[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

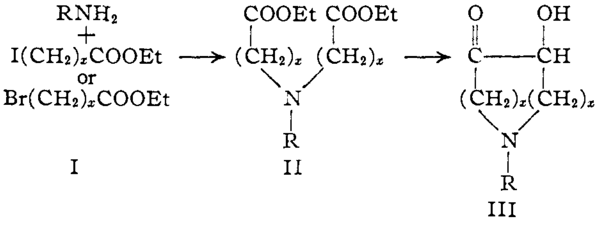
Cyclic Aminoacyloins. III. Synthesis, Properties and the Detection of Transannular Interaction between N and C_{CO}[1,2]

BY NELSON J. LEONARD, RICHARD C. FOX[3,4] AND MICHINORI ŌKI

RECEIVED MAY 29, 1954

1-Alkyl-1-azacycloalkanolones of type III have been synthesized *via* the acyloin condensation of the corresponding aminodiesters, which were made by treatment of the primary amine with the appropriate ω-haloester. Among the cyclic aminoacyloins obtained—of ring size: 7, 9, 11, 13, 15, 17, 19 and 23 members—the nine-membered ring compounds exhibited chemical and physical properties which were strikingly different from those of the other members in the series. Evidence of transannular interaction between RN< and >C=O in the nine-membered rings was obtained from infrared absorption data and pK'_a determinations. Moreover, it has been possible to assign the limits of ring size within which appreciable transannular interaction of these groups can be expected to occur. A comparison of the cyclic aminoacyloins as to ease of oxidation, ester formation, and dioxime formation has revealed further the dependence of chemical behavior upon ring size.

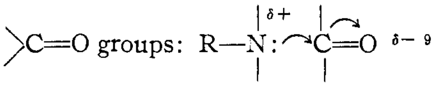
Increasing interest in the acyloin condensation prompted an investigation of this reaction as a route to medium and large rings containing nitrogen. Cyclic aminoacyloins of type III have been obtained in yields of 64–88% for ring sizes of 9–23 members (odd-membered rings).[5] This efficient application of the acyloin condensation augments the number of methods available for the synthesis of medium rings[6] (8–12 members)[7] and large rings[8] (13 and up)[7] in which nitrogen is part of the cycle.



I II III

	x	R		x	R		x	R
a	2	C_6H_5	e	4	C_2H_5	i	6	C_2H_5
b	3	CH_3	f	5	CH_3	j	7	CH_3
c	3	C_2H_5	g	5	C_2H_5	k	8	CH_3
d	4	CH_3	h	6	CH_3	l	10	C_2H_5

The chemical and physical properties of the cyclic aminoacyloins III were in general those expected for the functionality present and exhibited a dependence upon the ring size. However, the properties of the nine-membered ring aminoacyloins IIIb,c were strikingly out of line with those of their ring homologs. The most reasonable explanation[1] for the anomalous properties of the nine-membered ring compounds is found in the occurrence of transannular interaction between their RN< and



$>C{=}O$ groups: $R{-}\overset{\delta+}{N}{:}\curvearrowright C{=}O\ ^{\delta-}$ [9]

The synthesis of the cyclic aminoacyloins was initiated with the formation and careful purification of the known ω-haloesters (Ib-l) followed by reaction of these with the appropriate amine in ethanol solution in the presence of potassium carbonate. A minimum yield in the condensation reaction was obtained in the formation of diethyl κ,κ′-ethylimino-bis-hendecanoate (IIl) from ethylamine and ethyl κ-iodohendecanoate (Il) (35%) and a maximum, in the formation of diethyl ζ,ζ′-methylimino-bis-enanthate (IIh) from methylamine and ethyl ζ-bromoenanthate (Ih) (73%). Both iodo- and bromoesters were used, as considered desirable. Several of the aminodiesters had been prepared previously (IIa, b, d), and three known diesters of type IIa, in which R was CH_3, C_2H_5 and C_6H_5CO, also were prepared. The acyloin cyclization of the aminodiesters II was effected under purified nitrogen with finely dispersed sodium in refluxing xylene, utilizing high dilution and high speed stirring. The yields were uniformly good except in the closure of the N-phenyl seven-membered ring (10%). (The N-ethyl seven-membered ring acyloin could not be isolated—see below.) Although not strictly comparable, the yields of the 1-alkyl-1-azacycloalkanolones exceeded those reported in the acyloin synthesis of the analogous cycloalkanolones[10,11] and 1-oxacycloalkanolones[12] having the same ring size (9, 11 and 21-membered-ring examples).

The significant data for the cyclic aminoacyloins III are assembled in Table I. The eleven-membered ring aminoacyloins IIId and IIIe were most

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[1] Paper I. N. J. Leonard, R. C. Fox, M. Ōki and S. Chiavarelli, THIS JOURNAL, **76**, 630 (1954).

[2] Paper II. N. J. Leonard and M. Ōki, *ibid.*, **76**, 3463 (1954).

[3] Sinclair Refining Company Fellow in Organic Chemistry, 1951–1952. Work done under the sponsorship of the Sinclair Research Laboratories, Inc.

[4] E. I. du Pont de Nemours and Company, Inc., Fellow 1952–1953.

[5] R. C. Fox, Ph.D. Thesis, University of Illinois, 1953.

[6] *E.g.* (a) L. Knorr and P. Roth, *Ber.*, **39**, 1425 (1906); (b) E. R. Littman and C. S. Marvel, THIS JOURNAL, **52**, 287 (1930); (c) A. Müller and P. Bleier, *Monatsh.*, **56**, 391 (1930); (d) L. Ruzicka, M. Hürbin, M. W. Goldberg and M. Furter, *Helv. Chim. Acta*, **18**, 659 (1935); (e) L. Ruzicka, M. Kobelt, O. Häfliger and V. Prelog, *ibid.*, **32**, 544 (1949); (f) V. Prelog and R. Seiwerth, *Ber.*, **72**, 1638 (1939); (g) J. von Braun, K. Heider and W. Wyczatkowska, *ibid.*, **51**, 1215 (1918); (h) J. von Braun and L. Neumann, *ibid.*, **52**, 2015 (1919); (i) N. J. Leonard and R. C. Sentz, THIS JOURNAL, **74**, 1704 (1952); (j) N. J. Leonard, S. Swann, Jr., and J. Figueras, Jr., *ibid.*, **74**, 4620 (1952); (k) N. J. Leonard, S. Swann, Jr., and E. H. Mottus, *ibid.*, **74**, 6251 (1952); (l) N. J. Leonard, S. Swann, Jr., and G. Fuller, *ibid.*, **76**, 3193 (1954).

[7] Reference 21 in H. C. Brown, R. S. Fletcher and R. B. Johannesen, *ibid.*, **73**, 212 (1951).

[8] *E.g.* (a) L. Ruzicka, M. W. Goldberg, M. Hürbin and H. A. Boekenoogen, *Helv. Chim. Acta*, **16**, 1323 (1933); (b) R. Lukeš and J. Málek, *Chem. Listy*, **45**, 72 (1951); also refs. 6d, 6e.

[9] F. A. L. Anet, A. S. Bailey and Sir Robert Robinson, *Chem. and Ind.*, 944 (1953); also, Sir Robert Robinson in the Karl Folkers Lectures at the University of Illinois, September 29, 30, October 1, 1953.

[10] M. Stoll and A. Rouvé, *Helv. Chim. Acta*, **30**, 1822 (1947).

[11] N. J. Leonard and G. C. Robinson, THIS JOURNAL, **75**, 2714 (1953); also, G. C. Robinson, Ph.D. Thesis, University of Illinois, 1952.

[12] V. Prelog, M. Fausy El-Neweihy and O. Häfliger, *Helv. Chim. Acta*, **33**, 1937 (1950).

TABLE I

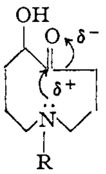
CYCLIC AMINOACYLOINS

Cyclic aminoacyloins (III)	Yield, %	M.p., °C., or b.p., °C. (mm.)	Oximation[a]	*p*-Nitrobenzoate ester[b]	Fehling test	Infrared max., cm.$^{-1}$	
						C=O	O–H
1-Phenyl-1-azacycloheptan-4-ol-5-one(a)	10	109–111	?[c]	Yes	+[e]	1701	3458[f]
1-Methyl-1-azacyclononan-5-ol-6-one(b)	75	95–97	No reacn.	?[d]	+	1666	3410
1-Ethyl-1-azacyclononan-5-ol-6-one(c)	73	64–65 (0.2)	Dioxime	?	++	1671	3428
1-Methyl-1-azacyclohendecane-6-ol-7-one(d)	64	85–86 (0.2)	Dioxime	Yes	+++	1700	3462
1-Ethyl-1-azacyclohendecane-6-ol-7-one(e)	85	65 (0.02)	Dioxime	?	+++	1705	3470
1-Methyl-1-azacyclotridecane-7-ol-8-one(f)	86	51–52	Monoxime	Yes	+	1707	3480
1-Ethyl-1-azacyclotridecane-7-ol-8-one(g)	77	51–52	?	?	++	1708	3460
1-Methyl-1-azacyclopentadecane-8-ol-9-one(h)	83	105–106 (0.03)	....	Yes	+	1708	3465
1-Ethyl-1-azacyclopentadecane-8-ol-9-one(i)	88	105–109 (0.05)	....	Yes	++	1709	3480
1-Methyl-1-azacycloheptadecane-9-ol-10-one(j)	84	122–123 (0.05)	....	Yes	+	1713	3500
1-Methyl-1-azacyclononadecane-10-ol-11-one(k)	83	130–131 (0.05)	....	Yes	+	1713	3500
1-Ethyl-1-azacyclotricosan-12-ol-13-one(l)	72	180–210 (0.1)	Monoxime	Yes	+	1712	3453

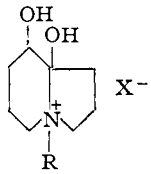
[a] Under conditions we shall describe as standard: excess hydroxylamine hydrochloride and pyridine for two hours in refluxing ethanol.[13a] [b] Under standard conditions.[13b] Results are not to be regarded as more than of qualitative significance. [c] Product may be impure monoxime. [d] The query indicates that decomposition occurred, especially on warming. It does not necessarily mean that ester was not formed initially. [e] +++, immediately; ++, on heating 1–2 min.; +, on longer heating. [f] $CHCl_3$ soln., others in CCl_4.

readily oxidized by Fehling solution, a fact which is reminiscent of the susceptibility of the cycloalkanolone of the same ring size to autoxidation as obobserved by Stoll and Rouvé.[10] Compounds IIId and IIIe were oxidized immediately at room temperature, whereas the rings of larger and smaller size required brief heating periods. The N-ethyl nine-membered ring aminoacyloin IIIc required 30 minutes at 25° for oxidation by Fehling solution; the N-methyl compound IIIb, by contrast, was not oxidized at 25°. The comparative resistance of 1-methyl-1-azacyclononan-5-ol-6-one (IIIb) to oxidation was further indicated by its relative inertness to some of the reagents which are normally used for the conversion of α-hydroxyketones to α-diketones: cupric acetate in 70% acetic acid[14]; cupric acetate in methanol[15,16]; chromic acid in glacial acetic acid.[17] The aminoacyloins of larger ring size (IIIf, h, j, k) were oxidized readily to the corresponding diketones by means of cupric acetate in 70% acetic acid.[14] The ease of oxidation of the eleven-membered ring aminoacyloins (IIId, e) by Fehling solution was paralleled by their conversion to dioximes on treatment with hydroxylamine,[13a] an oxidation similar to osazone formation. 1-Ethyl-1-azacyclononan-5-ol-6-one (IIIc) also formed a dioxime, while 1-methyl-1-azacyclononan-5-ol-6-one (IIIb) was unchanged under the usual conditions and required lengthy heating with hydroxylamine hydrochloride and pyridine to yield even a small quantity of dioxime.[18] The cyclic aminoacyloins of 13 and 23 members (IIIf, l) formed monoximes (Table I). A qualitative difference in reactivity dependent upon ring size also was observed in the reaction of *p*-nitrobenzoyl chloride with the cyclic aminoacyloins. Thus, whereas it was possible to obtain *p*-nitrobenzoate esters of aminoacyloins of ring size: 7, 11, 13, 15, 17, 19 and 23 members (IIIa, d, f, h, i, j, k, l), the *p*-nitrobenzoates of the nine-membered ring aminoacyloins (IIIb, c), if they were formed initially, were highly unstable, as indicated by conversion to tars.

Perhaps the most striking difference between the nine-membered ring aminoacyloins and the others in the series III lies in their infrared absorption spectra. The acyloins of ring size: 11, 13, 15, 17, 19 and 23 members possess normal ketone carbonyl absorption in the infrared (1700–1713 cm.$^{-1}$), as does IIIa, a seven-membered ring, while the two nine-membered ring examples (IIIb, c) have infrared maxima in the 6μ region which are at abnormally low frequency (Table I) for C=O stretching in a saturated ketone. The occurrence of transannular interaction[9] across the nine-membered ring IV,



IV



V

which would decrease the double bond character of the carbonyl group, could account for the low C=O stretching frequency observed in the spectra of the compounds of this ring size.[19] The perchlorate of the eleven-membered ring IIId shows both ketone (1710 cm.$^{-1}$) and O–H/N–H (3480 cm.$^{-1}$) absorption, whereas the perchlorate of the nine-membered ring (IIIb, 3440 cm.$^{-1}$; also IIIc, 3425 cm.$^{-1}$) is transparent in the 6 μ region (no C=O), indicating that the salts of IIIb and IIIc exist in the transannular quaternary form V in the mull. The *p*-toluenesulfonate salt of IIIb is transparent in the 6 μ region

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(13) (a) R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," third edition, John Wiley and Sons, Inc., New York, N.Y., 1948, p. 202; (b) *ibid.*, p. 164.

(14) P. Ruggli and P. Zeller, *Helv. Chim. Acta*, **28**, 741 (1945).

(15) L. L. Salomon, J. J. Burns and C. G. King, THIS JOURNAL, **74**, 5161 (1952).

(16) J. K. Hamilton and F. Smith, *ibid.*, **74**, 5162 (1952).

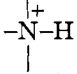
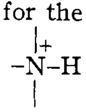
(17) V. Prelog, L. Frankiel, M. Kobelt and P. Barman, *Helv. Chim. Acta*, **30**, 1741 (1947).

(18) Greater differences in chemical and physical properties are exhibited between IIIb and IIIc (*e.g.*, the former is a solid; the latter, a liquid) than between any other pair of N-methyl and N-ethyl compounds (IIId, e; IIIf, g; IIIh, i) in the series of cyclic aminoacyloins.

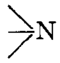
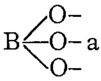
(19) We have not rigorously eliminated the possibility that the infrared absorption in the 6 μ region from IIIb, c could be due to C=C in an enediol grouping, stabilized and polarized by transannular O–H–N bonding. However, the observations reported previously[3] are difficult to explain in terms of this model.

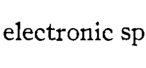
in the mull and in chloroform solution.[2] The contrast between the eleven- and nine-membered ring compounds is further illustrated by comparison of the pK'_a values of their conjugate acids as determined in different solvents.[20]

	pK'_a 66% DMF	pK'_a Water	$\Delta pK'_a$
11-Membered ring IIId	7.8	9.1	+1.3
9-Membered ring IIIb	10.6	9.2	−1.4

The increase in pK'_a observed for the eleven-membered ring in changing solvent from 66% dimethylformamide to water is consistent with attachment of the proton to the nitrogen in the conjugate acid of this base,[21] although the magnitude of the difference is greater than that normally encountered for these solvents[22] and is probably due to steric hindrance of solvation of  $-\overset{|+}{\underset{|}{N}}-H$ by the dimethylformamide. The decrease in pK'_a observed for the nine-membered ring in making the same change from the mixed solvent to water is typical of enols and acids,[21–23] and it is therefore clear that the proton is attached to the oxygen V in the conjugate acid of IIIb in the dimethylformamide solution. The 13-, 15- and 17-membered acyloins gave titration results similar to those for the eleven-membered ring, consistent with the  $-\overset{|+}{\underset{|}{N}}-H$ structure of the base conjugate acids.[24]

The assembled evidence points to the occurrence of transannular interaction between N and C_{CO} groups (IV) in the nine-membered ring aminoacyloins (IIIb, c) and the apparent absence of appreciable interaction in rings of eleven members and larger in the same series. There is no evidence available which suggests transannular interaction across a seven-membered ring (such as IIIa, or with R = CH_3 or C_2H_5), whereas additional evidence has been provided for the occurrence of such interaction across eight-, nine- and ten-membered rings:

Eight-membered Ring.—Brown and Fletcher[25] have demonstrated the coördination of  $>N:$ with  $B{<}(O-)_3$ across an eight-membered ring in triethanolamine borate. We have reported an eight-membered ring aminoketone, 1-methyl-1-azacyclooctan-5-one,[1] which, on the basis of pK'_a determinations and the infrared spectra of the base and its perchlorate, shows transannular interaction between N and C_{CO}.

Nine-membered Ring.—Wieland and his co-workers[26] suggested the contribution of a limiting electronic species,  $-\overset{|+}{\underset{|}{N}}-\overset{|}{\underset{|}{C}}-O^-$, to the structure of the alkaloid vomicine to account for the absence of normal ketone reactions and the low basicity of the nitrogen toward methyl iodide. In N-methylpseudostrychnine, which is similar in structure to vomicine but lacks the phenolic hydroxyl group, the low frequency observed for the infrared absorption of the carbonyl group has been ascribed by Robinson and his co-workers as due to transannular interaction between N and C_{CO}[27,28] ("transannular amide-type neutralization").[9] Evidence also was obtained from the infrared spectra of N-methylpseudostrychnine methoperchlorate and N-methylpseudostrychnidine and its hydriodide.

Ten-membered Ring.—Transannular interaction between N and C_{CO} was detected in the alkaloid cryptopine by means of infrared absorption spectra[9] and in the alkaloid protopine through the use of both infrared and ultraviolet absorption spectra.[29,30]

Formulations involving interaction of tertiary amine and ketone functions are thus indicated for eight-, nine- and ten-membered ring aminoketones and aminoacyloins in which a full transannular bond between N and C_{CO} can create a five- or six-membered ring within the larger cycle.[31] Other studies in this Laboratory[2] have indicated that steric strain (F-strain) places a further limitation on transannular interaction between N and C_{CO} in cyclic aminoacyloins, and it has also been shown that the physical state of the compounds under examination (whether as solids or in solution) and the nature of the solvent employed for solutions of these compounds may influence the extent to which transannular bonding may occur.

All of the 1-methyl-1-azacycloalkanolones (IIIb, d, f, h, j, k) in ethanol or aqueous ethanol were tested for qualitative color reactions with 0.1 *M* solutions of nickel, ferric, cobaltous, chromic and cupric nitrates. Other solutions were rendered

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[20] We are indebted to Mr. Donald O. Woolf, Jr., and Dr. Harold E. Boaz of Eli Lilly and Company, Indianapolis, Ind., for the electrometric titrations and for aid in their interpretation.

[21] M. Mitzutani, *Z. physik. Chem.*, **116**, 350 (1925).

[22] *Cf.* footnote 7 in the article by E. H. Flynn, J. W. Hinman, E. L. Caron and D. O. Woolf, Jr., THIS JOURNAL, **75**, 5867 (1953).

[23] (a) L. Michaelis and M. Mizutani, *Z. physik. Chem.*, **116**, 135 (1925); (b) J. C. Speakman, *J. Chem. Soc.*, 270 (1943).

[24] The pK'_a values for the larger rings are not included here as determined in water since precipitation was observed during the determinations and the figures were necessarily approximations. The approximate values were 0.9–1.2 unit higher in water than those obtained in 66% DMF: IIIf, pK'_a 8.6; IIIh, j, k, 1—all 9.0–9.1. It is not unlikely that some decomposition may have taken place in the samples used for the determinations mentioned in this footnote.

[25] H. C. Brown and E. A. Fletcher, THIS JOURNAL, **73**, 2808 (1951).

[26] R. Huisgen, H. Wieland and H. Eder, *Ann.*, **561**, 193 (1949).

[27] N. H. Cromwell, F. A. Miller, A. R. Johnson, R. L. Frank and D. J. Wallace, THIS JOURNAL, **71**, 3337 (1949), have shown that the spectral contribution of a tertiary amine group, acting through a carbon–carbon double bond conjugated with a ketone carbonyl,  $>N-\overset{|}{C}=CH-\overset{O}{\overset{\|}{C}}-$, is to lower the C=O stretching frequency in the infrared.

[28] We prefer the more general designation. It is possible that evidence also will be uncovered which indicates the occurrence of transannular interaction between –S– or –O– and the carbon of a carbonyl group in heterocyclic ketones of appropriate size.

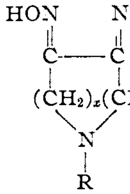
[29] E. H. Mottus, H. Schwarz and L. Marion, *Can. J. Chem.*, **31**, 1144 (1953); see also F. A. L. Anet and L. Marion, *ibid.*, **32**, 452 (1954).

[30] It is of interest that the alkaloid ochrobirine has been postulated by R. H. F. Manske (*Can. J. Res.*, **B14**, 354 (1936); **B17**, 89 (1939)) as a 13-hydroxyprotopine. If this is indeed a correct structural assignment, the alkaloid is a naturally occurring cyclic aminoacyloin capable of sustaining transannular N → C_{CO} interaction.

[31] It is interesting to relate the fact that transannular hydrogen migrations have been observed for eight-, nine- and ten-membered rings in the solvolytic opening of an ethylene oxide grouping: A. C. Cope, S. W. Fenton and C. F. Spencer, THIS JOURNAL, **74**, 5884 (1952); V. Prelog and K. Schenker, *Helv. Chim. Acta*, **35**, 2044 (1952); V. Prelog, K. Schenker and W. Kung, *ibid.*, **36**, 471 (1953).

acid with hydrochloric acid and basic with sodium hydroxide to determine whether any color or precipitating reaction would occur that differed from the controls, which were run simultaneously. The color changes which were observed for the nine-membered ring aminoacyloin IIIb with cobaltous and cupric ions in basic or in neutral solution were different from those of the controls and those of the aminoacyloins of other ring sizes. The color of the cobaltous ion with IIIb was transitory and could be obtained only with excess acyloin. With cupric ion, the same acyloin in molar excess produced a clear, deep blue solution. The visible spectrum of an ethanolic solution of IIIb and cupric nitrate (5:2 molar proportion) showed broad absorption with a maximum (not sharply defined) in the 700 mμ region. The eleven-membered ring acyloin IIId differed from the higher members of the series in that it gave a precipitate with cupric ion, an observation which is not surprising since this compound reduces Fehling solution immediately at 25°.

The dioximes VI were made by direct oximation of the 1-alkyl-1-azacycloalkanolones (III) (see above) or else *via* oxidation of the acyloins to the corresponding diketones with copper acetate in acetic acid followed by treatment with hydroxylamine. The dioximes of the 1-methyl-1-azacycloalkanediones were tested for qualitative reactions with 0.1 *M* solutions of ferric, nickel, chromic, cobaltous and cupric nitrates, in aqueous and ethanolic solutions. All of the dioximes gave the same color changes as did dimethylglyoxime with cobaltous, cupric, chromic and ferric ions. In contrast to the behavior of dimethylglyoxime with nickel ion, the dioximes VI gave yellow-orange precipitates in ethanol and none in water.



VI

Experimental[32]

ω-Haloesters.—The physical properties of the ω-haloesters are recorded in Table II for comparison with the properties as reported previously and as an indication of the purity of the compounds used in the subsequent steps in the synthesis of the aminoacyloins.

TABLE II

ω-Haloesters (I)	B.p. °C.	Mm.	$n^{20}D$
Ethyl γ-bromobutyrate[33]	133	96	1.4564
Ethyl γ-iodobutyrate[34]	97	13	1.4974
Ethyl δ-bromovalerate[35]	93–96	10–12	1.4585
Ethyl δ-iodovalerate[35d]	95–96	6	1.4960
Ethyl ε-bromocaproate[35d,36]	94–98	5	1.4589
Ethyl ε-iodocaproate[35d]	93–96	4–5	1.4940
Ethyl ζ-bromoenanthate[37]	115–117	8–9	1.4600
Ethyl ζ-iodoenanthate[a]	113–119	5–6	1.491
Ethyl η-bromocaprylate[38]	78–84	1–5	1.462
Ethyl θ-bromopelargonate[39]	90–96	1–5	1.461
Ethyl κ-bromohendecanoate[35d,40]	137–140	0.1–0.2	1.4611
Ethyl κ-iodohendecanoate[35d,41]	118–120	0–1	1.4835

[a] Made in 95% yield by the same method used for ethyl ε-iodocaproate.[35d]

Aminodiesters.—Variations of a general method were employed for the preparation of the aminodiesters II. The method can be illustrated by the synthesis of **diethyl ζ,ζ'-methylimino-bis-enanthate** (IIh). A solution of 71.1 g. (0.3 mole) of ethyl ζ-bromoenanthate and 4.65 g. (0.15 mole) of methylamine in 300 ml. of absolute ethanol was stirred at 25° for one hour, then under reflux for 3 hours. Potassium carbonate (20–30 g.) was added and the mixture was stirred at the reflux temperature for an additional 3 hours. The excess ethanol was removed by distillation, and ether and water were added with stirring to the residue. The layers were separated, the aqueous layer was extracted five times with ether, the combined ethereal extracts were dried and the ether was removed. The residue was distilled under vacuum through a modified Holzman[42] column. The pertinent data for IIh and the other aminodiesters are found in Table III.

Diethyl β,β'-phenylimino-bis-propionate was prepared from aniline and ethyl acrylate, as follows: a solution of 93 g. (1.0 mole) of redistilled aniline, 306.5 g. (3 moles) of redistilled ethyl acrylate and 25 ml. of glacial acetic acid[43] was heated under reflux for 24 hours. Additional ethyl acrylate (167 g.) was added and heating was continued for 24 hr. The reaction mixture was washed with 200 ml. of water, diluted with 300 ml. of ether and the ether solution was washed with 200 ml. of dilute sodium bicarbonate solution followed by 200 ml. of water. The ether solution was dried and the solvent was removed. The residual oil was twice distilled through a short Vigreux column, yielding 146.6 g. (57% based on aniline) of a colorless oil, b.p. 170–173° (1.5 mm.), $n^{20}D$ 1.5170 (reported[44] b.p. 182–184° (2.0 mm.), $n^{20}D$ 1.5176).

Cyclic Aminoacyloins.—The acyloin condensations were all run in a special apparatus. The reaction mixture was contained in a 1-l. Morton flask with a Morton high speed stirrer attached.[45] Inlets for purified nitrogen were provided through the stirrer cylinder and through one of the side-necks of the flask. In the other side-neck was placed a cyclic high-dilution apparatus[6f,46,47] which had a 500-ml. addition funnel and a reflux condenser with stopcock attached.[6f] The outlet for nitrogen in the system was through the reflux condenser and thence through a piece of tubing projecting below the surface of xylene contained in a bottle. This bubbler permitted a constant check on the flow of

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[32] We wish to thank Miss Helen Miklas for determination of the infrared absorption spectra and Mrs. Katherine Pih, Mrs. Esther Fett, Miss Emily Davis and Mr. Joseph Nemeth for the microanalyses. All melting points are corrected.

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TABLE III

Aminodiesters (II)	Yield, %	B.p. °C.	Mm.	$n^{20}D$	Specific gravity	Formula	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found
Diethyl γ,γ'-methylimino-bis-butyrate (b)[32]	53	118	1.0	1.4435		$C_{13}H_{25}NO_4$						
Diethyl γ,γ'-ethylimino-bis-butyrate (c)	60	95–96	0.15	1.4441	d^{25}_{25} 0.979	$C_{14}H_{27}NO_4$	61.51	61.51	9.96	9.98	5.12	5.23
Diethyl δ,δ'-methylimino-bis-valerate (d)[33]	47	135–140	.05	1.4458		$C_{15}H_{29}NO_4$						
Diethyl δ,δ'-ethylimino-bis-valerate (e)	64	112	.07	1.4468	d^{25}_{25} .965	$C_{16}H_{31}NO_4$	63.75	63.66	10.37	10.33	4.65	4.74
Diethyl ϵ,ϵ'-methylimino-bis-caproate (f)	59	127–129	0.1	1.4488	d^{24}_{24} .962	$C_{17}H_{33}NO_4$	64.72	64.72	10.54	10.72	4.44	4.78
Diethyl ϵ,ϵ'-ethylimino-bis-caproate (g)	46	166–169	1.4	1.4508	d^{20}_{20} .962	$C_{18}H_{35}NO_4$	65.61	65.58	10.71	10.62	4.25	4.59
Diethyl ζ,ζ'-methylimino-bis-enanthate (h)	73	136–138	.04	1.4498	d^{27}_{27} .948	$C_{19}H_{37}NO_4$	66.43	66.51	10.86	10.84	4.08	4.34
Diethyl ζ,ζ'-ethylimino-bis-enanthate (i)	39	146–147	.05	1.4511	d^{27}_{27} .944	$C_{20}H_{39}NO_4$	67.18	67.42	11.00	11.06	3.92	4.17
Diethyl η,η'-methylimino-bis-caprylate (j)	64	160–163	.3	1.4521	d^{27}_{27} .937	$C_{21}H_{41}NO_4$	67.88	67.92	11.12	10.96	3.77	3.74
Diethyl θ,θ'-methylimino-bis-pelargonate (k)	47	148–153	.05	1.4536	d^{26}_{26} .933	$C_{23}H_{45}NO_4$	69.13	69.17	11.35	11.25	3.51	3.58
Diethyl κ,κ'-ethylimino-bis-hendecanoate (l)[a]	35	235	0.1	1.4560		$C_{28}H_{55}NO_4$	71.60	71.65	11.79	11.81	2.98	2.94

[a] Infrared maximum at 1734 cm.$^{-1}$.

TABLE IV

Cyclic amino-acyloins[a]	Odor[5]	$n^{20}D$	Specific gravity	Formula	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found
IIIa	Odorless			$C_{12}H_{15}NO_2$	70.22	70.51	7.37	7.47	6.82	7.04
IIIb	Camphoraceous			$C_9H_{17}NO_2$	63.12	63.74	10.01	9.98	8.18	7.90
IIIc	Camphoraceous	1.4999	d^{27}_{27} 1.046	$C_{10}H_{19}NO_2$	64.83	65.12	10.33	10.49	7.56	7.69
IIId	Smoky	1.4926	d^{31}_{31} 1.031	$C_{11}H_{21}NO_2$	66.29	66.52	10.62	10.70	7.03	7.21
IIIe	Smoky	1.4907	d^{26}_{26} 1.021	$C_{12}H_{23}NO_2$	67.56	67.39	10.87	10.67	6.57	6.45
IIIf	Slightly smoky			$C_{13}H_{25}NO_2$	68.68	69.00	11.06	11.02	6.16	6.02
IIIg	Slightly smoky			$C_{14}H_{27}NO_2$	69.66	69.37	11.28	11.14	5.80	5.97
IIIh	Musky	1.4942		$C_{15}H_{29}NO_2$	70.54	70.83	11.45	11.42	5.48	5.74
IIIi	Musky	1.4925		$C_{16}H_{31}NO_2$	71.32	71.62	11.60	11.62	5.20	5.40
IIIj	Pleasant	1.4922		$C_{17}H_{33}NO_2$	72.03	72.20	11.73	11.65	4.94	4.90
IIIk	Faint	1.4888		$C_{19}H_{37}NO_2$	73.26	73.75	11.97	11.91	4.50	4.61
IIIl		1.4836	d^{29}_{29} 0.938	$C_{24}H_{47}NO_2$	75.53	75.59	12.41	12.39	3.67	3.77

[a] All of the compounds are colorless when pure.

nitrogen through the apparatus. Purified nitrogen was passed continually through the apparatus prior to starting the reaction and up until the flask and its contents were finally removed. Xylene or toluene was distilled from sodium into the reaction flask until it was three-quarters full. The solvent was redistilled from the Morton flask and the condensate was removed through the stopcock at the bottom of the reflux condenser. Water was thus removed azeotropically from the apparatus. The distillation process was continued until the flask was less than half full. Following cooling, a slight excess over four atom equivalents of freshly cut sodium was introduced into the flask. The solvent was heated to vigorous reflux as the mixture was stirred at 7500–9000 r.p.m. One mole of the aminodiester II in 500 ml. of anhydrous solvent was introduced into the reaction mixture through the addition funnel. The addition time was usually 4 to 6 hours. When the addition was complete, the refluxing and stirring were continued for an additional 30 minutes. The flask and contents were cooled slowly, while increasing the input of purified nitrogen. Finally the flask was cooled in an ice-bath and glacial acetic acid was added cautiously to the moderately stirred mixture until it became slightly acidic. Water (200 ml.) was added to dissolve the sodium acetate, and potassium carbonate was added to saturation. The two layers were separated, and the aqueous layer was extracted with ether. The combined organic portions were dried, the solvent was removed by distillation at reduced pressure, and the residue was distilled under reduced pressure through a modified Holzman column. In Table IV can be found the analyses of the cyclic aminoacyloins and additional physical properties. In the case of the 1-phenyl-1-azacycloheptan-4-ol-5-one (IIIa), distillation was not attempted. The crystalline product was obtained by extensive trituration of the crude product with boiling n-hexane, followed by concentration of the hexane solutions. Recrystallization from hexane gave colorless needles of the monomeric product (mol. wt. calcd. 205.3; found 193, cryoscopic in benzene). The residual product which did not dissolve in hexane was dried and ground to a light brown powder. The polymeric resin had a very low ion exchange capacity and a low adsorption capacity for the ions: Ni^{++}, Fe^{+++}, Mn^{++}.[48] In the acyloin cyclization there appeared to be concomitant formation of the six-membered cyclic β-ketoester taking place, since extracts and filtrates from the purification of the acyloin IIIa contained material which gave a striking ferric chloride test, while the acyloin gave a negative test.

The other solid cyclic aminoacyloins were IIIb (sublimed for purification), IIIf (colorless needles from low-boiling petroleum ether), and IIIg (colorless needles from low-boiling petroleum ether).

Under the favorable cyclization conditions used for IIIa, diethyl β,β'-ethylimino-bis-propionate[49] yielded a toluene extract that was practically colorless, but attempts at the isolation of 1-ethyl-1-azacycloheptan-4-ol-5-one or its derivatives were unsuccessful.

Compounds IIIb and c gave negative ferric chloride tests in aqueous solution.

***p*-Nitrobenzoate Esters of the Cyclic Aminoacyloins.**—The *p*-nitrobenzoate ester of IIIa was formed when the acyloin was allowed to react with an equivalent amount of *p*-nitrobenzoyl chloride in dry benzene in the presence of triethylamine. After the usual neutralization, extraction and evaporation steps, a residual red oil was obtained which was triturated with boiling n-hexane. Crystallization from methanol gave orange needles, m.p. 146–147°.

Anal. Calcd. for $C_{19}H_{18}N_2O_5$: C, 64.40; H, 5.12; N, 7.91. Found: C, 64.52; H, 5.13; N, 7.81.

The ester of IIId, which was formed at the reflux (15 min.) in benzene without added triethylamine, crystallized from petroleum ether (b.p. 40–60°) as yellow needles, m.p. 93–94°. This compound decomposed in a boiling solution of petroleum ether (b.p. 90–110°).

Anal. Calcd. for $C_{18}H_{24}N_2O_5$: C, 62.05; H, 6.95; N, 8.04. Found: C, 62.18; H, 6.99; N, 8.01.

The ester of IIIf was dimorphic: yellow needles from pe-

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(48) We wish to thank Mr. J. C. Harris and Mr. L. E. Weeks of the Monsanto Chemical Company for running tests on this resin.

(49) R. C. Fuson, W. E. Parham and J. Reed, THIS JOURNAL, **68**, 1239 (1946).

troleum ether (b.p. 90–110°), m.p. 93–94°; metastable form, apparently colorless needles, m.p. 84–85°.

Anal. Calcd. for $C_{20}H_{28}N_2O_5$: C, 63.81; H, 7.50; N, 7.44. Found: C, 63.94; H, 7.54; N, 7.51.

The ester of IIIh, formed in benzene containing triethylamine, crystallized as pale yellow needles from petroleum ether (b.p. 40–60°), m.p. 72–73°.

Anal. Calcd. for $C_{22}H_{32}N_2O_5$: C, 65.32; H, 7.97; N, 6.93. Found: C, 65.38; H, 8.18; N, 7.15.

The ester of IIIi, pale yellow needles, m.p. 81–82°, from petroleum ether.

Anal. Calcd. for $C_{23}H_{34}N_2O_5$: C, 66.00; H, 8.19; N, 6.69. Found: C, 66.08; H, 8.21; N, 6.85.

The ester of IIIj, cream-colored needles, m.p. 91–92°, from petroleum ether.

Anal. Calcd. for $C_{24}H_{36}N_2O_5$: C, 66.64; H, 8.39; N, 6.48. Found: C, 66.84; H, 8.61; N, 6.47.

The ester of IIIk, cream-colored needles, m.p. 72–73°, from petroleum ether.

Anal. Calcd. for $C_{26}H_{40}N_2O_5$: C, 67.79; H, 8.75; N, 6.08. Found: C, 68.21; H, 8.82; N, 6.15.

The ester of IIIl, clumps of orange needles from ethanol, m.p. 62.5°; infrared maxima (Nujol): 1718, 1732 cm.$^{-1}$.

Anal. Calcd. for $C_{31}H_{50}N_2O_5$: C, 70.15; H, 9.50; N, 5.28. Found: C, 70.44; H, 9.44; N, 5.53.

Oximation of the Cyclic Aminoacyloins.—The acyloin IIIb failed to react in 2 hours with excess hydroxylamine hydrochloride and pyridine in refluxing ethanol.[13a] After 24 hours at the reflux, followed by neutralization, extraction and concentration operations, a complex mixture resulted. Fractional sublimation of the mixture yielded a very small amount of 1-methyl-1-azacyclononan-5,6-dione dioxime (VIb), recrystallized several times from ethanol–petroleum ether and then from aqueous ethanol as tan granules, m.p. 180–181°.

Anal. Calcd. for $C_9H_{17}N_3O_2$: C, 54.25; H, 8.60; N, 21.09. Found: C, 54.53; H, 8.60; N, 21.01.

Treatment of the acyloin IIIb with potassium hydroxide and excess hydroxylamine hydrochloride in refluxing ethanol for 2 hours yielded 1-methyl-1-azacyclononan-5-ol-6-one oxime, colorless needles from benzene–petroleum ether (b.p. 90–110°), m.p. 130.5–131.5°.

Anal. Calcd. for $C_9H_{18}N_2O_2$: C, 58.04; H, 9.74; N, 15.04. Found: C, 58.31; H, 9.88; N, 14.35.

When IIIc was treated with excess hydroxylamine hydrochloride and pyridine in refluxing ethanol for 2 hours, the 1-ethyl-1-azacyclononan-5,6-dione dioxime (VIc) was obtained, colorless needles from aqueous ethanol, m.p. 161–162°.

Anal. Calcd. for $C_{10}H_{19}N_3O_2$: C, 56.31; H, 8.98; N, 19.70. Found: C, 57.31; H, 9.10; N, 19.46.

1-Methyl-1-azacyclohendecan-6,7-dione dioxime (VId), obtained directly[13a] from IIId, colorless needles from aqueous ethanol, m.p. 208–210° dec.

Anal. Calcd. for $C_{11}H_{21}N_3O_2$: C, 58.12; H, 9.31; N, 18.49. Found: C, 58.18; H, 9.20; N, 18.33.

1-Ethyl-1-azacyclohendecan-6,7-dione dioxime (VIe), from IIIe, colorless needles from aqueous ethanol, m.p. 203–204°.

Anal. Calcd. for $C_{12}H_{23}N_3O_2$: C, 59.73; H, 9.61; N, 17.41. Found: C, 59.49; H, 9.59; N, 17.63.

1-Ethyl-1-azacyclohendecan-6-ol-7-one oxime was produced when 1.25 g. of the acyloin IIIe was heated on a steam-bath for 10 minutes in an aqueous ethanol solution of 0.5 g. of hydroxylamine hydrochloride and 0.3 g. of sodium hydroxide, colorless needles from ethanol–petroleum ether (b.p. 90–110°), m.p. 130–131°.

Anal. Calcd. for $C_{12}H_{24}N_2O_2$: C, 63.12; H, 10.59; N, 12.27. Found: C, 63.25; H, 10.41; N, 12.28.

1-Methyl-1-azacyclotridecan-7-ol-8-one oxime was formed when IIIf was treated under either set of conditions (above) which led to dioxime or monoxime when applied to IIIe; colorless needles from aqueous ethanol, m.p. 117–118°.

Anal. Calcd. for $C_{13}H_{26}N_2O_2$: C, 64.42; H, 10.82; N, 11.56. Found: C, 64.48; H, 10.68; N, 11.55.

Treatment of IIIf with excess hydroxylamine hydrochloride and pyridine in refluxing ethanol for 24 hours gave **1-methyl-1-azacyclotridecan-7,8-dione dioxime (VIf)**, colorless needles from ethanol–petroleum ether, m.p. 205–207°.

Anal. Calcd. for $C_{13}H_{25}N_3O_2$: C, 61.15; H, 9.87; N, 16.46. Found: C, 61.30; H, 9.98; N, 16.24.

1-Ethyl-1-azacyclotricosan-12-ol-13-one oxime, prepared[13a] from IIIl, crystallized as colorless needles from aqueous ethanol, m.p. 99°.

Anal. Calcd. for $C_{24}H_{48}N_2O_2$: C, 72.67; H, 12.20; N, 7.06. Found: C, 73.67; H, 12.54; N, 7.42.

1-Methyl-1-azacyclononan-5-ol-6-one Perchlorate.—To a solution of 200 mg. of IIIb in 3 ml. of ethanol was added a slight excess (congo red paper) of 64% perchloric acid. Following dilution with ether and cooling in the refrigerator, the supernatant liquid was removed. The heavy viscous oil which remained was dissolved in a small amount of ethanol, warmed to 40–50°, and ether was added until turbidity just appeared. After cooling, the supernatant was removed. The purification process was repeated and finally the heavy viscous oil was dried under reduced pressure at 78°, after which it was in the nature of a hygroscopic glass.

Anal. Calcd. for $C_9H_{18}ClNO_6$: C, 39.97; H, 6.63. Found: C, 39.70; H, 6.93.

1-Ethyl-1-azacyclononan-5-ol-6-one Perchlorate.—This was made from IIIc by the same method as described above and was isolated as a hygroscopic glass.

Anal. Calcd. for $C_{10}H_{20}ClNO_6$: C, 42.08; H, 7.08. Found: C, 41.78; H, 7.13.

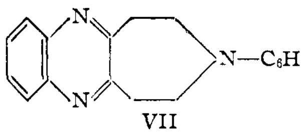
1-Methyl-1-azacyclohendecan-6-ol-7-one Perchlorate.—This salt, made from IIId in the same way, was also obtained as a hygroscopic glass.

Anal. Calcd. for $C_{11}H_{22}ClNO_6$: C, 44.04; H, 7.39. Found: C, 44.40; H, 7.67.

Oxidation of the Cyclic Aminoacyloins.—A solution of 1.0 g. (5 mmoles) of 1-phenyl-1-azacycloheptan-4-ol-5-one (IIIa) and 3.0 g. (15 mmoles) of cupric acetate monohydrate in 50 ml. of methanol[15,16] was heated under reflux for 15–20 minutes. The red-brown precipitate was removed and the methanol was distilled from the filtrate until the residue was near dryness. After trituration of the residue with *n*-hexane, the hexane-soluble material afforded two products: orange needles, m.p. 80–84°; yellow powder, m.p. 83–87°. The yellow powder could not be purified, and the orange needles appeared to decompose somewhat on warming in hexane. The orange compound exhibited strong infrared absorption at 1712 cm.$^{-1}$ and weak, at 3460 cm.$^{-1}$ in 10% chloroform solution. A quinoxaline was formed by allowing 23 mg. of the orange compound to react with 20 mg. of *o*-phenylenediamine in 20 ml. of 95% ethanol[50] at the reflux for 6 hours. Dilution of the ethanol solution with water caused the product to separate, and it was recrystallized from aqueous ethanol, m.p. 130–131°.

Anal. Calcd. for $C_{18}H_{17}N_3$: C, 78.51; H, 6.22. Found: C, 78.41; H, 6.21.

The compound can therefore be formulated as VII.



VII

Oxidation of IIIb with cupric acetate in acetic acid[14] or with chromic oxide in acetic acid[17] was not satisfactory. When 0.31 g. of the acyloin was heated under reflux for 15 minutes with Benedict solution, a red precipitate was formed. Extraction of the aqueous solution with ether and subsequent evaporation of the ether gave a residual yellow-brown oil. This oil was allowed to react with excess hydroxylamine hydrochloride and pyridine in refluxing ethanol for 22 hours. By fractional sublimation and several recrystallizations from aqueous ethanol, 0.05 g. of product was obtained, m.p. 181–182°, which was identical with the sample of 1-methyl-1-azacyclononan-5,6-dione dioxime described above.

Treatment of 0.40 g. of IIIf with cupric acetate mono-

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[50] B. K. Singh and J. K. Mazumdar, *J. Chem. Soc.*, **115**, 574 (1919).

hydrate in 25 ml. of 70% acetic acid[14] resulted in the precipitation of a small amount of cuprous oxide when the mixture was heated at the reflux for 15 minutes. The acid was diluted with water, potassium carbonate was added cautiously to saturation, and the aqueous mixture was extracted with ether. The ethereal extracts were dried and the ether was removed at reduced pressure. A small quantity of deep yellow oil remained. Treatment of the oil with excess hydroxylamine hydrochloride and pyridine in refluxing ethanol for two hours gave 0.13 g. of VIf (see above).

1-Methyl-1-azacyclopentadecan-8,9-dione dioxime (VIh) was obtained by oxidation of IIIh with cupric acetate in acetic acid[14] obtained by oxidation of IIIh with cupric acetate in acetic acid[14] followed by oximation,[13a] slightly pink needles from aqueous ethanol, m.p. 206–207°.

Anal. Calcd. for $C_{15}H_{29}N_3O_2$: C, 63.57; H, 10.31; N, 14.83. Found: C, 63.62; H, 10.24; N, 14.77.

1-Methyl-1-azacycloheptadecan-9,10-dione dioxime (VIj) was obtained in the same way, slightly pink needles from aqueous ethanol, m.p. 188–189°.

Anal. Calcd. for $C_{17}H_{33}N_3O_2$: C, 65.55; H, 10.68; N, 13.49. Found: C, 65.73; H, 10.94; N, 13.62.

1-Methyl-1-azacyclononadecan-10,11-dione dioxime (VIk), prepared by the same sequence, slightly pink needles from aqueous ethanol, m.p. 189°.

Anal. Calcd. for $C_{19}H_{37}N_3O_2$: C, 67.21; H, 10.99; N, 12.38. Found: C, 67.39; H, 11.37; N, 12.65.

URBANA, ILLINOIS

[CONTRIBUTION FROM THE WELLCOME RESEARCH LABORATORIES[a] AND THE MALLINCKRODT CHEMICAL LABORATORY, HARVARD UNIVERSITY[b]]

The Structures of the Isomeric Enols and Methyl Ethers of Formyldesoxybenzoin

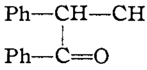
BY PETER B. RUSSELL[a] AND ERNEST CSENDES[b],[1]

RECEIVED APRIL 29, 1954

Two enolic forms of formyldesoxybenzoin (α-formyl-α-benzoyltoluene) were described by Wislicenus and Ruthing.[2] The α-form (m.p. 76–80°) is now shown to be a chelate of α,β-diphenyl-β-hydroxyacrolein (III) while the β-form (m.p. 112–113°) is the open hydroxy methylene compound, α-phenyl-β-hydroxyacrylophenone (II). The evidence upon which these conclusions are based was obtained by infrared and ultraviolet spectroscopy and from a study of the reactions of the two forms with diazomethane. The study illustrates the influence of steric factors in determining the structure of the enol under any set condition.

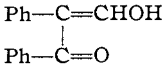
Wislicenus and Ruthing[2] obtained two crystalline modifications of formyldesoxybenzoin (I). One, the α-form, crystallized from petroleum ether and melted at 76–80°; the second, the β-form, melted at 112–113° after recrystallization from aqueous ethanol. Both forms gave a reaction with ferric chloride solution and both gave one and the same copper complex. The α-form was converted to the β-form by treatment with alcohol or by heating near its melting point. The conversion takes place slowly at room temperature. The β-form was converted to the α-form by crystallization from a non-polar solvent (*e.g.*, benzene, petroleum ether), by heating above its melting point and cooling rapidly or by distillation.

Wislicenus[2] considered the α-form to be the hydroxymethylene compound II[3] and the β-form to be the enol-aldehyde III. These conclusions were based on the observation that only the β-form gave an immediate fuchsin reaction.



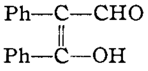
$$\begin{array}{l} \mathrm{Ph{-}CH{-}CHO} \\ \quad\;\;| \\ \mathrm{Ph{-}C{=}O} \end{array}$$

I



$$\begin{array}{l} \mathrm{Ph{-}C{=}CHOH} \\ \quad\;\;| \\ \mathrm{Ph{-}C{=}O} \end{array}$$

II



$$\begin{array}{l} \mathrm{Ph{-}C{-}CHO} \\ \quad\;\;\| \\ \mathrm{Ph{-}C{-}OH} \end{array}$$

III

Scheiber and Hopfer[4] reported that both the α- and β-forms of formyldesoxybenzoin gave benzil on ozonolysis in carbon tetrachloride at −20°, together with formic acid and a little benzoic acid. These authors concluded that the two forms were geometrical isomers of the hydroxymethylene form II.

Apart from the undesirability of basing conclusions regarding the structure of compounds containing mobile systems on the results of ozonolysis, the views of Scheiber and Hopfer are open to objection on other, more specific, grounds. As reported by Wislicenus[2] both forms of formyldesoxybenzoin give *immediate* reactions with ferric chloride and both react *at once* with copper to give the same complex. It is well recognized that one member of a pair of geometrically isomeric enols, the *trans* member, does not give either of these reactions although the ferric chloride color often develops after standing some time.[5,6] The best known examples of such geometrically isomeric pairs of enols are the *cis*- and *trans*-methyl and ethyl formylphenylacetates (hydroxymethylenephenylacetates).[7,8] In these compounds the *trans* form is not converted to the *cis* or *vice versa* by simple treatment with solvents, but heating is required. Both α- and β-forms of formyldesoxybenzoin would appear to be *cis*-isomers. It is probable then that one is an F-enol while the other is a B-enol.

The Infrared and Ultraviolet Spectra of α- and β-Formyldesoxybenzoins.—While the infrared spectra of the solid α- and β-forms (in Nujol mull) are very different, both show evidence of hydrogen bonding. The spectrum of the α-form (Table III, Experimental) shows a strong band between 6.1 and 6.2 μ similar to that shown by dibenzoylmethane[9] or benzoylacetone.[10] The β-form shows a sharp band at 6.3 μ and a strong broad band between 6.3 and 6.62 μ. Both forms show a weak band at

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[1] Organic Chemicals Department, E. I. du Pont de Nemours and Co., Jackson Laboratory, Wilmington 99, Del.

[2] W. Wislicenus and A. Ruthing, *Ann.*, **379**, 229 (1912).

[3] Enols and their derivatives related to II (*i.e.*, having the formyl group enolized) will be called "F-enols" or derivatives while enols of the type III (benzoyl group enolized) will be called "B-enols."

[4] F. Scheiber and G. Hopfer, *Ber.*, **47**, 2704 (1914).

[5] H. Henecka, *Chem. Ber.*, **81**, 189 (1948).

[6] B. Eistert, F. Arndt, L. Loewe and E. Ayça, *ibid.*, **84**, 156 (1951).

[7] W. Wislicenus, *Ann.*, **413**, 272 (1917).

[8] W. Dieckmann, *Ber.*, **50**, 1375 (1917).

[9] B. Eistert, F. Weygand and E. Csendes, *ibid.*, **84**, 756 (1951).

[10] B. Eistert and E. Merkel, *ibid.*, **86**, 904 (1953).