Arylglyoxylonitrile Oxime *p*-Toluenesulfonates and Related N-Halimines. Preparation and Rearrangement[1]

TRAVIS E. STEVENS

Rohm and Haas Company, Redstone Research Laboratories, Huntsville, Alabama

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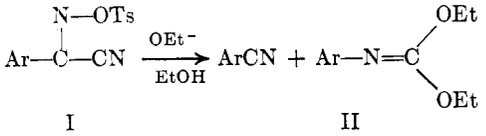
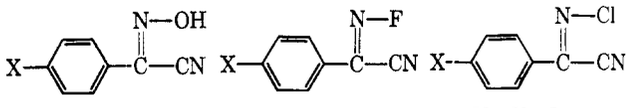
The *syn* and *anti* isomers of α-oximinophenyl- and *p*-chlorophenylacetonitrile and the corresponding oxime tosylates have been characterized. The configuration of the oxime tosylate had no effect on the rearrangement and fragmentation of the tosylate. The preparation of related N-chlor- and N-fluor-α-iminoarylacetonitriles is reported also.

Recently, the preparation of the tosylates of some α-oximinoarylacetonitriles[2] (I) and the sodium ethoxide induced rearrangement and fragmentation of these tosylates were reported.[3] Rearrangement gave arylimidocarbonates (II) while fragmentation produced aromatic nitriles.



I II

To determine whether the configuration of the oxime tosylate did indeed determine the extent of fragmentation or rearrangement,[3] and to observe the behavior of related imine derivatives, the oximes and oxime tosylates of both configurations of III, as well as the related N-fluor- (IV) and N-chlorimines (V), have been prepared. Table I summarizes the properties of these compounds.



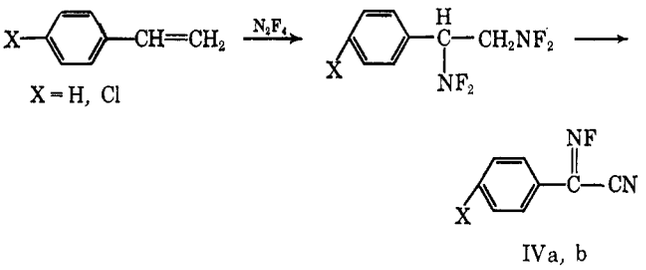
IIIa, X=H b, X=Cl IVa, X=H b, X=Cl Va, X=H b, X=Cl

Although the existence of isomers of the α-oximinoarylacetonitriles was recognized when these oximes were prepared,[4] isolation and characterization of the second isomer (aryl and OH groups *cis* or *syn*) was not accomplished.[5,6] Methylation of both the phenyl and 4-chlorophenyl-α-oximinoacetonitriles (IIIa,b) was reported to give two isomers, however.[4,7]

Only the *anti* isomers of the oximes IIIa and IIIb are isolated in the usual preparation that involves precipitation of the sodium salt of the oxime from an ether–ethanol mixture.[3,4] This precipitates only the *anti*-oxime salt; the mother liquor contains a mixture of *syn* and *anti* isomers. The isolation and characterization of *syn*-oximes IIIa and IIIb are reported in the Experimental Section.

Examination of the proton nmr spectra of the oximes allowed assignment of the configuration given in Table I. In the *syn* isomers of IIIa and IIIb, the *ortho* protons of the aromatic ring were deshielded by the *cis*-OH group.[8] Owing to the difficulty of extracting the constants of the $A_2'B_2'$ system of IIIb, the strongest peaks are listed in Table II in the manner of Lustig.[8] The results obtained from IIIa are consistent with this interpretation.[9]

Fluorimines IVa and IVb were prepared by the dehydrofluorination with pyridine of the adduct of the styrene and tetrafluorohydrazine.[10] A variety of



X=H, Cl IVa, b

fluoriminonitriles has been prepared by this method.[10] Only one isomer, presumably *anti*, of the fluorimines was isolated, although the *syn* isomer may have been present in crude samples of IV.[11,12]

Although it was reported earlier[4] that no reaction occurred when oxime IIIb was exposed to phosphorus pentachloride, both α-chloriminonitrile Vb and N-(4-chlorophenyl)imino-α-chloroacetonitrile VIb, as well as 4-chlorobenzoyl cyanide, could be isolated from this reaction.[13] With the phenyl oxime IIIa and phos-

(1) This research was supported by Army Ordnance Contract DA-01-021 AMC-11536 (Z).

(2) For the sake of clarity, the arylacetonitrile rather than the more proper arylglyoxylonitrile nomenclature is used here.

(3) T. E. Stevens, *J. Org. Chem.*, **28**, 2436 (1963).

(4) M. R. Zimmerman, *J. Prakt. Chem.*, [2] **66**, 353 (1902).

(5) The "labile" α-oximino-4-chlorophenylacetonitrile reported[4] appears to be a crystalline modification of the *anti* oxime of mp 112° since we often obtained a labile form of *anti* oxime with mp 68–70°.

(6) Here, at least, the isomer of OH, F, or Cl *cis* to the CN function and *trans* to the aromatic ring is called *anti*.

(7) Methylation of the sodium salt IIIb, mp 112°, with methyl tosylate gave only the methyl ether of mp 70°.

(8) E. Lustig [*J. Phys. Chem.*, **65**, 491 (1961)] reports a study of 4-chlorobenzaldoxime in which the isomer with the OH and aromatic ring *cis* shows similar deshielding.

(9) This phenyl case is complicated by the *para* proton and additional splitting. However, with *anti*-IIIa in DMSO, there is no obvious separation among *ortho*, *meta*, and *para* resonances ($\delta < 10$ cps), while for *syn*-IIIa (OH and phenyl *cis*) the *ortho* shift is at least 22 cps downfield from the *meta* and *para* resonances. In $CDCl_3$ the *ortho* shifts are greater; these being about 18 and 32 cps for *anti* and *syn* isomers, respectively.

(10) R. C. Petry and J. P. Freeman, *J. Am. Chem. Soc.*, **83**, 5912 (1961); R. C. Petry and J. P. Freeman, unpublished studies; A. L. Logothetis and G. N. Sausen, *J. Org. Chem.*, **31**, 3689 (1966).

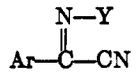
(11) Although it has little bearing on the configuration of IVb, fluorimine IVb readily underwent a Beckman rearrangement in concentrated sulfuric acid at 85°; N-(4-chlorophenyl)oxamide (80% yield) was the product.

(12) The F^{19} nmr peaks of IVa and IVb (see the Experimental Section) at about ϕ −50 were solvent and concentration dependent. In addition mnr peaks at about ϕ −40 were observed in dehydrofluorinated samples; this peak may be due to the *syn* isomer. Also the fluorimino ester $C_6H_5C(=NF)OC_2H_5$ has been isolated and has an F^{19} nmr peak at ϕ +45. No isomerization of IVa was caused by refluxing in ethanol or by heating (80°) in other solvents.

(13) Chlorimines have been obtained from oximes and phosphorous pentachloride; see S. O. O'Brien and D. C. C. Smith, *J. Chem. Soc.*, 2907 (1963); *Org. Reactions*, **11**, 22 (1960). Isolation of a chlorimine such as VIa or b is, of course, to be expected when an excess of phosphorus pentachloride is used: H. Stephen and B. Staskum, *J. Chem. Soc.*, 980 (1956).

TABLE I

α-IMINOARYLACETONITRILES



Ar	Y	Isomer[a]	Registry no.	Mp, °C	Anal—Calcd C	Calcd H	Calcd N	Found C	Found H	Found N
Phenyl	OH	*anti*		129[b]	...	...	...	...	...	...
Phenyl	OH	*syn*		97	65.74	4.14	19.17	65.59	4.15	18.84
Phenyl	OTs	*anti*	7541-04-0	135[c]	...	...	...	...	...	...
Phenyl	OTs	*syn*	7541-05-1	103	59.98	4.03	9.33	60.17	4.37	8.94
4-Chlorophenyl	OH	*anti*		112[d]	...	..	...	...	...	...
4-Chlorophenyl	OH	*syn*		123	53.21	2.79	15.51	53.01	3.11	15.32
4-Chlorophenyl	OTs	*anti*	7541-08-4	154[e]	...	...	...	...	...	...
4-Chlorophenyl	OTs	*syn*	7541-09-5	139	53.81	3.31	8.37	53.46	3.53	8.12
Phenyl	Cl			40	58.37	3.06	17.02	58.58	3.37	16.68
Phenyl	F[g]	*anti*		31	64.86	3.40	18.91	64.69	4.56	17.75
4-Chlorophenyl	Cl			80	48.27	2.02	14.08	48.11	1.99	13.78
4-Chlorophenyl	F[f]	*anti*		41	52.64	2.21	15.45	52.66	2.56	14.86

[a] See ref 6. [b] Lit.[4] mp 129°. [c] Characterized earlier (ref 3). [d] Lit.[4] mp 112°. [e] Also found F, 12.9 (calcd F, 12.8). [f] Also found F, 10.6 (calcd F, 10.4).

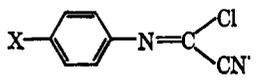
TABLE II

NMR CHARACTERISTICS OF α-OXIMINOARYLACETONITRILES

Compd	Solvent	Ring proton peaks[a,b]			
anti-IIIb	DMSO	−11,	−2,	+2,	+11
syn-IIIb	DMSO	−16,	−7,	+7,	+16
anti-IIIb	$CDCl_3$	−14.5,	−5.5,	+5.5,	+14.5
syn-IIIb	$CDCl_3$	−21,	−12,	+12,	+21

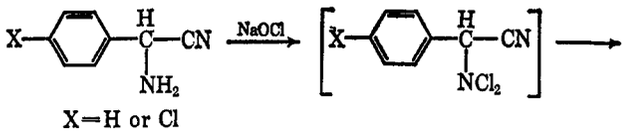
[a] In cps with the center of the aromatic ring multiplet taken as origin. [b] For 4-chlorobenzaldoxime, Lustig[8] reported for *cis*-OH and phenyl −21, −13, +13, +21 cps and for *trans*-OH and phenyl −12, −3, +3, +12 cps.

phorus pentachloride no N-chloriminonitrile was obtained; VIa was the major product.



VIa, X = H
b, X = Cl

A more general preparation of the chlorimines Va and b involved halogenation of the corresponding α-aminoarylacetonitrile[14] with sodium hypochlorite; the basic solution effected dehydrochlorination. Only one isomer was obtained in each case.



X = H or Cl

Va or Vb

It was interesting to observe that there was no significant difference in the products of the reaction of the tosylates of the *syn* and *anti* oximes IIIa and b with sodium ethoxide in ethanol. Thus, the amounts of 4-chlorobenzonitrile and diethyl(4-chlorophenyl) imido carbonate produced from *syn*-α-oximino-4-chlorophenylacetonitrile tosylate were essentially identical with those reported from the *anti* tosylate.[3,15] The results from the experiments with the *syn* and *anti* isomers of α-oximinophenylacetonitrile tosylates are summarized in Table III.

(14) N. Zelinsky and G. Stadnikoff, *Ber.*, **39**, 1722 (1906).

(15) This was about 6% nitrile and 64% imidocarbonate. The latter product was isolated as ethyl N-(4-chlorophenyl)carbamate.

TABLE III

PRODUCTS FROM IIIa TOSYLATES AND SODIUM ETHOXIDE IN ETHANOL

Tosylate	Conditions	Std area[a]	Benzonitrile[b]	imidocarbonate[b]
syn-IIIa	*c*	1.00	0.21	1.25
anti-IIIa	*c*	1.00	0.16	1.32
syn-IIIa	*d*	1.00	0.10	1.48
anti-IIIa	*d*	1.00	0.03	1.51

[a] Vpc peak area of 25 μl of acetophenone as standard. [b] Peak area relative to acetophenone using 5 ft G.E. SF-96 silicon on Chromosorb column at 150°. [c] 0.5 mmole of tosylate in 5 ml of ethanol at reflux, 1.3 mmoles of sodium ethoxide. [d] 0.5 mmole of tosylate in 5 ml of ethanol at reflux, 6.5 mmoles of sodium ethoxide.

The results of exposure of the N-halimines IV and V to sodium ethoxide and sodium methoxide are given in Table IV.[16] A much greater quantity of nitrile and related products formed from the halimines.

TABLE IV

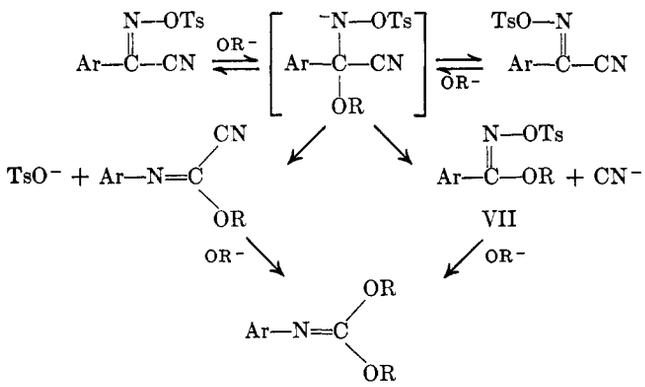
PRODUCTS FROM α-IMINOARYLACETONITRILES AND SODIUM ALKOXIDES

Imine	Base,[a] equiv	% nitrile plus amide[b]	% imidocarbonate[c]
IVa	NaOEt, 2.4	38[d]	62[d]
IVa	NaOEt, 10	20[d]	80[d]
Va	NaOEt, 2.4	*d, e*	
IVb	NaOEt, 2.3	41	53
Vb	NaOEt, 2.3	88	4
IVb	NaOEt, 5	24	59
IVb	NaOMe, 2.5	72	14
Vb	NaOMe, 2.5	85	5
IIIb	NaOEt, 2[f]	25	44

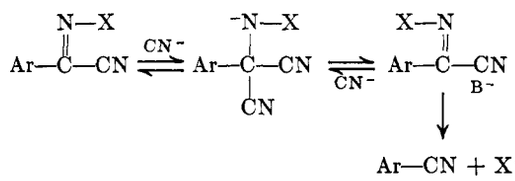
[a] The alkoxide in the corresponding alcohol. [b] The amide is considered to arise from the nitrile since 4-chlorobenzonitrile and 1 equiv of sodium methoxide in methanol for 2 hr gave amide (34%) and recovered nitrile (50%). [c] Isolated as carbamate after silica gel chromatography[3] except when vpc used to determine yield. [d] Yield determined by vpc, see Table III. This is ratio of peak areas, not absolute yield. [e] The major product was benzonitrile, but a small amount of ethyl benzoate was detected by vpc here; no appreciable amount of imidocarbonate was presented. [f] *anti*-Oxime tosylate, slow addition of alkoxide at reflux.[16]

(16) The reaction of sodium methoxide in methanol and the oxime tosylates produced mostly methyl tosylate and oxime anion as initial products; methylation of the oxime then occurred. Only a very small amount of ethylated oxime, probably arising in the same fashion, was found in reactions employing sodium ethoxide in ethanol.

The mechanism(s) by which the α-iminoacetonitriles are converted to aryl nitriles and imidocarbonates by alkoxides remains obscure. Certainly, the *syn*- and *anti*-oxime tosylates are equilibrated, or both are converted to the same intermediate, most likely by addition to the carbon–nitrogen double bond. One logical route involving equilibration, or such an intermediate (VII), is outlined below.



The scheme outlined above accounts for the rearrangement to give imidocarbonates, but nitrile formation (fragmentation) may involve nucleophilic attack at the cyano function. With imines IV and V in which the *syn* configuration necessary for a *trans*-elimination process (giving fragmentation) can be obtained easily, more nitrile is formed than with the bulky oxime tosylates. Also, the tosylate function may hinder attack at the carbon–nitrogen triple bond. With the N-fluoriminoacetonitriles sodium methoxide in methanol favors nitrile formation, and attack at the cyano function may be favored with this small base. The slow addition of or the use of a limited amount of alkoxide could allow cyanide (or halide) ions to participate in isomerization and, eventually, the cleavage of the imines to produce nitriles.[17] This is sketched below.



Experimental Section[18]

Preparation of *syn*-α-Oximinophenylacetonitrile.[2]—The interaction of phenylacetonitrile and butyl nitrite was carried out as usual.[3] After isolation of the first crop of the sodium salt of the *anti*-oxime, the filtrate was stripped to dryness. Addition of ether left an insoluble salt which was partitioned between water and ether. Acidification of the aqueous extract gave a mixture of *syn*- and *anti*-oximes. Chromatography of the oxime mixture over silica gel with pentane–methylene chloride as the eluent gave the *anti*-oxime followed by samples of *syn*-α-oximinophenylacetonitrile. About 1.0 g of pure *syn*-oxime was isolated from a 0.10-mole run, although 1 additional g of *syn*-oxime was not completely separated from the *anti* isomer. The *syn*-α-oximinophenylacetonitrile was recrystallized from hexane–chloroform, mp 97–99°. In the 9–11-μ infrared region it had bands at 9.3 (w), 9.45 (m), 9.7, 9.8 (s), 10.05 (m), 10.3 (s), and 10.85 (m) μ.

The *anti*-oxime, mp 125°, had 9–11-μ infrared bands at 9.35 (m), 9.5 (s), 9.75 (m), 10.05 (w), 10.4, 10.45 (s), and 10.9 (w) μ.

The oxime tosylate was prepared by addition of aqueous sodium hydroxide to an acetone solution of the oxime and tosyl chloride.[3] The recrystallized (hexane–chloroform) oxime tosylate melted at 103–105°.

Preparation of *syn*-α-Oximino-4-chlorophenylacetonitrile.—The procedure outlined above was followed. The *syn*-oxime, after recrystallization from chloroform–hexane, melted at 119–121°.[19] This sample apparently was a half-hydrate.

Anal. Calcd for $C_8H_5ClN_2O \cdot 0.5H_2O$: C, 50.68; H, 3.19; N, 14.77. Found: C, 50.36, 5.047; H, 3.64, 3.23; N, 14.81, 14.23.

A sample dried *in vacuo* for 24 hr melted at 123–125° and gave the elemental analysis reported in Table I.

The hydrated sample of the *syn*-oxime had a free OH peak at 2.8 μ in the infrared spectrum. In addition, the 9–11-μ region had peaks at 9.15 (m), 9.5, 9.62 (s), and 9.95 (m) μ.

The *anti*-oxime, mp 112°, in the 9–11-μ infrared had peaks at 9.15 (m), 9.40 (s), 9.90 (w), 10.3 (s), and a shoulder at 10.35 (m).

Reaction of toluenesulfonyl chloride and the *syn*-oxime in aqueous acetone gave *syn*-α-oximino-4-chlorophenylacetonitrile tosylate, mp 139–140°.

Reaction of Phosphorus Pentachloride and α-Oximino-4-chlorophenylacetonitrile.—A slurry of 7.0 g of phosphorus pentachloride in 80 ml of methylene chloride was stirred at ambient temperature while a slurry of 5.3 g of α-oximino-4-chlorophenylacetonitrile in 50 ml of methylene chloride was added dropwise. The mixture was refluxed for 1 hr and then was poured onto ice. The methylene chloride layer was separated and washed with dilute, aqueous sodium bicarbonate and water. The residue obtained upon evaporation of the methylene chloride was chromatographed on silica gel. The first fraction eluted from the column (0.18 g) was recrystallized from hexane to give α-chlorimino-4-chlorophenylacetonitrile, mp 82–84°.

The above fraction was followed closely by N-(4-chlorophenyl)-imino-α-chloroacetonitrile (1.35 g), mp 32–34° (from hexane).

Anal. Calcd for $C_8H_4Cl_2N_2$: C, 48.27; H, 2.02; N, 14.08. Found: C, 48.26; H, 2.09; N, 13.85.

The next fraction was 4-chlorobenzoyl cyanide (0.80 g), mp 40–41° (lit.[14] mp 40–41°).

When the reaction was conducted by adding 7.0 g of phosphorus pentachloride portionwise to 5.3 g of the oxime in 150 ml of methylene chloride at 35°, and then stirring the reaction mixture at 40–42° for 30 min, a different product distribution was obtained. Although some product was lost accidentally in work-up, the remainder gave (after chromatography on silica gel) α-chlorimino-4-chlorophenyl acetonitrile (1.09 g), the N-(4-chlorphenyl)imino-α-chloroacetonitrile (0.24 g), and 4-chlorobenzoyl cyanide (0.13 g). Further fractions were not characterized.

Reaction of Phosphorus Pentachloride and α-Oximinophenylacetonitrile.—A slurry of 7.0 g (33.6 mmoles) of phosphorus pentachloride in 80 ml of methylene chloride was stirred at 15° while 4.35 g (30 mmoles) of α-oximinophenylacetonitrile in 50 ml of methylene chloride was added slowly. The mixture was then warmed to 40° and, finally, was refluxed for 15 min. The mixture was poured into water and the methylene chloride layer was spearated and washed with water. The residue was chromatographed on silica gel. The first fraction eluted from the column was N-phenylimino-α-chloroacetonitrile ($C_6H_5N{=}CClCN$, 2.06 g), a pale yellow oil.

Anal. Calcd for $C_8H_5ClN_2$: C, 58.36; H, 3.09; Cl, 21.54; N, 17.02. Found: C, 58.32; H, 3.08; Cl, 21.6; N, 18.63.

The next fraction eluted was benzoyl cyanide (0.54 g), identified by infrared spectrum. Further fractions from the column were not characterized.

When 6.5 g of PCl_5 was added to 3.62 g of α-oximinophenylacetonitrile at 35° and the mixture was refluxed for 15 min, the products obtained on work-up as above were N-phenylimino-α-chloroacetonitrile (0.39 g) and benzoyl cyanide (0.12 g). Further fractions from the column were not characterized. No evidence for the formation of α-chloriminophenylacetonitrile could be found in either of the reactions.

Preparation of α-Chloriminophenylacetonitrile.—To 4.0 g of α-aminophenylacetonitrile[14] was added an excess of 10% aqueous hydrochloric acid, and the solution was stripped to dryness. The residue was dissolved in 200 ml of water, cooled to 10°, and 120 ml of commercial Clorox (0.74 *M* sodium hypochlorite) was added over 30 min. After 1 hr at 15° the solution was extracted with methylene chloride. The residue obtained from the organic

(17) The nature of the products other than aryl nitrile formed by attack at the cyano function have not been determined, although further studies of the interaction of IVa and methoxide ion are underway.

(18) Melting and boiling points are uncorrected.

(19) On one occasion a sample (mp 101–102°) was obtained here; its infrared spectrum was identical with that of the higher melting sample.

extract was recrystallized from hexane to give α-chloriminophenylacetonitrile (1.6 g), mp 40–42°.

Preparation of α-Fluorimino-4-chlorophenylacetonitrile.—A solution of the crude adduct from tetrafluorohydrazine and 10 g of 4-chlorostyrene (72.3 mmoles) in 120 ml of methylene chloride was stirred at ambient temperature while a solution of 17 ml (220 mmoles) of pyridine in 100 ml of methylene chloride was added dropwise. The temperature of the solution increased slowly, and the rate of pyridine addition was regulated so as to maintain a slow reflux of the solvent. The mixture was then stirred overnight. The methylene chloride solution was washed with water and dilute, aqueous hydrochloric acid, dried (magnesium sulfate), and stripped. One recrystallization from hexane gave α-fluorimino-4-chlorophenylacetonitrile (8.9 g), mp 39–41°. The sample was purified by chromatography on silica gel; elution was accomplished with pentane–methylene chloride (5:1), mp 41–42°.

The F^{19} nmr spectrum had a strong peak at ϕ −56.5 and a very weak peak at −41.6. In fractions eluted from the silica gel column just after the center cut the ϕ −41.6 peak was stronger.

α-Fluoriminiphenylacetonitrile.—The styrene–tetrafluorohydrazine adduct in methylene chloride was dehydrofluorinated as described above. The methylene chloride solution was washed with water, 10% aqueous hydrochloric acid, and water; the solution was dried and stripped. Distillation of the residue gave α-fluoriminophenylacetonitrile, bp 82° (4.5 mm). The F^{19} nmr had peaks at ϕ −52.8 (very strong) and −40.0 (very weak). A sample recrystallized from hexane had mp 31–32° and exhibited only the ϕ −52.8 fluorine resonance.

Reaction of α-Fluorimino-4-chlorophenylacetonitrile and Sulfuric Acid.—There was no sign of solution or interaction when 0.91 g (5 mmoles) of the fluorimine and 3 ml of concentrated sulfuric acid were mixed at room temperature. Warming to 60° produced a homogeneous solution, but white crystals separated upon cooling the mixture to 20°. The mixture was then maintained at 85° for 20 min, cooled, and poured into water. An insoluble solid was removed by filtration. Recrystallization of the solid from chloroform–ethanol gave N-4-chlorophenyloxamide (0.79 g, 80%), mp 238–240°, lit[24] 241°.

(20) F. D. Chattaway and W. H. Lewis, *J. Chem. Soc.*, **89**, 158 (1906).

Reaction of α-Fluorimino-4-chlorophenylacetonitrile and Sodium Ethoxide.—A solution of 0.91 g of the fluorimine in 10 ml of absolute ethanol was treated with 12 ml of 0.94 *N* sodium ethoxide in ethanol at ambient temperature. The mixture was stirred for 2 hr and was then poured into water. The organic products, isolated by extraction with methylene chloride, were chromatographed on silica gel. Pentane–methylene chloride mixtures eluted 4-chlorobenzonitrile (0.225 g, mp 92–93°, 33%) from the column. The next fraction eluted (methylene chloride–ethyl acetate, 9:1) was methyl N-(4-chlorophenyl)carbamate (0.428 g, 53%), having an infrared spectrum identical with that of an authentic sample. The last fraction eluted from the column (0.064 g, 8%) was 4-chlorobenzamide containing a little 4-chlorobenzoic acid (infrared spectrum).

Reaction of α-Fluorimino-4-chlorophenylacetonitrile and Sodium Methoxide.—A solution of 0.91 g of the fluorimine in 10 ml of methanol was treated with 20 ml of 0.54 *N* sodium methoxide in methanol. After 2 hr at ambient temperature the reaction mixture was processed as described above. The fractions isolated from the chromatographic column were 4-chlorobenzonitrile (0.313 g, 45.5%), methyl N-(4-chlorophenyl)carbamate (0.130 g, 14%, mp 116–117°; lit.[21] mp 115–116°), and 4-chlorobenzamide (0.205 g, 26.3%, mp 179–180°).

Reaction of Sodium Methoxide and α-Chlorimino-4-chlorophenylacetonitrile.—A solution of 0.51 g of the chlorimine, mp 82–84°, was treated with 10 ml of 0.54 *N* sodium methoxide in methanol at ambient temperature. After 1 hr at ambient temperature the mixture was poured into water. The organic product was isolated and chromatographed as usual. The products obtained from the column were 4-chlorobenzonitrile (0.205 g, 58.3%), methyl N-(4-chlorophenyl)carbamate (0.022 g, 4.7%), and 4-chlorobenzamide (0.107 g, 26.9%).

Registry No.—IIIa (*anti*), 7541-02-8; IIIa (*syn*), 7541-03-9; IIIb (*anti*), 7541-06-2; IIIb (*syn*), 7541-07-3; Va, 7541-10-8; IVa (*anti*), 7541-11-9; Vb, 7541-12-0; IVb (*anti*), 7541-13-1; VIa, 7541-14-2; VIb, 7541-15-3.

(21) M. J. Kolbezen, R. L. Metcalf, and T. R. Fukuto, *J. Agr. Food Chem.*, **2**, 864 (1954); *Chem. Abstr.*, **49**, 4224 (1955).

The Synthesis of (+)- and (−)-*cis*-S-(β-Styryl)-L-cysteine S-Oxides

JOHN F. CARSON AND LOIS E. BOGGS

Western Regional Research Laboratory,[1] *Albany, California 94710*

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L-cysteine in the presence of sodium in ethanol and dimethylformamide has been treated with phenylacetylene to yield *cis*-S-(β-styryl)-L-cysteine. *cis,cis*-β,β′-Distyryl sulfide is a by-product. Oxidation of the styrylcysteine with hydrogen peroxide in acetic acid–trifluoroacetic acid yielded the crystalline trifluoroacetic acid salts of the diastereomeric sulfoxides from which the pure (+)- and (−)-*cis*-S-(β-styryl)-L-cysteine S-oxides were isolated.

The S-(1-propenyl)-L-cysteine S-oxides have unusual properties in that they are attacked by an enzyme present in onion or garlic to yield a lachrymator[2] and in the presence of base, undergo internal addition to produce cyclic sulfoxide amino acids.[3] The (+)-*trans* isomer[4] and its γ-glutamyl peptide[5] are important consituents of *Allium cepa*. Däbritz and Virtanen[6] have synthesized the analog, S-vinyl-L-cysteine S-oxide and we have recently prepared the (+)- and (−)-*cis*-S-(1-propenyl)-L-cysteine S-oxides[7] which are isomers of the naturally occurring sulfoxide found in onions. For further investigations of the chemistry of this class of compounds, *cis*-S-(β-styryl)-L-cysteine (I) has been prepared and converted into the (+)- (VI) and (−)-sulfoxides (V). (See Scheme I.)

In particular, it was of interest to determine whether the styrylcysteine sulfoxides would cyclize in base in a manner similar to the propenylcysteine sulfoxides.[3] Virtanen[2] has proposed propenylsulfenic acid ($CH_3CH{=}CHS(H)O$) as the structure of the highly unstable lachrymator produced on enzymic decomposition of propenylcysteine sulfoxide. It was hoped that the new sulfoxide amino acids might produce a more stable analog of the lachrymator.

L-cysteine and phenylacetylene in the presence of sodium in ethanol and dimethylformamide reacted to

(1) A laboratory of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

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