

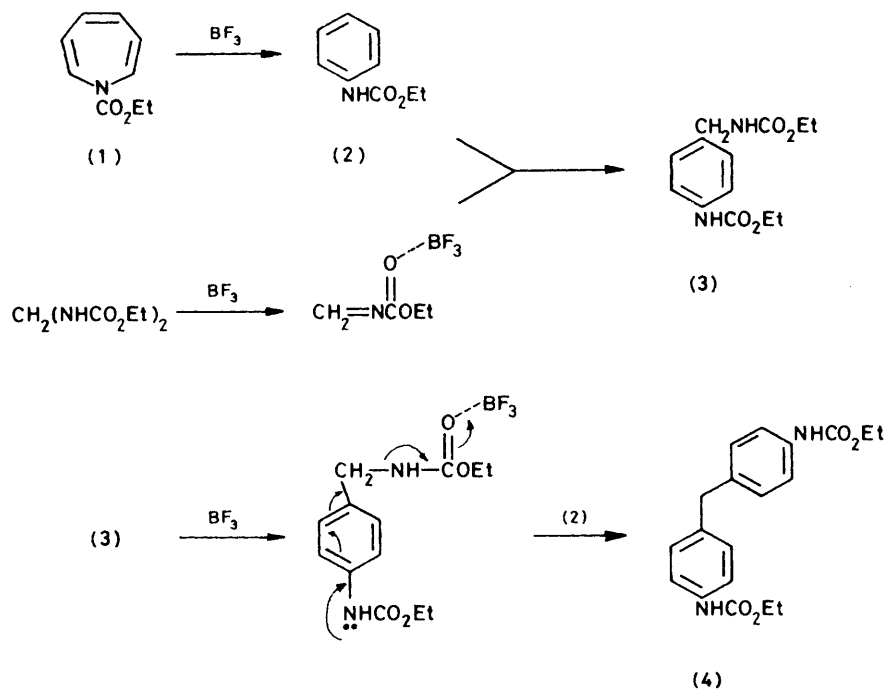
Attempted Cycloaddition of *N*-Ethoxycarbonylmethylenamine to *N*-Ethoxycarbonylazepine: Formation of 4,4'-Bis(ethoxycarbonylamino)-diphenylmethane

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Three products were formed in the boron trifluoride-catalysed reaction of *N*-ethoxycarbonylmethylenamine with *N*-ethoxycarbonylazepine, *N*-ethoxycarbonylaniline (2), 4-(*N*-ethoxycarbonylaminoethyl)-*N*-ethoxycarbonylaniline (3), and 4,4'-bis-(*N*-ethoxycarbonylamino)diphenylmethane (4). Product (4) was independently synthesised. The mechanisms of formation of the products (2), (3), and (4) were established.

Thermal (6 + 2) cycloaddition reactions are uncommon, though permitted by either a ($\pi_{6a} + \pi_{2s}$) or ($\pi_{6s} + \pi_{2a}$) pathway.¹ Both cycloheptatriene² and *N*-ethoxycarbonylazepine³ (1) undergo a formal (6 + 2) cycloaddition reaction with nitrosobenzene. Since Krow and co-workers⁴ noted that *N*-ethoxycarbonylmethylenamine (NEM) ($\text{CH}_2=\text{NCO}_2\text{Et}$) undergoes a (6 + 2)

were formed (Scheme) together with the dimer of (1) (see Experimental section). *N*-Ethoxycarbonylaniline (2) was readily identified and the assignment confirmed by comparison with an authentic sample. The second product had spectra consistent with structure (3). In addition (3) was readily hydrogenated to a hexahydro-derivative. The spectral properties of the latter, which



SCHEME

cycloaddition to cycloheptatriene, albeit in a step-wise manner, we undertook an investigation of the reaction of NEM with (1).

RESULTS AND DISCUSSION

It has been established that NEM is formed by the boron trifluoride-catalysed fragmentation of bis-(*N*-ethoxycarbonylamino)methane.⁴ Accordingly (1) was heated in benzene with bis-(*N*-ethoxycarbonylamino)methane and boron trifluoride-ether. No cycloadducts were detected. The three products (2), (3), and (4) only

included a u.v. difference spectrum [λ_{max} , 250 nm (ϵ 7 839)], were consistent with a structure derived from (3). The structure (4) was indicated by its spectra, and was confirmed by synthesis from diphenylmethane. Diphenylmethane was nitrated, reduced to the 4,4'-diamine,⁵ and converted to the bis-(*N*-ethoxycarbonyl)-derivative by reaction with ethyl chloroformate.⁶ This product was identical with compound (4).

The modes of formation of (2)—(4) were investigated. Treatment of (1) with boron trifluoride-ether in benzene effected rapid and quantitative rearrangement (<5 min)

into (2) at room temperature. Although mineral acid is known⁷ to induce this rearrangement, boron trifluoride catalysis has not been noted hitherto. The rapidity of this rearrangement explains the absence of cycloaddition products. Cycloaddition reactions of (1) are generally slow.^{3,8} It seemed probable, then, that the formation of the products (3) and (4) involved (2). Accordingly when (2) was heated with boron trifluoride-ether in either benzene or chloroform with bis-(*N*-ethoxycarbonylamino)methane, (3) and (4) were formed exclusively. In addition, it was noted that, by following the reaction by t.l.c., (3) was formed first, followed slowly by (4). This indicated that boron trifluoride catalysed a reaction of (2) with (3). When, therefore, an equimolar solution of (2) and (3) in either benzene or chloroform was refluxed for 24 h in the presence of boron trifluoride-ether, the diphenylmethane (4) was the only product. No reaction occurred in the absence of boron trifluoride.

On this basis we suggest the mechanism outlined in the Scheme. The mode of fragmentation of bis-(*N*-ethoxycarbonylamino)methane is well established and the boron trifluoride-catalysed cleavage of (3) is formally related. However, this fragmentation may require a suitably oriented activating ring-substituent to be effective.

EXPERIMENTAL

Microanalyses were performed in this Department. Spectra were recorded with a Perkin-Elmer 257 i.r. spectrophotometer for KBr discs, a Unicam SP 800 u.v. spectrophotometer for solutions in ethanol, a Perkin-Elmer R20A 60-MHz ¹H n.m.r. spectrometer, a JEOL FX60 ¹³C n.m.r. spectrometer, and an A.E.I. MS 902 mass spectrometer. T.l.c. involved the use of Merck silica gel HF₂₅₄ plates. For preparative t.l.c., Merck Kieselgel PF₂₅₄ was used. The eluant in both cases was ethyl acetate-light petroleum (30 : 70). The u.v. extinction coefficient (ϵ) is expressed in mol⁻¹ l cm⁻¹ units.

Boron Trifluoride-catalysed Reaction of (1) with Bis-(*N*-ethoxycarbonylamino)methane.—A solution of (1) (0.825 g, 0.005 mol), bis-(*N*-ethoxycarbonylamino)methane (0.95 g, 0.005 mol), and freshly distilled boron trifluoride-ether (0.5 ml) in dried benzene (30 ml) was refluxed until no further change was apparent (t.l.c., 24 h). The solution was cooled, washed with water, 5% sodium hydrogencarbonate, dilute hydrochloric acid, and water, and dried with magnesium sulphate. The solvent was removed to give a pale yellow solid (1.35 g) which consisted (t.l.c.) of four compounds, three of which were isolated by preparative t.l.c.; the fourth had the same R_F (0.01) as the dimer⁹ of (1) and was not isolated.

The first component was 4-(*N*-ethoxycarbonylamino-methyl)-*N*-ethoxycarbonylaniline (3) (0.3 g, 22%), m.p. 101—102 °C, R_F 0.14 (Found: C, 58.7; H, 7.0; N, 10.6. C₁₃H₁₈N₂O₄ requires C, 58.6; H, 6.8; N, 10.5%); ν_{\max} 3 322, 2 980, 1 690, and 1 595 cm⁻¹; λ_{\max} 212 (ϵ 1 957) and 248 nm (8 370); τ 2.60—3.04 (4 H, q, A₂B₂, J 8 Hz, Ph), 3.15 (1 H, br s, NH, disappeared with D₂O), 5.0 (1 H, br s, NH), 5.83 (2 H, d, J 7 Hz, CH₂), 5.70—6.15 (4 H, 2 \times q, J 7.5 Hz, 2 \times OCH₂), and 8.62—8.92 (6 H, 2 \times t, J 7.5 Hz, 2 \times Me); δ_C 14.61 (q, 2 \times Me), 44.63 (t, OCH₂), 61.20 (t, OCH₂), 119.03 (d, Ph), 128.29 (d, Ph), 133.58 (s, Ph), 137.48 (s, Ph),

153.79 (s, C=O), and 156.77 (s, C=O); m/e 266 (M^+). Product (3) (0.4 g, 0.0015 mol) was hydrogenated with PtO₂ (0.1 g) at 50 lb in⁻² for 120 h. Filtration and evaporation of the solvent afforded the hexahydro-derivative (0.39 g, 80%), m.p. 108—110 °C (Found: C, 57.7; H, 8.7; N, 9.9. C₁₃H₂₄N₂O₄ requires C, 57.3; H, 8.9; N, 10.3%); ν_{\max} 3 310, 2 910, 1 680, and 1 540 cm⁻¹; λ_{\max} 224 nm (ϵ 2 160); τ 5.35 (2 H, br s, 2 \times NH), 6.00 (4 H, q, J 7.5 Hz, 2 \times OCH₂), 7.00 (2 H, br s, CH₂N), 8.00—8.60 (10 H, m, 4 \times CH₂ + 2 \times CH), and 8.20 (6 H, J 7.5 Hz, 2 \times Me); m/e 272 (M^+).

The second component was 4,4'-bis-(*N*-ethoxycarbonylamino)diphenylmethane (4) (0.08 g, 6%), m.p. 133—134 °C, R_F 0.22 (Found: C, 66.35; H, 6.6; N, 7.8. C₁₉H₂₂N₂O₄ requires C, 66.66; H, 6.43; N, 8.20%); ν_{\max} 3 300, 3 030, 2 910, 1 690, and 1 590; λ_{\max} 255 (ϵ 1 172), 278 (157), and 290sh nm (98); τ 2.95 (8 H, q, Ph), 3.45 (2 H, br s, 2 \times NH), 5.90 (4 H, q, J 7.5 Hz, 2 \times OCH₂), 6.21 (2 H, s, CH₂), and 8.75 (6 H, t, J 7.5 Hz, 2 \times Me); m/e 342 (M^+). Product (4) (0.06 g) was hydrogenated in methanol (25 ml) with PtO₂ (0.01 g) for 100 h at 50 lb in⁻² and room temperature. The perhydro-product (0.05 g, 83%), m.p. 118—120 °C was isolated (Found: C, 64.5; H, 9.85; N, 7.8. C₁₉H₃₄N₂O₄ requires C, 64.40; H, 9.70; N, 7.90%); ν_{\max} 3 300, 2 910, 1 720, and 1 650br cm⁻¹; τ 5.30 (2 H, s, 2 \times NH), 5.95 (4 H, q, 2 \times CH₂), 6.30 (2 H, s, CH₂), 7.75—8.60 (20 H, m, 8 \times CH₂ + 4 \times CH), and 8.80 (6 H, t, J 8 Hz, 2 \times Me); m/e 354 (M^+). Product (4) was identical (m.p., mixed m.p., ¹H n.m.r.) with a sample prepared from 4,4'-diaminodiphenylmethane⁵ by treatment with ethyl chloroformate in the presence of aqueous sodium hydroxide.⁶

The third product (2) (0.10 g, 8%), m.p. 53—54 °C, mixed m.p. 53—54 °C (lit.¹⁰ 53 °C), R_F 0.33, was identified as *N*-ethoxycarbonylaniline (Found: C, 65.2; H, 7.0; N, 7.4. Calc. for C₉H₁₁NO₂: C, 65.4; H, 6.7; N, 8.5%).

Boron Trifluoride-catalysed Reaction of *N*-Ethoxycarbonylaniline (2) with Bis-(*N*-ethoxycarbonylamino)methane.—A solution of aniline (2) (0.5 g, 0.003 mol) was treated in the same manner as (1). The same work-up and separation by preparative t.l.c. afforded (2) (0.28 g, 35%), (3) (0.4 g, 50%), and (4) (0.105 g, 13%). No other products were formed.

Boron Trifluoride-catalysed Reaction of *N*-Ethoxycarbonylaniline (2) with 4-(*N*-ethoxycarbonylaminoethyl)-*N*-ethoxycarbonylaniline (3).—A solution of (2) (0.025 g), (3) (0.04 g), and boron trifluoride-ether (0.3 ml) in benzene (7 ml) was heated under reflux 24 h. The usual work-up provided exclusively (4) (0.048 g, 94%).

[0/675 Received, 8th May, 1980]

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