightarrow CO_2 + R'Cl + C_6H_5-COOH + C_2H_5NHOH.HCl \qquad (1)$$


$$C_2H_5O-C(-OR')=N-O-C(=O)-C_6H_5 + H_2O + 3HCl \longrightarrow C_2H_5Cl + R'Cl + C_6H_5C(=O)OH + CO_2 + NH_2OH.HCl \qquad (2)$$

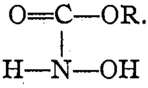
Since the simple benzoyl derivatives had uniformly yielded silver salts in which the metal was "bound to nitrogen," the corresponding *m*- and *p*-nitrobenzoyl and *p*-chlorobenzoyl silver salts were prepared and studied in the hope that their behavior would lead to other conclusions, but the results were consistent with those previously obtained.

None of the silver salts, now described for the first time, showed the requisite solubilities or transition points to permit molecular-weight determinations.

It is our purpose to extend this study to derivatives containing large aliphatic radicals and also to derivatives of the carbacyl-oxy-hydroxamic acids.

Experimental Part

Since this study required the preparation of a series of compounds not hitherto described, a general description of the preparation of each type will suffice to show the procedure followed.

Derivatives of Carbalkoxy-hydroxamic Acids,  $H-N(-OH)-C(=O)-OR$.—The methyl, ethyl, *iso*propyl, *iso*butyl, amyl and benzyl derivatives have been described by Jones and Oesper.[4] The method of Jones[5] for the preparation of carbethoxy-hydroxamic acid (oxyurethan) was used to obtain the corresponding *n*-propyl, *n*-butyl and *iso*-amyl derivatives, with the exception that hydroxylamine sulfate was substituted for the chloride. The products were pale yellow oils having a characteristic

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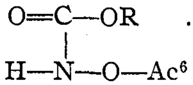
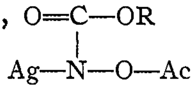
[4] Ref. 2 a, p. 2213.

[5] Jones, *Am. Chem. J.*, **20**, 39 (1898).

odor and the respective yields were 85%, 81% and 86%. These acids were not analyzed, since no practicable methods were found for purification.

Benzoyl and Substituted Benzoyl Esters,  $\begin{array}{l} \mathrm{O{=}C{-}OR} \\ \quad\;\, | \\ \mathrm{H{-}N{-}O{-}Ac} \end{array}$[6] .—The simple benzoyl esters were prepared by the method described by Jones and Oesper.[7] The substituted benzoyl esters were obtained by the action of the sodium salt of the corresponding hydroxamic acid on an equivalent of the acid chloride using dry ether as diluent. The sodium chloride was removed by filtration and the ether distilled, the desired product constituted the bulk of the residue. The benzoyl esters are oils and no purification or analysis of them was attempted. The substituted benzoyl esters are solids and were recrystallized from ether and ligroin.

Silver Salts of the Esters,  $\begin{array}{l} \mathrm{O{=}C{-}OR} \\ \qquad\;\, | \\ \mathrm{Ag{-}N{-}O{-}Ac} \end{array}$.—The method of Jones and Oesper[8] was used. The silver salts of the substituted benzoyl derivatives were rather unstable and since they were only slightly soluble in chloroform and benzene and were insoluble in carbon tetrachloride, ether and ligroin, purfication by recrystallization was unsatisfactory. Extraction of the impure salts with ether which removed extraneous matter, chiefly unreacted benzoyl ester, gave products sufficiently pure for our purposes. The silver salts of the *p*-chlorobenzoyl esters of carbethoxy and *n*-propoxy hydroxamic acids, of the *m*-nitrobenzoyl esters of carbethoxy-, *n*-propoxy- and *n*-butoxy-hydroxamic acids, and of the *p*-nitrobenzoyl derivative of carbo-*n*-butoxy-hydroxamic acid, when dry, were distinctly white. When first prepared these salts were yellow in most cases, but turned white on drying. The silver derivatives of the *p*-nitrobenzoyl esters of carbethoxy- and *n*-propoxy-hydroxamic acids were distinctly yellow and were insoluble in the solvents listed above. The silver salts of the *m*-nitrobenzoyl esters gave yellow solutions in chloroform and benzene, and spontaneous evaporation of the chloroform solutions yielded the white form. The silver salts of the benzoyl derivatives of carbo-*n*-propoxy-, *n*-butoxy- and *iso*-amyloxy-hydroxamic acid were yellow when dry and gave yellow solutions with chloroform and benzene. The benzoylated carbo-*n*-propoxy-hydroxamic acid silver salt when heated to 132–133° changed to the white form. Small quantities heated under diminished pressure to the temperature of boiling water were converted to the white modification. Several g. of the white form was obtained by suspending the yellow salt in absolute alcohol for several hours. Both forms of this salt are identical in composition and when treated with ethyl iodide, the yellow modification in chloro-

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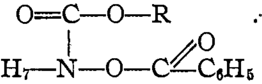
[6] Ac = acyl group.

[7] Ref. 2 a, p. 2214.

[8] Ref. 2 a, p. 2215.

form, the white in ether, and in ligroin produced alkyl-N esters which were identical in composition. A study of the hydrolysis products of the esters showed them to be identical in structure. Similarly, the white silver salts of the *m*-nitrobenzoyl esters of carbethoxy-, *n*-propoxy, *n*-butoxy-hydroxamic acids, when suspended separately in chloroform and ether, on treatment with ethyl iodide gave esters that were identical in composition and structure. Assuming direct replacement of metal by alkyl in all these cases, it follows that the yellow and white forms of the silver salts are identical structurally. The benzoylated carbo-*iso*-amyloxy-hydroxamic acid yellow silver salt gave no indications of transformation to a white form. When heated slowly it changed from orange-yellow to lemon-yellow at about 88°, and at higher temperatures no further change was apparent until melting occurred at 141–142°. Since these findings did not correspond with those recorded by Jones and Oesper[9] for this derivative, the dibenzoyl ester was prepared in order to compare its data further with those previously reported. The dibenzoyl derivative obtained melted at 65°, as compared with the published value 69–70° for presumably the same material. The discrepancy between the melting points for both silver salts and dibenzoyl derivatives, indicated that these derivatives were related to different parent alcohols. The boiling point of the alkyl chlorocarbonate used in the present work was found to be 151–154°, a value in agreement with that given by Roese[10] for the *iso*-amyl derivative, and therefore the data recorded in this communication are correct for the derivatives of carb-*iso*-amyloxy-hydroxamic acid while the values given by Jones and Oesper[9] apply to isomeric derivatives. None of the material used by them was available and an explanation of the discordant results must await further investigation.

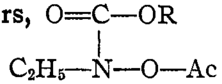
Benzyl-N Derivatives of the Benzoyl Esters,



$$\begin{array}{l} \quad\quad\;\; O{=}C{-}O{-}R \\ \quad\quad\quad\;\; | \\ C_7H_7{-}N{-}O{-}C({=}O){-}C_6H_5 \end{array}$$

.—These were prepared by refluxing chloroform solutions of equivalent quantities of the silver salt and benzyl chloride until the yellow solutions became colorless. After removal of the silver chloride, the chloroform was distilled from the filtrate and the residual oil was the desired product. The yields were almost quantitative.

Ethyl-N Derivatives of the Acyl Esters,



$$\begin{array}{l} \quad\quad\; O{=}C{-}OR \\ \quad\quad\quad\;\; | \\ C_2H_5{-}N{-}O{-}Ac \end{array}$$

.—These esters were obtained by allowing equivalent quantities of the silver salt and ethyl iodide to react in the dark, in the presence of ether, ligroin or chloroform. Evaporation of the media yielded the desired material. Without exception the alkyl derivatives obtained from all the silver salts

[9] Ref. 2 a, pp. 2220–21.

[10] Roese, *Ann.*, **205,** 230 (1881).

studied yielded β-substituted hydroxylamine on hydrolysis with concd. hydrochloric acid,[11] which was identified by condensation with *p*-nitrobenzaldehyde.[12] Assuming direct replacement of metal by alkyl, it follows that in all cases studied, the silver was bound to nitrogen.

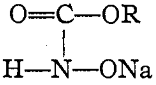
Sodium Salts of the Hydroxamic Acids,  $\mathrm{O{=}C{-}OR}$ over $\mathrm{H{-}N{-}ONa}$.—The sodium salts of the carbethoxy-, *n*-propoxy- and *n*-butoxy-hydroxamic acids were prepared by treating an alcoholic solution of the hydroxamic acid

TABLE I

HYDROXAMIC ACIDS

	Carbethoxy			*n*-Propoxy			*n*-butoxy		
	M. p. °C.	Analysis, % N Calcd.	Found	M. p. °C.	Analysis, % N Calcd.	Found	M. p. °C.	Analysis, % N Calcd.	Found
Benzoyl ester	...	...	...	...	...	...	...	...	...
Benzyl-N derivative	...	4.68	4.44[a]	...	4.47	4.14	...	4.28	4.23
Silver salt	174	34.15*	34.08	174	32.67*	32.54[d]	154	31.37*	31.38[e]
Ethyl-N derivative	...	5.90	6.09	...,	5.57	5.33	...	5.28	5.55
Sodium salt	...	18.0**	17.78[b]	...	16.3**	17.2[c]	...	14.83**	15.14
p-Chlorobenzoyl ester	75–76	5.75	5.75	38	5.43	5.05[g]	...	...	...
Silver salt	210	30.78*	30.63[i]	...	29.6**	29.4	...	...	...
Ethyl-N derivative	...	5.16	5.33	...	4.91	5.28	...	...	...
m-Nitrobenzoyl ester	88–89	11.03	10.95	59	10.45	10.30	44	9.93	9.97
Silver salt	...	29.9**	29.60	...	28.77**	28.36	...	27.73**	27.2
Ethyl-N derivative	67–68	9.93	9.81[h]	38	9.46	9.42[h]	57	9.02	9.22[h]
p-Nitrobenzoyl ester	92	11.03	10.85	75	10.45	10.40	74	9.93	10.0
Silver salt	...	29.9*	30.28	235	28.77*	28.57	...	27.73**	27.56
Ethyl-N derivative	...	9.93	9.66	43	9.46	9.76[h]	...	9.03	9.19
Dibenzoyl derivative	...	...	...	...	...	...	...	...	...

* Percentage of silver.

** Percentage of sodium.

[a] The benzyl-N derivative of benzoylated carbethoxy-hydroxamic acid boils at 172–175° (55 mm.).

[b] The hydrated form of this salt is described by Jones, Ref. 5, p. 40.

[c] The analytical data are not unsatisfactory since no purification was attempted. The high sodium content was probably due to the presence of a small quantity of sodium ethylate.

[d] Transition point, 132–133°; m. p., 174–175°. This salt was recrystallized from chloroform and ligroin. The isomeric silver salt described by Jones and Oesper gave no indications of a transition point.

[e] Recrystallized from chloroform and ether. This salt undergoes no change on heating as contrasted with the isomeric *iso*butyl silver salt described by Jones and Oesper.

[f] Recrystallized from chloroform and alcohol.

[g] Recrystallized from boiling ligroin.

[h] Recrystallized from ether and ligroin.

[i] The melting points of the silver salts of the substituted benzoyl esters were approximate. In these cases, the salt usually suffered decomposition before melting.

[j] Recrystallized from warm ligroin. Prepared by the method described by Jones and Oesper, Ref. 2 a, p. 2221.

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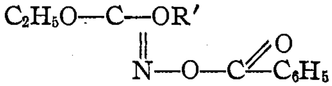
[11] Ref. 2 b, p. 729.

[12] Behrend and Leuchs, *Ann.*, **257,** 239 (1890).

with an equivalent of sodium ethylate. A crystalline mass of the salt separated after several hours. These salts were very hygroscopic and were dried to constant weight over phosphorus pentoxide. Attempts to purify them by recrystallization were unsatisfactory and the slightly impure salts were used in the preparation of the acylated derivatives.

Oximido-carbonic Esters

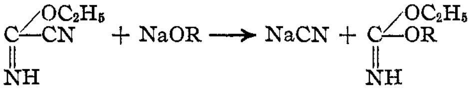
Hydrolysis of the ethyl derivatives of the acylated esters, prepared from the silver salts, invariably yielded β-ethyl hydroxylamine. This indicated that these esters were alkyl-N derivatives, assuming that no rearrangement occurred during hydrolysis. However, numerous examples of migration of an alkyl group from oxygen to nitrogen are recorded in the literature.[13] To establish definitely that no such rearrangement occurred in the present study and since it has been suggested that the two forms of the silver salts were "oxygen and nitrogen" isomers, it seemed advisable to prepare benzoyl derivatives of oximido-carbonic esters



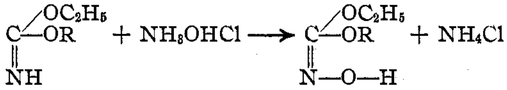
$C_2H_5O{-}C({=}N{-}O{-}C({=}O)C_6H_5){-}OR'$

isomeric with several of the ethyl-N derivatives described above, in order to compare their physical properties and behavior on hydrolysis.

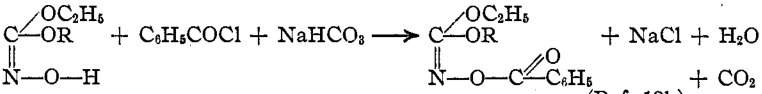
The following equations illustrate the steps involved in the synthesis of these derivatives.



$$HN{=}C(OC_2H_5){-}CN + NaOR \longrightarrow NaCN + HN{=}C(OC_2H_5){-}OR \qquad \text{(Ref. 14)} \qquad (3)$$



$$HN{=}C(OC_2H_5){-}OR + NH_3OHCl \longrightarrow H{-}O{-}N{=}C(OC_2H_5){-}OR + NH_4Cl \qquad \text{(Ref. 15)} \qquad (4)$$



$$H{-}O{-}N{=}C(OC_2H_5){-}OR + C_6H_5COCl + NaHCO_3 \longrightarrow C_6H_5C({=}O){-}O{-}N{=}C(OC_2H_5){-}OR + NaCl + H_2O + CO_2 \qquad (5)$$

(Ref. 13b)

Imidocarbonic Ethyl-*n*-propyl Ester.—Ten g. of ethyl cyanimido-carbonate and an ethereal suspension of sodium propylate,[16] prepared from 2.3 g. of sodium and 6.1 g. of *n*-propyl alcohol, yielded 12.9 g. of a light yellow oil with a strong basic odor. This was not purified or analyzed.

Oximido-carbonic Ethyl-*n*-propyl Ester.—12.7 g. of the imido ester and 6.7 g. of hydroxylamine hydrochloride gave 10 g. of the oximido ester.

Benzoyl Derivative of Oximido-carbonic Ethyl-*n*-propyl Ester.—Five g. of the ester, 2.8 g. of sodium bicarbonate and 4.7 g. of benzoyl chloride yielded by the ordinary pro-

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[13] (a) Hoffman and Olshausen, *Ber.*, **3**, 272 (1870). (b) Ponomarew, *Ber.*, **18**, 3269 (1885). (c) Wheeler and Johnson, *Am. Chem. J.*, **21**, 185 (1899). (d) Wislicenus and Goldschmidt, *Ber.*, **33**, 1467 (1905).

[14] (a) Nef, *Ann.*, **287**, 293 (1895); (b) Ref. 2 b, p. 731.

[15] (a) Houben and Schmidt, *Ber.*, **46**, 2458 (1913); (b) Ref. 2 b, p. 732.

[16] Brühl, *Ber.*, **37**, 2066 (1904).

cedure a colorless oil. The mixture, shaken for 30 minutes, gave an oil which was dissolved in chloroform and the latter dried with fused sodium sulfate. After most of the chloroform had been removed, ligroin was added and the resulting precipitate was recrystallized from a mixture of the same solvents; m. p., 151–152°.

Anal. Subs., 0.2420: N_2, 12.3 cc. (747 mm., 26°). Calcd. for $C_{13}H_{17}O_4N$: N, 5.57. Found: 5.58.

The isomeric ethyl-N derivative of the benzoylated carbo-propyloxy-hydroxamic acid was an oily liquid which gave no indications of solidifying.

Imidocarbonic Ethyl-*n*-butyl Ester.—Twelve g. of ethyl cyanimido-carbonate and 2.8 g. of sodium dissolved in 9 g. of *n*-butyl alcohol yielded 18 g. of a light yellow oil that was immediately converted into the oximido derivative.

Oximido-carbonic Ethyl-*n*-butyl Ester.—Eighteen g. of imido ester and 8.6 g. of hydroxylamine hydrochloride gave 18 g. of an oil that was immediately benzoylated.

Benzoyl Derivative of Oximido-carbonic Ethyl-*n*-butyl Ester.—Nine g. of oximido ester, 4.7 g. of sodium bicarbonate and 7.9 g. of benzoyl chloride gave a product that after recrystallization from chloroform and ligroin melted at 148–149°.

Anal. Subs., 0.2714: N_2, 13.5 cc. (745 mm. 25.5°). Calcd. for $C_{14}H_{19}O_4N$: N, 5.29. Found: 5.46.

The isomeric ethyl-N derivative of the benzoylated carbo-butyloxy-hydroxamic acid is definitely liquid and gave β-ethyl-hydroxylamine on hydrolysis. The compound under consideration gave hydroxylamine, as confirmed by the appearance of a fuchsin-red color in the nitroprusside test,[17] and the purple color in the yellow ammonium sulfide test.[18] The negative results of attempts to condense the hydrolysis product with *p*-nitrobenzaldehyde indicated the absence of β-ethyl-hydroxylamine.

Benzoyl Derivative of Oximido-carbonic Ethyl-*iso*-Amyl Ester.—Seven g. of oximido-carbonic ethyl-*iso*-amyl ester,[15b] 4.7 g. of sodium bicarbonate and 7.9 g. of benzoyl chloride yielded white crystals; m. p., 156–157°.

Anal. Subs., 0.3134: N_2, 15.2 cc. (745.5 mm., 29°). Calcd. for $C_{15}H_{21}O_4N$: N, 5.02. Found: 5.23.

This derivative on hydrolysis gave hydroxylamine.

Summary

Several new hydroxamic acids, their benzoyl and substituted benzoyl esters, their silver salts and alkyl derivatives, are described for the first time. Hydrolysis of all of the alkyl derivatives prepared from the silver salts of the acyl derivatives, both yellow and white, indicated that the alkyl group is bound to nitrogen. Hence, the white and yellow silver salts are polymers rather than isomers, assuming direct replacement of metal by alkyl. Benzoylated oximido-carbonic esters, isomeric with the above alkyl derivatives, are described for the first time; hydrolysis of these was found to yield hydroxylamine.

CINCINNATI, OHIO

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[17] Angeli, *Jahresber*, **1893**, p. 2068.

[18] Ball, *Proc. Chem. Soc.*, **18**, 9 (1902).