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3-Monosubstituted 1-Benzoyl-2,2-dichloroaziridines. Methanolysis, Thermolysis, and Benzoylation

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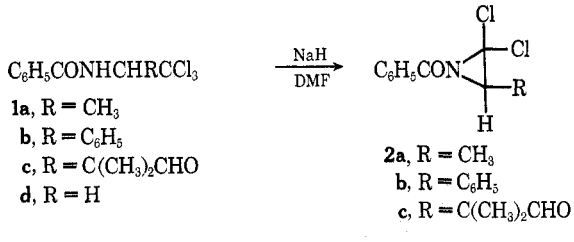
Three 3-monosubstituted 1-benzoyl-2,2-dichloroaziridines **2** have been prepared by cyclization of the corresponding trichloroethylamides **1**. Their behavior on methanolysis and thermolysis was examined. Unlike the corresponding 1-arylaziridines, acid catalysis is required for the methanolysis of the 1-benzoylaziridines. The course of this reaction is sensitive to the nature of the 3 substituent. Like many other 1-acyl-3-arylaziridines, **2b** rearranges thermally giving the oxazole derivative **8**. In contrast, the 3-alkylaziridines **2a** and **2c** are thermally stable in the absence of acid. A novel ring-opening reaction of **2a** occurs with benzoyl chloride. It is concluded that ring cleavage of the 1-benzoyl-3-alkylaziridines is generally initiated by electrophilic attack at the amide oxygen atom. Curiously, however, acid catalysis leads to C-2–N bond cleavage of the aziridine ring of **2a**, whereas benzoylation results in C-3–N bond rupture.

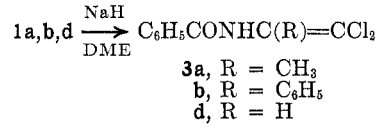
Previous work[1] has demonstrated the ready accessibility of *N*-trichloroethylbenzamides of type **1**. If



the proximity of the amido group could be utilized to facilitate displacement of halogen from the normally inert trichloromethyl group, these compounds might serve as intermediates for a new general synthesis of α-amino acids. While exploring this possibility it was found that treatment with sodium hydride in dimethylformamide (DMF) did indeed lead to the 1-benzoyl-2,2-dichloroaziridines **2** in three examples tried.[2]

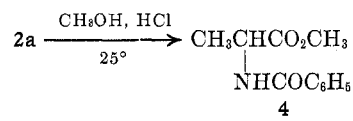
Unfortunately, cyclization was not the exclusive reaction. Some decomposition occurred and elimination of HCl from **1** was not completely preventable. Indeed, in 1,2-dimethoxyethane (DME) as solvent in place of DMF, the amides **1a**, **1b**, and **1d** gave the products of elimination **3a** (27%), **3b** (83%), and **3d** (79%), respectively.[4]

Although achievement of the original objective of this work was clearly thwarted by the poor yields



(45–60%) of **2** obtainable even under the best conditions, further study of the chemistry of these aziridines was of interest. 1-Aryl-2,2-dichloroaziridines have been thoroughly studied,[5,6] and at least one report of 1-benzoyl-monochloroaziridines has appeared.[7] However, the 1-benzoyl-2,2-dichloroaziridines **2** represent a new type worthy of study in view of the reports[8] that 1-aryl-monochloroaziridines differ chemically from their 2,2-dichloro analogs.

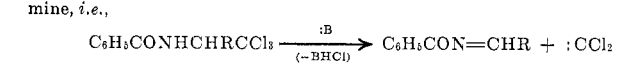
Two reactions were chosen: acid-catalyzed methanolysis and thermolysis. Treatment of the methylaziridine **2a** with methanolic hydrogen chloride at room temperature for 1 week gave two products: *N*-benzoyl-*dl*-alanine methyl ester (**4**) (39% yield, partly hydrolyzed to the acid during isolation) and the trichloroethylamide **1a** (13% yield). Similar treatment of the



phenylaziridine **2b** resulted in more radical rupture of the molecule. Essentially all of the nitrogen was converted to ammonium chloride (93% yield), the 1-benzoyl group appeared as methyl benzoate (90% yield), and the rest of the molecule emerged as a mixture of the chloro ester **5** (53% yield) and the methoxy ester **6**

(1) H. E. Zaugg, *Syn.*, **2**, 49 (1970).

(2) That these cyclizations result from intramolecular nucleophilic displacement of halide ion and not by addition of dichlorocarbene to an acylimine, *i.e.*,



is indicated by experiments in which the yield of **2b** in the presence of tetramethylethylene, although reduced somewhat, is no poorer than the yield obtained in the presence of an equal volume of cyclohexane.[3]

(3) Compare J. A. Deyrup and R. B. Greenwald, *Tetrahedron Lett.*, 321 (1965).

(4) An attractive rationalization for this marked solvent effect involves the reasonable assumption that the sodium derivatives of the amides **1** are largely contact ion pairs in DME and either solvent-separated ion pairs or free ions in DMF. The proximity of the sodium ion in the contact ion pairs could lower the nucleophilic reactivity of the amide anion as well as assist in the removal of chloride ion through a cyclic transition state, with both effects favoring elimination.

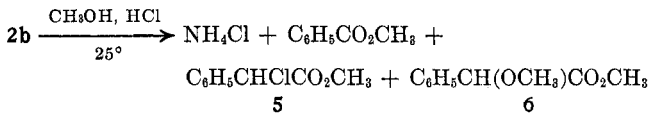
(5) (a) E. K. Fields and J. M. Sandri, *Chem. Ind. (London)*, 1216 (1959); A. G. Cook and E. K. Fields, *J. Org. Chem.*, **27**, 3686 (1962); (b) P. K. Kadaba and J. O. Edwards, *ibid.*, **25**, 1431 (1960); (c) H. W. Heine and A. B. Smith, III, *Angew. Chem., Int. Ed. Engl.*, **2**, 400 (1963); (d) K. Ichimura and M. Ohta, *Tetrahedron Lett.*, 807 (1966); *Bull. Chem. Soc. Jap.*, **40**, 1933 (1967).

(6) R. E. Brooks, J. O. Edwards, G. Levey, and F. Smyth, *Tetrahedron*, **22**, 1279 (1966).

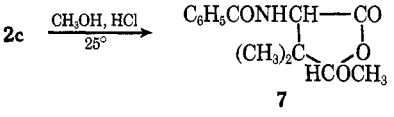
(7) F. W. Fowler and A. Hassner, *J. Amer. Chem. Soc.*, **90**, 2875 (1968).

(8) J. A. Deyrup and R. B. Greenwald, *Tetrahedron Lett.*, 5091 (1966); *J. Amer. Chem. Soc.*, **87**, 4538 (1965).

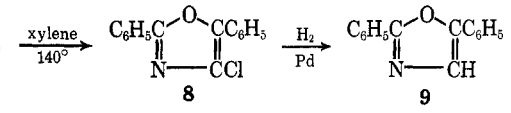
(32% yield). In the absence of acid, **2b** was stable in methanol.



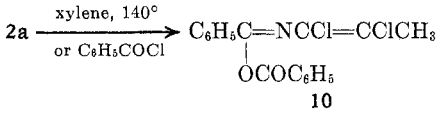
Methanolysis of the aziridine **2c** resembled that of the methyl derivative **2a**. However, the aldehyde and carboxyl groups interacted in the process to give the lactonic acetal **7** as the ultimate product (43% yield).



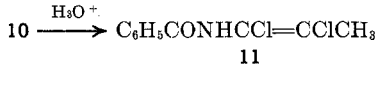
The thermolytic reactions also varied. In boiling xylene the phenylaziridine **2b** smoothly rearranged to 4-chloro-2,5-diphenyloxazole (**8**, 81% yield), identified by catalytic hydrogenolysis to the known[9] 2,5-diphenyloxazole (**9**). In contrast to **2b**, the aziridine **2c** could be



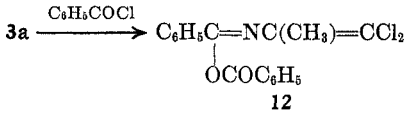
recovered quantitatively from boiling xylene (24 hr). It could be distilled with only slight decomposition using bath temperatures up to 215°. Likewise, the methylaziridine **2a** was distillable under reduced pressure *in the absence of acidic impurities*. On standing for long periods (6 months) even at room temperature, both **2a** and **2c** slowly decomposed with the evolution of acidic fumes. A solid product of this acid decomposition of **2a** proved to be the trichloroamide **1a**. In boiling xylene **2a** slowly evolved hydrogen chloride, and from the largely decomposed reaction mixture four crystalline compounds could be isolated: benzoic acid, benzamide, the trichloroamide **1a**, and a very poor yield of a compound, mp 160–161°, to which the structure **10** (cis or trans) has been assigned on the basis of



spectral and microanalytical data (see Experimental Section). Further support for this assignment was derived (1) from the observed formation of methyl benzoate by the base-catalyzed methanolysis of **10**, (2) from acid hydrolysis of **10** to an amide possessing the spectral properties and elemental composition required of structure **11**, yet different from the isomeric **3a**, and



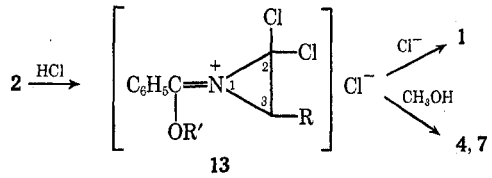
(3) from the observation that a better yield (32%) of **10** was obtainable by treatment of the aziridine **2a** directly with benzoyl chloride. Also obtained in this reaction was an 11% yield of a homogeneous oil whose ir, nmr, and mass spectra were similar to those of **10**. That this oil is the other isomer of structure **10** was shown by its nonidentity with the only possible alternative, *i.e.*, **12**, prepared by benzoylation of the amide **3a**.



Discussion

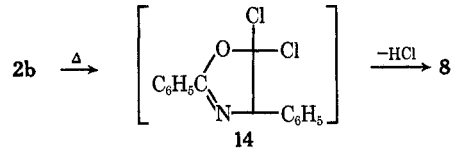
A thorough mechanistic study[6] of the solvolysis of 2,2-dichloro-1,3-diarylaziridines provided strong evidence for the intermediacy of a nonexchanging ion pair formed in a rate-limiting process that is not acid catalyzed. In the absence of acid, the *N*-benzoylaziridines **2** of the present work are clearly more stable than the corresponding *N*-arylaziridines. This is consistent with the decreased availability in **2** of the nitrogen lone pair necessary for the stabilization of the postulated[6] imonium–carbonium ion intermediate. The same explanation has been used to account for the increased stability of certain nonbasic monochloroaziridines as compared to analogous 1-arylmonochloroaziridines.[8]

The observed requirement for acid catalysis in the methanolysis of the 1-benzoylaziridines **2** suggests initial protonation, presumably at the carbonyl oxygen atom as the most basic center in the molecule. Attack of chloride ion at C-2 of the resulting ion pair **13** (R′ = H) would give products of type **1** (*i.e.*, when R = alkyl). Similar nucleophilic attack by solvent would eventually lead to the amido esters of types **4** and **7**.



Methanolysis of the phenylaziridine **2b** presents a different picture. Ring rupture of **13** (R′ = H, R = C_6H_5) now involves the C-3–N bond, a cleavage mode that is common to the analogous 1,3-diaryl-2,2-dichloroaziridines.[5,6] Indeed, methanolysis of 1,3-diphenyl-2,2-dichloroaziridine also has been found to lead to **5** and **6** (in addition to aniline hydrochloride).[8]

The thermolytic rearrangement of the phenylaziridine **2b** is straightforward. In contrast to **2a** and **2c**, the phenyl substituent in **2b** labilizes the C-3–N bond and transformation to oxazoline **14** occurs. This type of rearrangement is common to many 1-acylaziridines,[10] but in the present case further elimination of HCl takes place to give the oxazole **8**. In this respect the reaction is analogous to the rearrangement of 1-benzoyl-3-chloro-2-methyl-3-phenylaziridine to 2,5-diphenyl-4-methyloxazole, reported by Fowler and Hassner.[7]

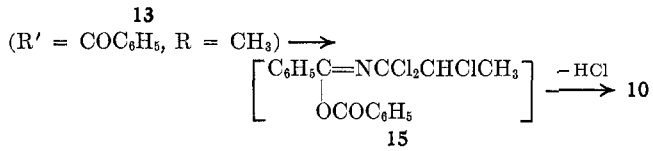


The formation of the imidate ester **10** from **2a** provides support for the view that the carbonyl oxygen

(9) E. Fischer, *Ber.*, **29**, 205 (1896).

(10) H. W. Heine and M. S. Kaplan, *J. Org. Chem.*, **32**, 3069 (1967), and references cited therein.

atom in **2** constitutes the most vulnerable site for initial attack on this relatively stable system. A likely mechanism for this process involves initial benzoylation (by benzoyl chloride formed as a decomposition product in the thermal process) to the ion pair **13** (R′ = COC_6H_5, R = CH_3). Chloride ion attack at C-3 with C-3–N bond rupture would give **15**, from which **10** would form by HCl elimination. Why C-2–N bond cleavage should occur in **13** (R′ = H, R = CH_3) and C-3–N bond rupture in **13** (R′ = COC_6H_5, R = CH_3), however, is not readily apparent.



Experimental Section

α-(1-Benzoyl-2,2-dichloro-3-aziridinyl)isobutyraldehyde (2c).—To a stirred suspension of 2.9 g (0.12 mol) of sodium hydride (washed free of mineral oil dispersant using pentane) in dry dimethylformamide (100 ml) was added a solution of **1c**[1] (18.5 g, 0.0575 mol) in dimethylformamide (50 ml). The addition rate was adjusted to maintain a temperature of 35° and the mixture was then stirred overnight at room temperature. The solution was separated from unreacted sodium hydride by centrifugation. The hydride was washed by centrifugation twice with dimethylformamide and once with benzene. The combined decantates were then concentrated to dryness under reduced pressure at a maximum temperature of 50°. The semisolid residue was partitioned between water and ether. From the ether layer, after washing, drying, and concentrating, was obtained 13.7 g of an amber oil. All but 2.6 g of this material dissolved in 250–300 ml of boiling pentane. This solution was decolorized with charcoal, concentrated to 75–100 ml, and allowed to stand at room temperature overnight in an open conical flask. The residual waxy solid (9 g) was slurried in pentane and filtered to give **2c** (7.5 g, 45%), mp 57–60°, sufficiently pure for further use. Two recrystallizations from pentane gave pure **2c**: mp 64–65°; ir ($CHCl_3$) 1690 (amide I) and 1720 cm^{-1} (HC=O), no NH; nmr ($CDCl_3$) δ 9.70 (s, 1, HCO), 8.3–7.6 (m, 5, Ar H), 3.23 (s, 1, NCH), 1.42 (s, 3, CH_3), and 1.37 ppm (s, 3, CH_3).

Anal. Calcd for $C_{13}H_{13}Cl_2NO_2$: C, 54.56; H, 4.58; Cl, 24.79; N, 4.90. Found: C, 54.86; H, 5.01; Cl, 24.46; N, 4.49.

The dichloroaziridine **2c** is thermally stable. It distilled at 140–145° (0.5 mm, bath temperature 215°) with only slight decomposition. When refluxed in xylene for 24 hr it could be recovered quantitatively.

When an equivalent rather than an excess of sodium hydride was used in the foregoing procedure the yield was reduced. When 1,2-dimethoxyethane was used as the solvent no **2c** could be isolated.

1-Benzoyl-2,2-dichloro-3-phenylaziridine (2b).—A solution of **1b**[1] (37.2 g, 0.113 mol, mp 172–173°) in dimethylformamide (200 ml) was added to a suspension of sodium hydride (4.9 g, 0.202 mol) in dimethylformamide as in the foregoing procedure. The mixture was then stirred at 40° for 5–6 hr and overnight at room temperature. The dark brown reaction mixture was poured onto ice. The precipitated amber-colored oil solidified, collected, and dried *in vacuo* at 45–50°. This crude product (27 g, mp 80–90°) was recrystallized once from methanol (200 ml + charcoal) to give 20.6 g (62%) of **2b**, mp 96–98°. Another recrystallization gave pure **2b**: mp 97–98°; ir ($CHCl_3$) 1700 cm^{-1} (amide I), no NH; nmr ($CDCl_3$) δ 8.5–7.5 (m, 10, Ar H) and 4.28 ppm (s, 1, NCH).

Anal. Calcd for $C_{15}H_{11}Cl_2NO$: C, 61.66; H, 3.80; Cl, 24.27; N, 4.80. Found: C, 61.78; H, 3.92; Cl, 24.58; N, 4.66.

When hexamethylphosphoramide was used as the solvent in the foregoing procedure, no **2b** could be isolated. When 3 equiv of 2,3-dimethyl-2-butene was added to a small run (2 g, 0.006 mol of **1b**), the yield of **2b** was reduced to 42%, but 36% of **1b** remained unreacted. When a volume of cyclohexane equal to that of the 2,3-dimethyl-2-butene was substituted for the latter, the yield of **2b** declined still further to 32%, and only 29% of **1b** remained.

1-Benzoyl-2,2-dichloro-3-methylaziridine (2a).—A solution of **1a**[1] (26.6 g, 0.1 mol, mp 111–112°) in dimethylformamide (120 ml) was added to a suspension of sodium hydride (4.32 g, 0.18 mol) in dimethylformamide as in the foregoing procedures. The mixture was stirred overnight at room temperature and then poured onto ice; the precipitated oil was taken up in ether, washed, and dried. The residual oil, obtained after removal of the ether, was distilled under reduced pressure to give 11.9 g (52%, $n^{25}D$ 1.549) of crude **2a**, bp 90–100° (0.8 mm). Redistillation gave pure **2a**: bp 87–89° (0.5 mm); $n^{25}D$ 1.5470; ir ($CDCl_3$) 1697 cm^{-1} (amide I), no NH; nmr ($CDCl_3$) δ 8.3–7.5 (m, 5, Ar H), 3.18 (q, 1, J = 6 Hz, NCH), and 1.53 ppm (d, 3, J = 6 Hz, CH_3).

Anal. Calcd for $C_{10}H_9Cl_2NO$: C, 52.20; H, 3.94; Cl, 30.82; N, 6.09; O, 6.96. Found: C, 52.00; H, 3.87; Cl, 30.57; N, 6.21; O, 7.23.

During 6 months at room temperature the analytical sample of **2a** gave off acidic fumes and became partially solid. Both ir and nmr spectra of this mixture showed that some of the trichloroamide **1a** had re-formed from the aziridine **2a**.

***N*-(2,2-Dichlorovinyl)benzamide (3d).**—*N*-(2,2,2-Trichloroethyl)benzamide (**1d**), mp 134–136°,[11] was prepared from chloralbenzamide[12] by treating it with thionyl chloride and reducing the resulting *N*-(1,2,2,2-tetrachloroethyl)benzamide (without purification) to **1d** (87% yield) using sodium borohydride in ethylene glycol dimethyl ether (at 0–25°) followed by an equivalent quantity of triethylamine. To a stirred suspension of 1.1 g (0.045 mol) of sodium hydride in 1,2-dimethoxyethane (50 ml) was added at 20–25° a solution of **1d** (5 g, 0.02 mol) in 25 ml of the same solvent. The mixture was stirred at room temperature for 3 days, precipitated sodium chloride (1.52 g) was removed by filtration, and the filtrate was concentrated *in vacuo* to give a yellow oil (7.35 g) that slowly solidified. Trituration, successively, with water and chloroform gave **3d** (3.4 g, 79%), mp 61–63°, identical (mixture melting point and ir spectrum) with an authentic specimen, mp 63–64°, prepared by the method of Meldrum and Bhojraj.[13] When dimethylformamide was substituted for the dimethoxyethane in this procedure, only unreacted **1d** was obtained.

***N*-(2,2-Dichloro-1-styryl)benzamide (3b).**—A 6.57-g (0.02 mol) sample of **1b** was submitted to the foregoing procedure except that the reaction mixture was heated under reflux for 2 hr and stirred at room temperature overnight before work-up. The crude washed (water) product (4.9 g, 83%, mp 163–165°) was recrystallized from methanol to give pure **3b** (2.7 g, 46%): mp 173–174°; ir ($CHCl_3$) 1460 (amide II), 1680 (amide I), and 3410 cm^{-1} (NH). [For the known **3d**:[13] ir ($CHCl_3$) 1460 (amide II), 1689 (amide I), and 3420 cm^{-1} (NH). Furthermore, in both **3b** and **3d**, the amide II bands are (unusually) more intense than the corresponding amide I bands.]

Anal. Calcd for $C_{15}H_{11}Cl_2NO$: C, 61.66; H, 3.80; Cl, 24.27; N, 4.80. Found: C, 61.75; H, 4.05; Cl, 24.22; N, 4.56.

When the foregoing reaction was allowed to proceed for 8 days at room temperature, spectral (nmr) examination of the crude product indicated the presence only of **1b** (24%) and **3b** (76%). No aziridine **2b** was detectable.

***N*-(2,2-Dichloroisopropenyl)benzamide (3a).**—After treatment of **1a** (5.32 g, 0.02 mol) with sodium hydride in DME in the usual way, the mixture was heated under reflux for 6 hr. The crude washed product (3.4 g) was taken up in ether, decolorized with charcoal, filtered from some crystallized benzamide (0.39 g, mp 124–126°), and concentrated. The residual oil (2.27 g) was distilled under reduced pressure to give 1.23 g (27%) of an oil, bp 115–130° (0.5 mm), that partially solidified. Several recrystallizations from aqueous methanol gave pure **3a**: mp 100–102°; ir ($CHCl_3$) 1472 (amide II), 1685 (amide I), and 3420 cm^{-1} (NH); nmr ($CDCl_3$) δ 8.0–7.3 (m, 5, Ar H), 2.43 ppm (s, 3, CH_3).

Anal. Calcd for $C_{10}H_9Cl_2NO$: C, 52.20; H, 3.94; Cl, 30.82; N, 6.09. Found: C, 52.19; H, 3.87; Cl, 30.55; N, 6.17.

(11) A. N. Nesmeyanov, L. I. Zakharkin, and R. H. Friedlina, *Izv. Akad. Nauk SSSR, Otd. Khim. Nauk*, 841 (1958); *Chem. Abstr.*, **53**, 1111 (1959).

(12) F. Feist, *Ber.*, **45**, 945 (1912).

(13) A. N. Meldrum and M. G. Bhojraj, *J. Indian Chem. Soc.*, **13**, 185 (1936).

Methanolysis of 2a.—A solution of the dichloroaziridine **2a** (1.31 g, 0.0057 mol) in dry methanol (25 ml) containing 5% hydrogen chloride was allowed to stand at room temperature for 1 week. The solvent was removed by distillation under reduced pressure and the residual semisolid oil (1.53 g) was allowed to stand in dry ether for several days. The ether solution was filtered from insoluble material (0.05 g), decolorized, and concentrated to dryness. The residual oil (1.2 g) was combined with equivalent material (1.2 g) from another run, and distilled under reduced pressure to give a colorless glass [2.17 g, bp 130–140° (0.8 mm), $n^{25}D$ 1.545)] that could not be crystallized. It was taken up in ether, washed with dilute hydrochloric acid and water, and finally washed with aqueous sodium bicarbonate and water. Acidification of the bicarbonate extract gave no precipitate. The combined acid extract and washings were concentrated to dryness under reduced pressure. The residual colorless solid (0.31 g, 14%, mp 154–157°) on recrystallization from chloroform gave pure *N*-benzoyl-*dl*-alanine, mp 158–159°, identical (mixture melting point, ir and nmr spectra, and elemental analysis) with an authentic sample.

From the washed, dried, and concentrated ether layer was obtained an oil (1.6 g) that was triturated first with pentane and then with a mixture of isopropyl alcohol (60%) and water (40%). Crystalline product (0.40 g, 13%, mp 105–107°) separated and was recrystallized from more of the isopropyl alcohol–water mixture to give pure *N*-(1,1,1-trichloro-2-propyl)benzamide (**1a**, 0.32 g), mp 111–112°, identical (mixture melting point, ir and nmr spectra, and elemental analysis) with the authentic material.[1]

The original aqueous isopropyl alcohol filtrate was decolorized and taken to dryness under reduced pressure. The residue (0.75 g) solidified and was recrystallized from benzene–hexane to give crude *N*-benzoyl-*dl*-alanine methyl ester (**4**, 0.60 g, 25%, mp 75–80°). Another recrystallization gave pure **4**, mp 80–81°, identical (mixture melting point, ir and nmr spectra, and elemental analysis) with a true sample.

When the methanolysis was conducted at reflux temperature for 48 hr instead of at room temperature, a 23% yield of *dl*-alanine methyl ester hydrochloride could be isolated in addition to **1a** and **4**.

Methanolysis of 2b.—A solution of **2b** (2 g, 0.00685 mol) in methanolic hydrogen chloride (30 ml, 5%) was allowed to stand at room temperature for 6 days. The solvent was removed by distillation under reduced pressure and the residue was taken up in dry ether. Insoluble material was collected at the filter, washed with ether, and dried. It proved to be ammonium chloride (0.34 g, 93% yield). Concentration of the ethereal filtrate gave a residual oil (1.9 g) that was separated into three pure components using preparative glc. By comparison (nmr spectra and qualitative glc) with authentic samples, they proved to be methyl benzoate, methyl α-chlorophenylacetate (**5**), and methyl α-methoxyphenylacetate (**6**). The composition of the mixture using quantitative glc was 49% methyl benzoate, 35% **5**, and 16% **6**. From the integrals of the nmr spectrum of the same mixture the calculated percentages were 44, 35, and 21%, respectively, corresponding to yields (based on the 1.9 g of crude methanolysis product) of 90% methyl benzoate, 53% **5**, and 32% **6**.

Methanolysis of 2c.—A solution of **2c** (7.5 g, 0.0262 mol) in dry methanol (75 ml) was allowed to stand at room temperature for 7 weeks. The mixture became deep yellow and strongly acidic. It was concentrated to dryness under reduced pressure and the semisolid residue (7.5 g) was triturated with ethanol. Colorless solid (2.94 g, 43%, mp 156–158°) was collected at the filter and recrystallized from methanol to give pure **4-hydroxy-4-methoxy-2-benzamido-3,3-dimethylbutyric acid γ-lactone (7)**: mp 158–159°; ir ($CHCl_3$) 1668 (amide I), 1778 (lactone C=O), 2835 (OCH_3), 3370 and 3425 cm^{-1} (NH); nmr ($CDCl_3$) δ 8.0–7.3 (m, 5, Ar H), 6.77 (d, 1, J = 8 Hz, NH), 5.22 (d, 1, J = 8 Hz, NCH), 5.00 (s, 1, OCH), 3.57 (s, 3, OCH_3), 1.28 (s, 3, CCH_3), and 1.08 ppm (s, 3, CCH_3).

Anal. Calcd for $C_{14}H_{17}NO_4$: C, 63.86; H, 6.51; N, 5.32; O, 24.31. Found: C, 63.68; H, 6.50; N, 5.33; O, 24.44.

Inhibition of Methanolysis by β-Pinene.—When each of the three aziridines **2** was allowed to stand for 1 week (at 25°) in methanol containing 5% of the acid trap, β-pinene, the solution remained neutral and the starting material was recovered unchanged (85–95% yield).

Thermolysis of 2b.—A solution of **2b** (5 g, 0.0171 mol) in xylene (30 ml) was heated under reflux overnight. The solvent was removed by distillation under reduced pressure and the residual solid (4.3 g) was recrystallized (charcoal) from methanol to give 4-chloro-2,5-diphenyloxazole (**8**, 3.55 g, 81%, mp 67–69°). Two more recrystallizations gave pure **8**: mp 69–70°; uv max (C_2H_5OH) 224 mμ (ϵ 16,600) and 307 (25,300).

Anal. Calcd for $C_{15}H_{10}ClNO$: C, 70.45; H, 3.94; Cl, 13.87; N, 5.48; O, 6.26. Found: C, 70.59; H, 4.06; Cl, 13.67; N, 5.31; O, 6.50.

Hydrogenolysis of 8 to 9.—A suspension of 5% palladium on charcoal in methanol (150 ml) was prehydrogenated, and the chlorooxazole **8** (0.05 g, 0.002 mol) together with triethylamine (0.28 ml) were added. Hydrogenation in a microscale apparatus was continued until no further pressure drop (41 to 27 psi) was detectable. The catalyst was removed by filtration, and the filtrate was concentrated to dryness under reduced pressure. The residual solid (0.55 g) was slurried in water and collected at the filter. The dried product (0.36 g, mp 69–70°) was recrystallized from ethanol to give pure 2,5-diphenyloxazole (**9**), mp 70–71°, identical (mixture melting point, elemental analysis, and ir spectrum) with a true specimen prepared by the method of Fischer.[9]

Thermolysis of 2a.—Over a period of several months five portions of **2a** (17.8 g, 0.077 mol total) were submitted to the thermolysis conditions described above for **2b**. In all cases evolution of hydrogen chloride occurred with considerable decomposition. The product obtained after removal of the xylene was separated from tar by dissolving it in ether, decolorizing the solution with charcoal, filtering, and concentrating to dryness. The residual yellow oil was then treated in a number of ways. These included column chromatography on silica gel (heptane–ethanol solvent) and solvent fractionation using ether, methanol, chloroform, and hexane at various times. Four crystalline compounds were isolated (not all from any single run). Three were easily identified as benzoic acid, benzamide, and the trichloromethyl compound **1a**, mp 111–112°. The fourth (total yield, less than 150 mg) was obtained in pure form (tlc) by recrystallization from methanol: mp 160–161°; uv max (C_2H_5OH) 241 mμ (ϵ 11,500); ir ($CHCl_3$) 1117, 1250 (benzoate C–O stretch), 1715 cm^{-1} (benzoate C=O), and no NH; nmr ($CDCl_3$) δ 8.0–7.4 (m, 10, Ar H) and 2.28 ppm (s, 3, $=CClCH_3$); mass spectrum *m/e* (rel intensity, assignment) 333.0326 [0.5, calcd for $C_{17}H_{13}Cl_2NO_2$ (**10**): 333.0322], 298.0645 (1.3; calcd for $C_6H_5C(OCOC_6H_5)=NC^+=CClCH_3$: 298.0634), 193.0309 (5, calcd for $C_6H_5CON=C=CClCH_3$: 193.0294), 105 (100, $C_6H_5CO^+$), 77 (92, $C_6H_5^+$).

Anal. Calcd for $C_{17}H_{13}Cl_2NO_2$: C, 61.10; H, 3.92; Cl, 21.22; N, 4.19; O, 9.57. Found: C, 60.93; H, 3.95; Cl, 21.30; N, 4.36; O, 9.54.

The presence of a benzoate group in this compound was established by refluxing (16 hr) a sample (46 mg) in methanol (1 ml) containing sodium methoxide (from 0.012 g of Na). Presence of methyl benzoate in the reaction mixture was established by odor, nmr spectrum, and qualitative glc comparison with the authentic material.

Considering the method of preparation, the foregoing physical and chemical properties of the unknown compound (mp 160–161°) can be accommodated by only three possible structures: either the cis or trans form of **10** (*O*-benzoyl-*N*-(1,2-dichloropropenyl)benzimidate), or the isomeric imidate **12**. The third possibility (*i.e.*, **12**) was ruled out by the following experiment.

Hydrolysis of 10.—A solution of the imidate **10** (0.30 g, 0.9 mmol) and concentrated hydrochloric acid (4 ml) in tetrahydrofuran (20 ml) was heated under reflux for 2 days. The colorless solution was concentrated to dryness, and finally under reduced pressure (<1 mm) at 100°. The semisolid residue was pressed on a clay plate to obtain friable solid (0.095 g, 46%) which was recrystallized once from an ether–pentane mixture to give pure ***N*-(1,2-dichloropropenyl)benzamide** (**11**): mp 115–117°; ir ($CHCl_3$) 1500 (amide II), 1695 (amide I), 3420 cm^{-1} (NH); nmr ($CDCl_3$) δ 8.2–7.5 (m, 5, Ar H), and 2.33 ppm (s, 3, $=CCH_3$); mass spectrum *m/e* (rel intensity, assignment) 229.0067 [0.1, calcd for $C_{10}H_9Cl_2NO$ (**11**): 229.0060], 194 (19, $C_6H_5CONHC^+=CClCH_3$), 159 (3, $C_6H_5CONHC=CCH_3$), 105 (100, $C_6H_5CO^+$), 77 (81, $C_6H_5^+$).

Anal. Calcd for $C_{10}H_9Cl_2NO$: C, 52.20; H, 3.94; Cl, 30.82; N, 6.09. Found: C, 52.20; H, 4.03; Cl, 30.30; N, 6.17.

That this hydrolysis product **11** is isomeric with but different from **3a** rules out **12** as a possible structure for the pyrolysis product **10**.

Benzoylation of 2a.—A solution of **2a** (1 g, 0.00435 mol) and benzoyl chloride (1.4 g, 0.01 mol) in dry xylene (15 ml) was heated under reflux for 16 hr using a fiberglass heating mantle. The dark brown solution was diluted with benzene (10 ml), decolorized with charcoal, and concentrated to dryness in a rotating evaporator under reduced pressure. The residual yellow oil (1.8 g) partially crystallized. Trituration with cold dry ether and collection at the filter gave 0.47 g (32% yield) of product, mp 145–150°. Recrystallization from methanol gave pure **10** (0.35 g, mp 158–160°) identical with the material obtained from the pyrolysis of **2a**. From the ethereal filtrate there was obtained an oil (0.47 g) which gave a colorless fraction (0.17 g) soluble in warm pentane. This oil could not be crystallized despite indications of virtual homogeneity by tlc analysis. Although its infrared and mass spectra (M^+ = 333.0339; calcd for $C_{17}H_{13}Cl_2NO_2$: 333.0322) were nearly identical with the corresponding spectra of **10**, the CH_3 singlet in the nmr appeared at δ 2.13 ppm instead of at 2.28 ppm for compound **10**. Structure **12** for this oil was again ruled out by the following experiment.

Benzoylation of 3a.—Application of the foregoing procedure to 1.31 g (0.0057 mol) of **3a** gave a dark oil (1.8 g) that crystallized upon trituration with ether. Collection at the filter gave 1.05 g (mp 108–111°, 55% yield) of crude product. Several recrystallizations from methanol gave pure ***O*-benzoyl-*N*-(2,2-dichloroisopropenyl)benzimidate (12)**: mp 111–113°; ir ($CHCl_3$) 1700 cm^{-1} (C=O), and no NH; nmr ($CDCl_3$) δ 8.3–7.3 (m, 10, ArH), and 2.13 ppm (s, 3, CH_3).

Anal. Calcd for $C_{17}H_{13}Cl_2NO_2$: C, 61.10; H, 3.92; Cl, 21.22; N, 4.19. Found: C, 61.36; H, 3.73; Cl, 21.43; N, 4.30.

Two solvent systems were used in tlc analyses to compare the three isomeric compounds **12**, **10**, and the oil obtained along with **10**: methylene chloride–nitrobenzene, 6:1, R_f 0.76, 0.86, and 0.86, respectively; and carbon tetrachloride–nitrobenzene, 6:1, R_f 0.47, 0.54, and 0.57, respectively. Tlc analysis of a crude reaction mixture from the benzoylation of the aziridine **2a** showed no more than a trace of material of R_f corresponding to that of **12**.

Registry No.—**2a**, 29431-38-7; **2b**, 29431-39-8; **2c**, 29431-40-1; **3a**, 29431-41-2; **3b**, 29431-42-3; **3d**, 29431-43-4; **7**, 29431-44-5; **8**, 29431-45-6; **10**, 29431-46-7; **11**, 29431-47-8; **12**, 29431-48-9.

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An Oxygen-18 Study of the Reaction of *N*-Phenylmaleamic Acid with Acetic Anhydride[1,2]

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N-Phenylmaleamic acid **1** labeled in the carboxyl group was prepared by basic hydrolysis of *N*-phenylmaleisoimide. The dehydration of **1** with *N*,*N*′-dicyclohexylcarbodiimide gave *N*-phenylmaleisoimide and *N*,*N*′-dicyclohexylurea; each contained 50% of the original label. Dehydration of the carboxyl-labeled **1** with an acetic anhydride–sodium acetate mixture produced an isoimide–imide product mixture which contained 34% of the original label. Treatment of carboxyl-labeled **1** with acetic anhydride alone was followed by isolation of maleic anhydride (as *endo-cis*-norbornene-5,6-dicarboxylic acid monomethyl ester) and acetanilide. These products contained 94 and 4% of the original label, respectively. The results rule out two mechanisms for this transacylation reaction: (1) a bicyclo [3.2.1] rearrangement of the mixed anhydride of **1** and acetic acid to give maleic anhydride and acetanilide, and (2) the reaction of acetic acid with the isoimide to produce these products. Other mechanisms for the transacylation and dehydration reactions of *N*-phenylmaleamic acid with acetic anhydride are discussed.

In a previous study[4] of the reaction of *N*-arylmaleamic acids **1** with acetic anhydride at 75°, maleic anhydride **2** and acetanilides **3** were found as products along with *N*-arylmaleisoimides **4** and *N*-arylmaleimides **5**. When sodium acetate was added to the reaction mixture, the same four products were observed, but the yields of maleic anhydride and the acetanilides decreased and the yields of the dehydration products **4** and **5** were increased. Furthermore, the production of **2** and **3** was more important when substituents attached to the position para to the amide nitrogen were electron donating than when the substituents were electron withdrawing. These reactions are outlined in Scheme I.

In earlier work Kretov and Kul'chitskaya[5] had isolated acetanilides from similar reactions run at the temperature of refluxing acetic anhydride, and Roderick and Bhatia[6] reported that heptafluorobutyranilide and *p*-methoxyheptafluorobutyranilide were obtained from the reaction of heptafluorobutyric anhydride with *N*-phenylsuccinamic acid and with *N*-*p*-anisylsuccinamic acid.

The previous study of the rearrangement of *N*-arylmaleisoimides to *N*-arylmaleimides in acetic anhydride with and without sodium acetate showed that the formation of the acetanilides and maleic anhydride did not occur as a result of the reaction of the isoimide with the solvent during kinetic runs.[4] We have now found that a small amount of acetanilide (and presumably maleic anhydride) is formed during a longer exposure of *N*-phenylmaleisoimide to acetic anhydride containing 2% acetic acid and that the acetanilides are unstable to the reaction conditions and react slowly with the solvent to form products which have been identified by mass spectra and nmr as *N*,*N*-diacylanilines. Previous

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(2) A preliminary account of part of this work has appeared: C. K. Sauers, *Tetrahedron Lett.*, 1149 (1970).

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