reaction mixture was then concentrated to one-third volume under reduced pressure at 65° and extracted with ether. The ether extract was washed with water, dried over sodium sulfate, concentrated, and distilled giving 19.90 g (30%) of 2-ethyl-5-phenyltetrazole (7): bp 77–78° (0.20 mm); ir (neat) 1575 (s), 1555 (s), 1374 (s), 1342 (s), 786 (s), 730 (s), 715 (s), 690 (s), and 653 cm^{-1} (w).

Anal. Calcd for $C_9H_{10}N_4$: C, 62.05; H, 5.79; N, 32.17; mol wt, 174. Found: C, 62.11; H, 5.72; N, 32.23; mol wt, 174 (mass spectrometry).

The still pot residue that solidified after cooling was recrystallized from ethanol affording 6.05 g (10%) of 1-ethyl-5-phenyltetrazole[13] (6): mp 70–71°; ir (KBr) 1451 (s), 1170 (s), 1114 (s), 1076 (s), 776 (s), 735 (s), 694 (s), and 650 cm^{-1} (s).

1,4-Diethyl-5-phenyltetrazolium Fluoroborate (9).—A solution of 1-ethyl-5-phenyltetrazole (6) (5.00 g, 0.03 mol) and triethyloxonium fluoroborate (5.46 g, 0.03 mol) in ethylene chloride (50 ml) was stirred at reflux temperature for 4 hr. The solvent was removed under reduced pressure and the remaining residue was washed with ether. Recrystallization from ethanol gave 4.15 g (59%) of 1,4-diethyl-5-phenyltetrazolium fluoroborate (9): mp 131–132°; ir (KBr) 1486 (s), 1449 (m), 1100–1000 (vs), 770 (s), 742 (s), 717 (s), and 691 cm^{-1} (s).

Anal. Calcd for $C_{11}H_{15}BF_4N_4$: C, 45.54; H, 5.21; N, 19.32. Found: C, 45.93; H, 5.43; N, 19.41.

1,2- or 1,3-Diethyl-5-phenyltetrazolium Fluoroborate (10).—A solution of 2-ethyl-5-phenyltetrazole (7) (5.00 g, 0.03 mol) and triethyloxonium fluoroborate (5.46 g, 0.03 mol) in ethylene chloride (50 ml) was stirred at reflux temperature for 4 hr. The product was isolated in the same manner as the tetrazolium salt described above. Compound 10 (5.5 g, 78%) was recrystallized from ethanol to give a white crystalline solid which had a melting point of 71–72°: ir (KBr) 1605 (m), 1477 (s), 1449 (s), 1100–1000 (vs), 802 (m), 781 (s), 773 (s), 747 (s), 728 (s), and 694 cm^{-1} (s).

Anal. Calcd for $C_{11}H_{15}BF_4N_4$: C, 45.54; H, 5.21; N, 19.32. Found: C, 45.37; H, 5.30; N, 19.26.

1,4-Diethyl-5-methyltetrazolium Fluoroborate (8).—1-Ethyl-5-methyltetrazole (5.00 g, 0.045 mol) was added dropwise to a magnetically stirred solution of triethyloxonium fluoroborate (8.47 g, 0.045 mol) in ethylene chloride (50 ml). The reaction temperature was maintained at 25–35° by means of a cooling bath. After the addition was complete, the reaction mixture was stirred at 25° for 4 hr. The solvent was then removed under pressure at 40° leaving a 4.50 g (88%) of hygroscopic 8: mp 129–130° after recrystallization from ethanol; ir (solid film) 1575 (m), 1445 (s), 1111–1000 (s), 722 (m), 689 (w), and 665 cm^{-1} (m).

Anal. Calcd for $C_6H_{13}BF_4N_4$: C, 31.67; H, 5.76; N, 24.63. Found: C, 31.48; H, 5.25; N, 24.25.

4-Methyl-3,5-diphenyl-1,2,4-triazole (15).—*N*-Methylbenzamide (54.05 g, 0.40 mol) was treated with phosphorus pentachloride (83.30 g, 0.40 mol) and benzhydrazide (54.46 g, 0.40 mol) in chloroform (200 ml) by the method of Scheuing and Walach[14] yielding 59.20 g (63%) of 4-methyl-3,5-diphenyl-1,2,4-triazole (15): mp 242–243° (lit.[14] mp 243°) after recrystallization from ethanol; ir (KBr) 1464 (s), 1064 (m), 1020 (w), 1005 (m), 769 (s), 727 (s), and 687 cm^{-1} (s).

4-Methyl-1-ethyl-3,5-diphenyl-1,2,4-triazolium Fluoroborate (17).—A stirred solution of 4-methyl-3,5-diphenyl-1,2,4-triazole (2.35 g, 0.01 mol) and triethyloxonium fluoroborate (1.90 g, 0.01 mol) in ethylene chloride (50 ml) at reflux temperature for 2 hr gave 3.30 g (94%) of 17: mp 148–149°; ir (solid film) 1608 (m), 1100–1000 (vs), 794 (m), 733 (m), and 697 cm^{-1} (s). The isolation procedure used was described previously for compound 8.

Anal. Calcd for $C_{17}H_{18}BF_4N_3$: C, 58.15; H, 5.17; N, 11.97. Found: C, 58.20; H, 5.26; N, 11.90.

Registry No.—**1**, 3641-05-2; **2**, 3641-06-3; **3**, 15284-40-9; **4a**, 3999-10-8; **5**, 20743-50-4; **6**, 24433-71-4; **7**, 31818-94-7; **8**, 32827-41-1; **9**, 32675-44-8; **10**, 32675-45-9; **11**, 32675-46-0; **12**, 32675-47-1; **13**, 32675-48-2; **14a**, 2039-06-7; **15**, 32272-86-9; **16**, 32675-51-7; **17**, 32675-52-8; **18**, 32675-53-9.

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(13) E. K. Harvill, R. M. Herbst, E. C. Schreiner, and C. W. Roberts, *J. Org. Chem.*, **15**, 662 (1950).

(14) G. Scheuing and B. Walach, German Patent 543,026 [*Chem. Abstr.*, **26**, 3263 (1932)].

Reactions of Pyrrole with Isocyanates. Preparation and Reactions of *N*-Ethoxycarbonylpyrrole-2-carboxamide and Pyrrole-1,2-dicarboximide

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Treatment of pyrrole with ethoxycarbonyl isocyanate in toluene yields *N*-ethoxycarbonylpyrrole-2-carboxamide (1), which is readily hydrolyzed to either pyrrole-2-carboxamide or pyrrole-2-carboxylic acid and cyclized to pyrrole-1,2-dicarboximide (8). Reaction of 8 with ammonia gives *N*-carbamoylpyrrole-2-carboxamide (10) and its N-tosylation followed by hydrolysis affords *N*-tosylpyrrole-2-carboxamide (13), which is found to be identical with the compound formed from pyrrole and tosyl isocyanate in dioxane. Pyrrolylpotassium reacts with ethoxycarbonyl isocyanate in tetrahydrofuran to form, after acidification, *N*-ethoxycarbonylpyrrole-1-carboxamide (2).

The reactions of pyrrole with phenyl isocyanate[1] and trichloroacetyl isocyanate[2] are known to yield the corresponding derivatives of pyrrole-2-carboxamide. Of these, *N*-phenylpyrrole-2-carboxamide has been shown to react further with phenyl isocyanate, in the presence of triethylamine, to form *N*-phenylpyrrole-1,2-dicarboximide (7).[3] Unexpectedly, in view of the higher reactivity of the 2 position of pyrrole toward electrophilic reagents,[4] treatment of pyrrole with tosyl isocyanate in dioxane has been reported to lead to *N*-tosylpyrrole-3-carboxamide.[5]

In analogous reactions of enamines with ethoxycarbonyl isocyanate, the initial products have been shown

(1) A. Treibs and W. Ott, *Justus Liebigs Ann. Chem.*, **577**, 119 (1952).

(2) L. R. Smith, A. J. Speziale, and J. E. Fedder, *J. Org. Chem.*, **34**, 633 (1969).

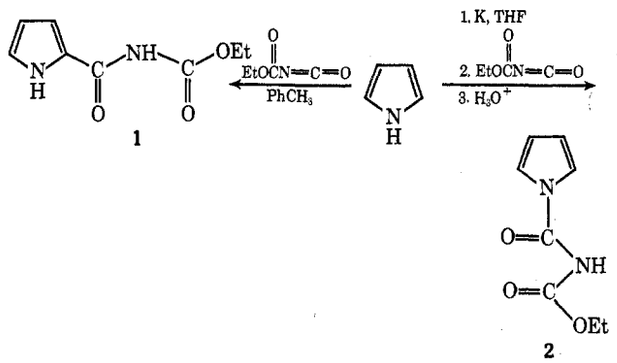
(3) E. P. Papadopoulos and H. S. Habiby, *ibid.*, **31**, 327 (1966).

(4) K. Schofield, "Hetero-Aromatic Nitrogen Compounds," Butterworths, London, 1967, pp 90, 91.

(5) M. Seefelder, *Chem. Ber.*, **96**, 3243 (1963).

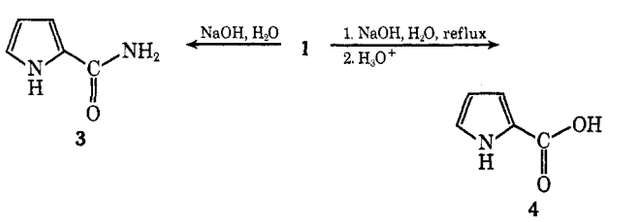
to undergo cyclization to form heterocyclic systems.[6] It was of interest to investigate the reaction of pyrrole with this isocyanate, because cyclization of the expected product (**1**) would yield pyrrole-1,2-dicarboximide (**8**). Availability of this compound would allow an unambiguous synthesis of *N*-tosylpyrrole-2-carboxamide (**13**) for comparison with the product of the reaction of pyrrole with tosyl isocyanate.

Pyrrole reacts readily with ethoxycarbonyl isocyanate to form *N*-ethoxycarbonylpyrrole-2-carboxamide (**1**). The reaction must be run in solution, because the neat reagents react violently and resinification of their mixture cannot be prevented. Structure **1** is

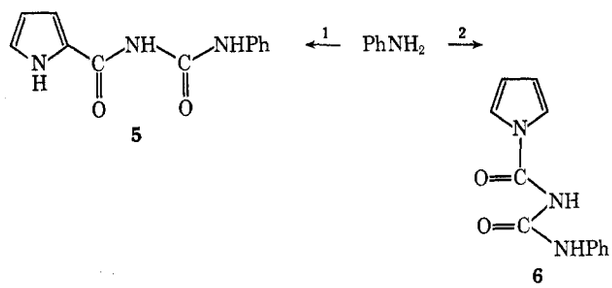


consistent with the infrared spectrum of the product, which contains strong NH absorption bands at 3450 and 3320 cm^{-1}, as well as carbonyl bands at 1770 and 1680 cm^{-1}. The relatively low frequency of the second carbonyl band indicates attachment of the side chain to a carbon atom of the ring.[3] This is confirmed by the nmr spectrum which, in addition to singlets at δ 11.8 (pyrrole NH) and 10.5 (imide NH), displays three multiplets centered at δ 7.3, 7.1, and 6.3, characteristic of the CH protons of a pyrrole ring with a carbonyl substituent at the 2 position.[2] For the sake of comparison of spectral data, *N*-ethoxycarbonylpyrrole-1-carboxamide (**2**) was prepared by the reaction of pyrrolylpotassium with ethoxycarbonyl isocyanate in tetrahydrofuran followed by acidification. The infrared spectrum of **2** shows relatively weak NH absorption at 3450 and 3300 cm^{-1} [7] and contains carbonyl bands at 1800 and 1730 cm^{-1}. Its nmr spectrum displays a singlet at δ 10.9 for the imide proton, and two triplets centered at δ 7.6 and 6.3 for the pyrrole CH protons.

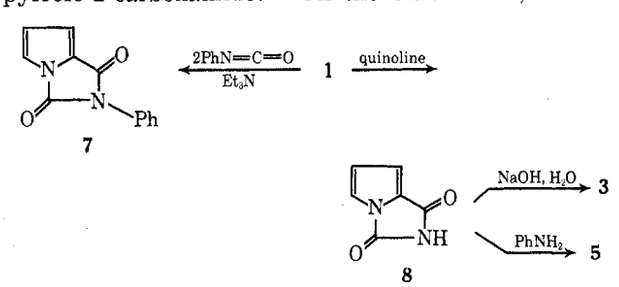
Treatment with warm, aqueous sodium hydroxide hydrolyzes and decarboxylates **1** with formation of pyrrole-2-carboxamide (**3**). More drastic hydrolysis of **1** yields pyrrole-2-carboxylic acid (**4**). These reactions provide convenient methods of preparation of **3** and **4** in two steps from pyrrole. As would be expected,[3] the carbonyl group attached to the pyrrole ring in **2** is considerably more reactive toward nucleophilic reagents than the corresponding group in **1** and alkaline hydrolysis of **2** results in formation of pyrrole.



Upon brief heating with aniline, both **1** and **2** undergo substitution at the ester carbonyl to form *N*-phenylcarbamoylpyrrole-2-carboxamide (**5**) and *N*-phenylcarbamoylpyrrole-1-carboxamide (**6**), respectively. In support of the above structures, the infrared spectrum (Nujol) of **5** displays NH absorption bands at 3320 and 3230 cm^{-1}, and carbonyl bands at 1700 and 1650 cm^{-1}. Its nmr spectrum contains singlets at δ 12.0, 11.1, and 10.7 for the three NH protons. Correspondingly, the infrared spectrum (Nujol) of **6** shows NH stretching at 3250 and carbonyl stretching at 1720 and 1690 cm^{-1}, while its nmr spectrum contains only two NH singlets at δ 10.8 and 10.3.



When **1** is treated with phenyl isocyanate, in the presence of triethylamine, *N*-phenylpyrrole-1,2-dicarboximide (**7**) is formed in a reaction completely analogous to that involving formation of **7** from *N*-phenylpyrrole-2-carboxamide.[3] On the other hand, the anticipated cyclization to pyrrole-1,2-dicarboximide (**8**) occurs readily when **1** is heated with quinoline. The infrared spectrum of **8** exhibits absorption at 3440 cm^{-1}, due to the cyclic imide NH,[8,10] and carbonyl bands at 1795 and 1745 cm^{-1}, consistent with the hydantoin ring.[8,10] Its nmr spectrum confirms the structure by displaying a broad singlet at δ 11.2 for the imide proton,[9,10] and three multiplets centered at δ 7.5, 6.9, and 6.6, corresponding to pyrrole ring protons. Treatment of **8** with aqueous alkali opens the hydantoin ring to yield **3** with loss of carbon dioxide. Hydantoin ring opening is observed also when **8** is heated with aniline to form **5**. The results of the last two reactions, together with the nmr data, exclude the alternate structure of pyrrole-2,3-dicarboximide for the cyclization product of **1**.



(6) (a) R. W. Lamon, *J. Heterocycl. Chem.*, **6**, 261 (1969); (b) R. Niess and R. K. Robins, *ibid.*, **7**, 243 (1970).

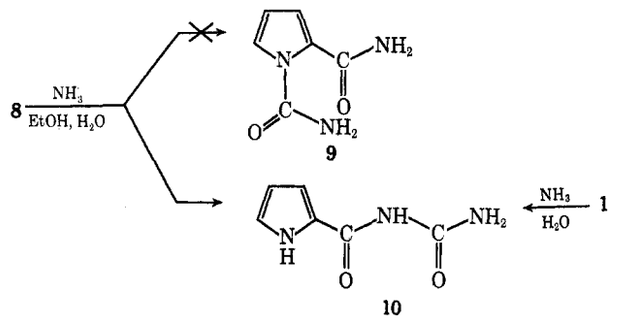
(7) In this and other similar cases, pyrrole and imide NH absorption bands appear at nearly the same frequency in solution spectra. In spectra of mulled samples, however, pyrrole NH stretching appears at a frequency 50–100 cm^{-1} higher than that of imide NH.

(8) Broad band at 3250–3120 cm^{-1} in spectrum of mulled sample.[9]

(9) E. E. Smissman, P. L. Chien, and R. A. Robinson, *J. Org. Chem.*, **35**, 3818 (1970).

(10) Compare with corresponding spectral values of phthalimide: ν_{NH} 3430 cm^{-1}; $\nu_{C=O}$ 1780, 1740 cm^{-1}; δ_{NH} 11.4.

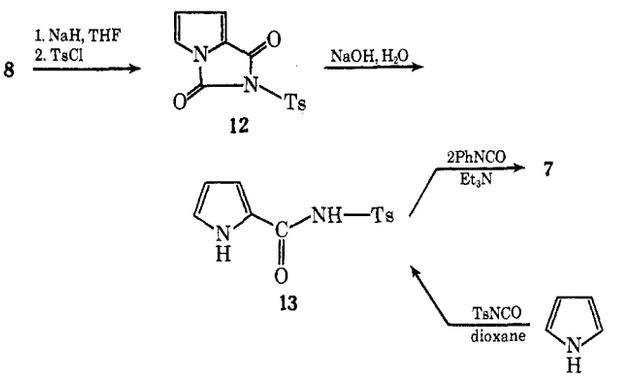
In a communication on the isolation of **8** from the urine of patients with rheumatoid arthritis,[11] this compound is reported to melt at 180–183°, in a sealed capillary, as it sublimes at 130–140°, and to yield pyrrole-1,2-dicarboxamide (**9**), mp 237°, upon treatment with aqueous alcoholic ammonia. In the present study, **8** has been found to melt at 210–212°, in an open capillary. Because conversion of **8** into **9** would involve a hydantoin ring opening different from that observed in the cases of its hydrolysis and reaction with aniline, the action of ammonia on **8** was reinvestigated.



When treated with a mixture of ethanol and concentrated aqueous ammonia (1:1), or the latter reagent alone, **8** goes into solution and a new solid (mp 240–241°) precipitates in a few moments. Instead of **9**, spectroscopic data strongly support the structure of *N*-carbamoylpyrrole-2-carboxamide (**10**) for this product. A compound of structure **9** would be expected to show carbonyl absorption below 1700 cm^{-1} in its infrared spectrum (Nujol)[12] and no signal corresponding to either pyrrole or imide NH proton in its nmr spectrum. In contrast, the infrared spectrum (Nujol) of the compound in question displays carbonyl bands at 1710 and 1670 cm^{-1},[12] and its nmr spectrum displays singlets for both pyrrole (δ 11.8) and imide (δ 10.2) NH protons.[13] Finally, the formation of **10** from **1** by treatment with aqueous ammonia at room temperature, or much faster at 100° under pressure, adds further support to its assigned structure.

As in the case of hydrolysis, the reaction of **2** with aqueous or alcoholic ammonia follows a different pattern and leads to formation of pyrrole-1-carboxamide (**11**).

The identity of the product of the reaction of pyrrole with tosyl isocyanate[5] has been established in the following manner. Treatment of the sodium salt of **8** with tosyl chloride in tetrahydrofuran yields *N*-tosylpyrrole-1,2-dicarboximide (**12**), as evidenced by the absence of NH absorption in the infrared spectrum of the product and the presence in it of strong bands at 1290 and 1180 cm^{-1}, indicative of *N*,*N*-disubstituted sulfonamide.[14] Furthermore, structure **12** is entirely consistent with the nmr spectrum of the product. Warm aqueous sodium hydroxide hydrolyzes **12** rapidly to yield a compound identical in all respects (ir and nmr spectrum, mixture melting



point) with the product of the reaction of pyrrole with tosyl isocyanate in dioxane.[5] In the light of the ring opening observed in the hydrolysis of **7**,[3] **8**, and other condensed hydantoins,[9] it can be concluded that the above compound is *N*-tosylpyrrole-2-carboxamide (**13**). The nmr spectrum confirms this structure by displaying singlets at δ 12.0 and 11.8 for the NH protons, and three multiplets centered at δ 7.3, 7.1, and 6.2, characteristic of 2-substituted pyrrole derivatives of this type.[2] Attachment of the side chain at the 2 position of the pyrrole ring in the adduct of pyrrole and tosyl isocyanate is further indicated by the formation of *N*-phenylpyrrole-1,2-dicarboximide (**7**) upon treatment of the adduct with phenyl isocyanate and triethylamine.

Experimental Section[15]

***N*-Ethoxycarbonylpyrrole-2-carboxamide** (**1**).—To a stirred solution of 16.7 g (0.25 mol) of pyrrole in 50 ml of toluene was added 28.7 g (0.25 mol) of ethoxycarbonyl isocyanate[6a] dissolved in 50 ml of toluene, dropwise, over 1 hr. The reaction mixture was kept under nitrogen and its temperature was held at 30–40° by intermittent cooling. After completion of the addition, the solution was stirred at room temperature for a further 22 hr, then it was filtered and the precipitate was washed with five 25-ml portions of dichloromethane. The yield was 37.0 g (81%) of crude **1**, mp 137–139°. Recrystallization from dichloromethane yielded the pure compound: mp 140–141°;[16] ir 3450, 3320, 1770, 1680, 1540, 1480, 1300, 1280, 1155, 1110, 1090, 1045, 1030, 905, and 570 cm^{-1}; nmr δ 11.8 (s, 1, pyrrolyl NH), 10.5 (s, 1, imide NH), 7.3 (m, 1, pyrrolyl CH), 7.1 (m, 1, pyrrolyl CH), 6.3 (m, 1, pyrrolyl CH), 4.2 (q, 2, J = 7 Hz, $-CH_2-$), and 1.3 (t, 3, J = 7 Hz, $-CH_3$).

Anal. Calcd for $C_8H_{10}N_2O_3$: C, 52.74; H, 5.53; N, 15.38. Found: C, 52.87; H, 5.40: N, 15.36.

***N*-Ethoxycarbonylpyrrole-1-carboxamde** (**2**).—Pyrrolylpotassium was prepared in a nitrogen atmosphere by refluxing a stirred solution of 16.1 g (0.24 mol) of pyrrole in 50 ml of tetrahydrofuran with 7.8 g (0.20 g-atom) of potassium until all of the metal had reacted. Following dilution with 150 ml of solvent and cooling of the slurry to about 5° there was added 20.7 g (0.18 mol) of ethoxycarbonyl isocyanate dissolved in 100 ml of tetrahydrofuran, dropwise, over 0.5 hr. Throughout the addition and for a further 15 min the temperature of the reaction mixture was held below 15°. After it had been stirred at room temperature for an additional 5 hr, the mixture was diluted with an excess of anhydrous ethyl ether and filtered. The precipitate, washed with anhydrous ether, dried, and crushed into a fine powder, was mixed thoroughly with cold, dilute hydrochloric acid. There

(11) M. Yamaguchi, Y. Mori, and N. Nishimura, *Wakayama Med. Rep.*, **11**, 119 (1966); *Chem. Abstr.*, **68**, 11169*s* (1968).

(12) Consider $\nu_{C=O}^{cm^{-1}}$ (Nujol) values: **3**, 1650; **11**, 1680; phthalamide, 1670; benzoylurea, 1710, 1670; acetylurea, 1710, 1640.

(13) Compare with δ values for NH_2 protons of **3**, 7.3; **11**, 7.6; NH (imide) proton of benzoylurea, 10.6; acetylurea, 10.2.

(14) L. J. Bellamy, "The Infra-red Spectra of Complex Molecules," 2nd ed, Wiley, New York, N. Y., 1958, p 363.

(15) Melting points were determined in a Thomas-Hoover apparatus with use of a calibrated thermometer. A Perkin-Elmer Model 337 infrared spectrophotometer was used to take infrared spectra (in chloroform solution, unless otherwise indicated). Nmr spectra were obtained on a Varian A-60A spectrophotometer using solutions in hexadeuteriodimethyl sulfoxide, unless otherwise specified, with tetramethylsilane as internal standard. Spectral data of model compounds were determined experimentally.

(16) Some variation of melting point was observed depending on solvent of recrystallization, size of crystals, and rate of heating.

resulted 27.9 g (85%) of crude **2**, mp 117–119°, an analytical sample of which (recrystallized from ethanol) melted at 121.5–123°: ir 3450, 1800, 1730, 1495, 1325, 1275, 1155, 1095, 1075, 1020, 960, 900, and 590 cm^{-1}; nmr δ 10.9 (s, 1, NH), 7.6 (t, 2, J = 2 Hz, pyrrolyl CH), 6.3 (t, 2, J = 2 Hz, pyrrolyl CH), 4.3 (q, 2, J = 7 Hz, $-CH_2-$), and 1.3 (t, 3, J = 7 Hz, $-CH_3$).

Anal. Calcd for $C_8H_{10}N_2O_3$: C, 52.74; H, 5.53; N, 15.38. Found: C, 52.84; H, 5.29; N, 15.10.

Pyrrole-2-carboxamide (3). A. By Hydrolysis of 1.—A mixture of 2.0 g of **1**, 1.0 g of sodium hydroxide, and 10 ml of water was heated on the steam bath until a clear solution had been obtained (about 5 min). Upon cooling, there precipitated 0.80 g (66%) of **3**: mp 174–175°, raised to 175–177° by recrystallization from aqueous ethanol (lit.[17] mp 176.5°); ir 3545, 3460, 3425, 1660, 1590, 1420, 1360, 1190, 1115, 1080, and 1040 cm^{-1}; nmr δ 11.5 (s, 1, pyrrolyl NH), 7.3 (s, 2, NH_2), 6.9 (m, 2, CH), and 6.2 (m, 1, CH).

B. By Hydrolysis of 8.—A solution of 0.50 g of **8** in 5 ml of 10% aqueous sodium hydroxide was heated on the steam bath for 15 min. Cooling, followed by filtration, yielded 0.25 g of a solid, mp 172–174°, the ir and nmr spectra of which were identical with those of the product of the previous reaction. Recrystallization from aqueous ethanol raised the melting point to 173.5–175°, and a mixture of the two products melted at 174–175°.

Pyrrole-2-carboxylic Acid (4).—A mixture of 2.0 g of crude **1**, 4.0 g of sodium hydroxide, and 20 ml of water was refluxed for 2 hr and the resulting solution was cooled and washed with ether. Following acidification with cold, dilute hydrochloric acid, the solution was extracted with ether and the extract was treated with charcoal, dried ($MgSO_4$), and evaporated to dryness to yield 0.90 g (74%) of pyrrole-2-carboxylic acid: mp 206–208° dec (lit.[18] mp 207–208°); ir (Nujol) 3370, 1650, 1550, 1320, 1190, 1120, 1035, 950, 885, 755, 690, 600, and 555 cm^{-1}; nmr δ 11.7 (s, 2, NH and COOH) 7.0 (m, 1, CH), 6.9 (m, 1, CH), and 6.3 (m, 1, CH).

Hydrolysis of 2.—A mixture of 2 g of **2**, 4 g of sodium hydroxide, and 20 ml of water was refluxed for 1 hr. Removal of the solvent from an ethereal extract of the resulting solution yielded pyrrole, recognized from its ir spectrum. Careful acidification of the chilled aqueous solution with ice-cold, dilute hydrochloric acid followed by extraction and the usual isolation procedure did not give any other product.

***N*-Phenylcarbamoylpyrrole-2-carboxamide (5). A. From 1.**—A mixture of 1 g of **1** and 5 ml of aniline was boiled for about 1 min. Cooling, then filtration and washing of the precipitate with carbon tetrachloride, yielded 1.1 g (87%) of **5**: mp 254–255°, raised to 257–257.5° by recrystallization from ethanol; ir (Nujol) 3320, 3230, 1700, 1650, 1600, 1550, 1325, 1305, 1250, 1225, 1170, 1125, 890, 835, 760, 740, 690, 595, 575, and 505 cm^{-1}; nmr δ 12.0 (s, 1, pyrrolyl NH), 11.1 (s, 1, NH), 10.7 (s, 1, NH), 7.7–7.2 (m, 7, phenyl and pyrrolyl CH), 6.3 (m, 1, pyrrolyl CH).

Anal. Calcd for $C_{12}H_{11}N_3O_2$: C, 62.87; H, 4.84; N, 18.33. Found: C, 63.17; H, 4.67; N, 18.44.

B. From 8.—Run as above, a reaction of 1 g of **8** with aniline yielded 1.3 g of product, mp 254.5–255°, raised to 257° after recrystallization from ethanol. Comparison of the ir and nmr spectra, as well as a mixture melting point (256.5–257.5°), showed that this compound was the same as the product of the previous reaction.

***N*-Phenylcarbamoylpyrrole-1-carboxamide (6).**—Run as for **5**, a reaction of 1 g of **2** with aniline afforded 1.2 g (95%) of **6**: mp 224–225°, raised to 229–230° by recrystallization from isopropyl alcohol; ir (Nujol) 3250, 1720, 1690, 1600, 1560, 1550, 1500, 1325, 1300, 1250, 1230, 1175, 1070, 960, 885, 750, 735, 690, 585, 575 and 505 cm^{-1}; nmr δ 10.8 (s, 1, NH), 10.3 (s, 1, NH), 7.7–7.2 (m, 7, phenyl and pyrrolyl CH), and 6.4 (m, 2, pyrrolyl CH).

Anal. Calcd for $C_{12}H_{11}N_3O_2$: C, 62.87; H, 4.84; N, 18.33. Found: C, 62.97; H, 4.69; N, 18.36.

***N*-Phenylpyrrole-1,2-dicarboximide (7). A. From 1.**—To 1.8 g (0.010 mol) of finely powdered **1** mixed with 2.4 g (0.020 mol) of phenyl isocyanate was added 3 ml of triethylamine and the resulting mixture was allowed to stand at room temperature for 5 min and on the steam bath for another 5 min, under a calcium chloride tube. Washing of the cooled product with two 25-ml portions of ethanol yielded 1.6 g (76%) of **7**: mp 225–226° (lit.[3] mp 226–227°); ir 1800, 1770, 1750, 1725, 1560, 1495, 1440, 1410, 1370, 1315, 1275, 1145, 1090, 1050, 1005, 835, 630, and 585 cm^{-1}; nmr (CF_3COOH) δ 7.6 (m, 6, phenyl and pyrrolyl CH), 7.1 (d, 1, J = 3 Hz, pyrrolyl CH), and 6.7 (t, 1, J = 3 Hz, pyrrolyl CH).

B. From 13.—A mixture of 1.3 g (0.005 mol) of **13**, 1.2 g (0.010 mol) of phenyl isocyanate, and 2 ml of triethylamine was heated on the steam bath for 22 hr, under a calcium chloride tube, and the product was washed with an excess of ethanol to yield 0.8 g (76%) of **7**, mp 225–227°.

Pyrrole-1,2-dicarboximide (8).—A mixture of 10 g of **1** and 20 ml of dry quinoline was heated in a 125-ml Erlenmeyer flask until the temperature of the escaping vapor reached 170–180°. Treatment of the cooled product with cold, dilute hydrochloric acid, followed by filtration, yielded a solid which was added to an ether extract of the filtrate. The resulting ethereal solution was washed with saturated aqueous sodium chloride, treated with charcoal, dried ($MgSO_4$), and evaporated under reduced pressure to yield 5.4 g (72%) of **8**, mp 206–209°, and 1 g of less pure material, mp 190–200°. Sublimation under vacuum raised the melting point to 209–211° and subsequent recrystallization from ethanol gave pure **8**, pale yellow crystals: mp 210.5–212°; ir 3440, 1795, 1745, 1560, 1445, 1410, 1310, 1150, 1050, 1005, 995, 640, and 585 cm^{-1}; nmr δ 11.2 (s, 1, NH), 7.5 (m, 1, CH), 6.9 (m, 1, CH), and 6.6 (m, 1, CH).

Anal. Calcd for $C_6H_4N_2O_2$: C, 52.94; H, 2.96; N, 20.59. Found: C, 53.21; H, 2.80; N, 20.50.

***N*-Carbamoylpyrrole-2-carboxamide (10). A. From 8.**—A solution of 0.40 g of **8** in a mixture of 1.0 ml of concentrated aqueous ammonia and 1.0 ml of ethanol was allowed to stand at room temperature for 3 hr. Filtration yielded 0.30 g (67%) of **10**, mp 236–237°.

Similarly, from 0.50 g of **8** and 5 ml of concentrated aqueous ammonia, there was obtained 0.40 g (71%) of **10**, mp 237–238°.

Recrystallization from ethyl alcohol gave the pure compound: mp 240–241°; ir (Nujol) 3390, 3345, 3200, 1710, 1660, 1580, 1550, 1320, 1170, 1140, 1085, 1050, 1045, 890, 850, 785, 750, 610, 575, 540, and 445 cm^{-1}; nmr δ 11.8 (s, 1, pyrrolyl NH), 10.2 (s, 1, imide NH), 8.1–7.1 (broad, ill-formed doublet, partly overlapping with two multiplets, 4, NH_2 and CH), and 6.2 (m, 1, CH).

Anal. Calcd for $C_6H_7N_3O_2$: C, 47.06; H, 4.61; N, 27.44. Found: C, 47.03; H, 4.83; N, 27.38.

B. From 1.—A solution of 0.50 g of **1** in 10 ml of concentrated aqueous ammonia was allowed to stand at room temperature for 8 hr. Dilution with water and filtration yielded 0.25 g of a solid, mp 237–238°, raised to 240–241° by recrystallization from ethanol. Examination of the ir and nmr spectra and a mixture melting point determination showed that this compound was **10**.

Similarly, 0.6 g of **10** was obtained upon cooling of the solution formed when a mixture of 1 g of **1** and 10 ml of concentrated aqueous ammonia, contained in a pressure bottle, was heated on the steam bath for a few minutes.

Pyrrole-1-carboxamide (11).—A mixture of 2 g of **2** and 10 ml of concentrated aqueous ammonia was placed in a pressure bottle and heated on the steam bath for 1 hr. Upon cooling, there precipitated 0.8 g of crude **11**: mp 148–156°, raised to 163–165° by recrystallization from aqueous ethanol (lit.[19] mp 165–166); ir 3540, 3430, 1720, 1585, 1470, 1410, 1375, 1200, 1100, 1080, 1070, and 940 cm^{-1}; nmr δ 7.6 (s, 2, NH_2), 7.4 (t, 2, J = 2 Hz, CH), and 6.3 (t, 2, J = 2 Hz, CH).

***N*-Tosylpyrrole-1,2-dicarboximide (12),**—To a solution of 2.7 g (0.020 mol) of **8** in 25 ml of tetrahydrofuran was added 0.9 g of sodium hydride emulsion in mineral oil (57%) and the resulting mixture was stirred under nitrogen, at room temperature, for 2 hr. After dilution with 15 ml of solvent and dropwise addition (30 min) of 3.4 g (0.018 mol) of tosyl chloride dissolved in 50 ml of tetrahydrofuran, the reaction mixture was stirred at room temperature for a further 21 hr. Addition of 300 ml of dry ether followed by filtration yielded a solution which was washed with cold water, treated with charcoal, dried ($MgSO_4$), and evaporated to small volume under reduced pressure. Upon chilling, the residual solution yielded 2.4 g of **12**, mp 182–183°. Evaporation of the mother liquor to dryness and recrystallization of the residue from toluene afforded an additional 0.30 g (total yield 52%), mp 178–182°. An analytical sample of **12** (from toluene) melted at 183.5–184.5°: ir 1820, 1800, 1770, 1600, 1560, 1450,

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1400, 1290, 1180, 1145, 1095, 1030, 1005, 920, 585, 565, and 545 cm^{-1}; nmr δ 8.0 (d, 2, J = 8 Hz, phenyl CH), 7.8 (d, 1, J = 3 Hz, pyrrolyl CH), 7.6 (d, 2, J = 8 Hz, phenyl CH), 7.2 (d, 1, J = 3 Hz, pyrrolyl CH), 6.7 (t, 1, J = 3 Hz, pyrrolyl CH), and 2.5 (s, 3, $-CH_3$).

Anal. Calcd for $C_{13}H_{10}N_2O_4S$: C, 53.78; H, 3.47; N, 9.65. Found: C, 53.62; H, 3.52; N, 9.50.

***N*-Tosylpyrrole-2-carboxamide (13).**—Brief (2–3 min) heating on the steam bath of a mixture of 1 g of **12** with 10 ml of 10% aqueous sodium hydroxide yielded a solution which was filtered cooled, and acidified with dilute hydrochloric acid. There precipitated 0.85 g of **13**: mp 214–218, raised to 224–225° by recrystallization from ethanol; ir (Nujol) 3300, 3275, 1675, 1590, 1550, 1350, 1300, 1190, 1175, 1145, 1120, 1090, 1070, 950, 875, 810, 740, 660, 605, 570, and 540 cm^{-1}; nmr δ 12.0 (s, 1, NH), 11.8 (s, 1, NH), 8.0 (d, 2, J = 8 Hz, phenyl CH), 7.5 (d, 2, J = 8 Hz, phenyl CH), 7.3 (m, 1, pyrrolyl CH), 7.1 (m, 1, pyrrolyl CH), 6.2 (m, 1, pyrrolyl CH), and 2.4 (s, 3, $-CH_3$). The above spectra were identical with the corresponding spectra of the product of the reaction of pyrrole with tosyl isocyanate in dioxane [mp 224–226° (lit.[5] mp 222–224°), mmp 224–226°].

Registry No.—**1**, 32846-52-9; **2**, 32846-53-0; **3**, 4551-72-8; **4**, 634-97-9; **5**, 32846-56-3; **6**, 32846-57-4; **7**, 4778-77-2; **8**, 13939-91-8; **10**, 32846-60-9; **11**, 21972-99-6; **12**, 32846-62-1; **13**, 32846-63-2.

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6,11-Dihydroacridizinium Derivatives Having a 6,11-Etheno Bridge[1]

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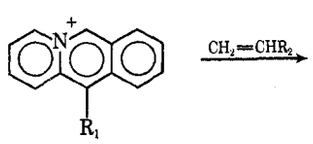
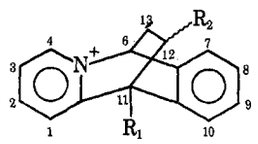
Ethano-bridged derivatives may be made by addition of vinyl alcohol or amine derivatives to the acridizinium ion, but no means has been found for converting these to etheno-bridged derivatives. Etheno-bridged derivatives may be prepared by addition of acetylenic compounds to 11-substituted acridizinium ions, but if no substituent is present at position 11 rearrangement occurs, affording derivatives of 1-(2-pyridyl)naphthalene.

Cycloaddition Reactions Using Vinyl Derivatives.—The synthesis of 6,11-dihydroacridizinium compounds having a 6,11-etheno bridge would provide a means for the study of the inductive effect of an adjacent but unconjugated positive charge on the addition reactions of a double bond, as well as an intermediate for the possible synthesis of an azoniajanusene.[2] Our initial plan was to prepare an ethano-bridged compound having a hydroxyl group (or suitable derivative) on the bridge, and to convert this to an etheno-bridged derivative *via* an elimination reaction.

It was found that ethyl vinyl ether, butyl vinyl ether, and vinyl acetate all added to the acridizinium ion in good yield (Table I). As would be expected from the strong polarization of such vinyl derivatives, the orientation in each case was that with the oxy function at position 12. Acid-catalyzed cleavage of the ether or ester linkages gave the same alcohol (**3**, R_1 = H; R_2 = OH). Acetylation of this hydroxyl derivative gave the acetate **7**, identical with that obtained in the cycloaddition reaction with vinyl acetate. It was also possible to convert the hydroxyl compound (**3**, R_1 = H; R_2 = OH) to the tosylate (**3**, R = H; R_2 = Tos) by action of tosyl chloride and pyridine.



1, R_1 = H
2, R_1 = Ph



3

4, R_1 = H; R_2 = OEt
5, R_1 = Ph; R_2 = OEt
6, R_1 = H; R_2 = OBu
7, R_1 = H; R_2 = OAc
8, R_1 = H; R_2 = *N*-carbazyl
9, R_1 = H; R_2 = 1-pyrrolidin-2-one

The alcohol (**3**, R_1 = H; R_2 = OH) was not dehydrated when allowed to stand in concentrated sulfuric acid for 24 hr. The acetate **7** survived heating in a sealed tube at 210°, refluxing for 10 hr in dimethylformamide, or refluxing for 24 hr in pyridine. The tosylate was recovered (95%) after refluxing for 20 hr in pyridine and after refluxing in diglyme (162°) for 11 hr. It also resisted for 86 hr solvolysis in refluxing acetic acid containing sodium acetate.[3]

The addition of *trans*-1,2-dichloroethylene to acridizinium fluoroborate at 130° gave the expected 12,13-dichloro-6,11-dihydro-6,11-ethanoacridizinium fluoroborate. An attempt to remove the chlorine by the action of a zinc–copper couple[4] yielded a substance which was not a quaternary salt.

The addition of *N*-vinylcarbazole and *N*-vinyl-2-pyrrolidone to the acridizinium nucleus occurs quite readily but neither of the resulting bases (**8** or **9**) was suitable for a Cope elimination reaction.

Cycloaddition Reactions Using Acetylenic Derivatives.—Due to the lack of promise shown by these indirect approaches to the synthesis of etheno-bridged compounds, the addition of acetylenic derivatives to the acridizinium nucleus (Table II) was reexamined.

(1) This research was supported by Public Health Service Research Grant No. HE-02170 of the National Heart Institute of the National Institutes of Health.

(2) *Cf.* S. J. Cristol, and D. C. Lewis, *J. Amer. Chem. Soc.*, **89**, 1476 (1967).

(3) On the basis of subsequent experiments (*vide infra*) it would seem probable that decomposition products obtained in these and more drastic elimination attempts may have contained some salts of 1-(2-pyridyl)naphthalene.

(4) *Cf.* S. J. Cristol and W. Y. Lim, *J. Org. Chem.*, **34**, 1 (1969).