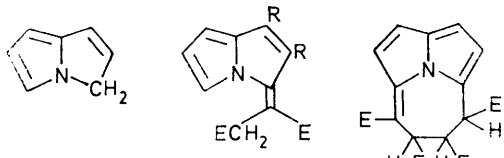
Reaction between 3*H*-Pyrrolizines and Acetylenedicarboxylic Esters. Part III.[1] The Photochemical Reaction

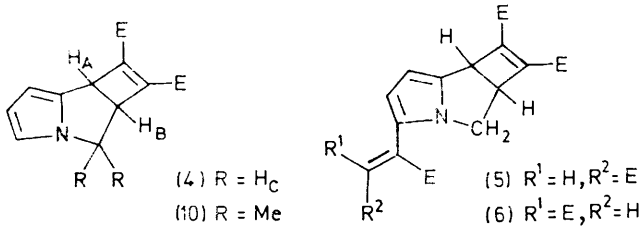
By **D. Johnson** and **Gurnos Jones,*** Department of Chemistry, University of Keele, Keele, Staffordshire ST5 5BG

The photochemical addition of dimethyl acetylenedicarboxylate to 3*H*-pyrrolizine (1) and to 3,3-dimethyl-3*H*-pyrrolizine (7) gave low yields of 7-azatricyclo[5,3,0,$0^{2,5}$]decatriene-3,4-dicarboxylates (4) and (10). The former reaction also gave the 8-maleate and 8-fumarate derivatives (5) and (6). Thermal ring opening of compound (10) gave dimethyl 5,5-dimethyl-5*H*-pyrrolo[1,2-*a*]azepine-7,8-dicarboxylate (11); photochemical reaction gave a dimer (13). Attempts to prepare 5-methyl-3*H*-pyrrolizine (14) gave a mixture containing a 1*H*-pyrrolizine (16): reaction of 3-ethoxycarbonylmethylene-3*H*-pyrrolizine (23) with dimethyl acetylenedicarboxylate gave the cycl[3,2.2]azine (pyrrolo[2,1.5-*cd*]indolizine) triester (25).

In Parts I and II we described reactions between 3*H*-pyrrolizines and acetylenedicarboxylates, giving 1 : 1 and 1 : 2 adducts. The original aim of the synthesis was to produce systems which could, by valence isomerisation, give aza-azulenes. The present paper gives details of partial success in this objective, by a photochemical [$_\pi$2 + $_\pi$2] addition reaction.



(1) (2) a; R = H, b; R = Me (3)



(4) R = H_C (10) R = Me (5) R^1 = H, R^2 = E (6) R^1 = E, R^2 = H

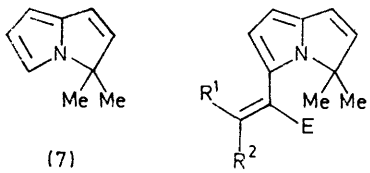
Throughout the paper E = CO_2Me

On the parent 3*H*-pyrrolizine system (1) the non-photochemical reaction[1,2] was too rapid for the satisfactory isolation of photochemical products when irradiation through quartz (unsensitised) was used. With acetophenone as sensitiser, and a Pyrex filter, irradiation of a mixture of 3*H*-pyrrolizine and dimethyl acetylenedicarboxylate (DMAD) (1 : 10) in benzene gave variable yields of five products. In a typical experiment the major product (42%) was the previously reported 1 : 1 adduct (2a),[2] with a smaller amount (8%) of the 1 : 2 adduct (3).[1] The other products were a new 1 : 1 (pyrrolizine–DMAD) adduct and two new 1 : 2 adducts, all of which were shown by their spectral data to be the products of a [$_\pi$2 + $_\pi$2] addition. The 1 : 1 adduct (5%) showed no u.v. maxima at wavelengths greater than 230 nm (the thermal adducts are orange), and its n.m.r. spectrum left no doubt that the compound was an azatricyclo[5,3,0,$0^{2,5}$]decatriene-3,4-dicarboxylate (4) [δ 5·8, 6·01, and 6·35 (pyrrole protons) and 4·1 p.p.m. (4H, m, H_A, H_B, and H_C)]. The 1 : 2 adducts were very similar in their n.m.r. absorption pattern to the 1 : 1 adduct (4); the most noteworthy difference was the presence of only two pyrrole protons (the α-proton signal was absent) and the presence of a sharp singlet (1H) at δ 5·88 in one isomer and at δ 6·61 p.p.m. in the other. These signals are those found previously for maleates and fumarates respectively, and lead to the formulae (5) (14%) and (6) (3%) for the isomeric 1 : 2 adducts. Since the monoadduct (2) was inert to photochemical addition, we presume that the photoproduct is formed first and reacts further

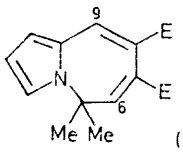
[1] Part II, D. Johnson and G. Jones, *J.C.S. Perkin I*, 1972, 844.

[2] D. Johnson and G. Jones, *J.C.S. Perkin I*, 1972, 840.

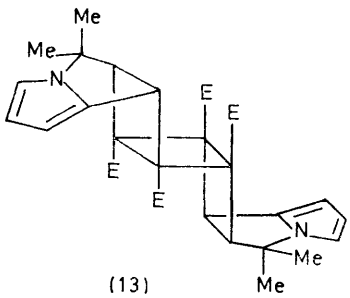
with DMAD in a normal pyrrolic electrophilic substitution, producing first compound (5) and then compound (6).



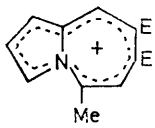
(7) (8) $R^1 = E, R^2 = H$ (9) $R^1 = H, R^2 = E$



(11)



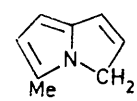
(13)



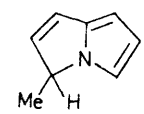
(12)

The quantity of photoproduct (4) available was small, so two further 3*H*-pyrrolizines were examined. The known[3] 3,3-dimethyl-3*H*-pyrrolizine (7) was heated with DMAD; it reacted very slowly in hydrocarbon solvents, probably because of steric hindrance to electrophilic attack at position 5. From a methanolic solution it was possible to obtain (22 h boiling) a mixture of the fumarate (8) (26%) and the maleate (9) (5%). The thermal reaction in hydrocarbon solvents was so slow that the photochemical addition could compete successfully, and from the irradiation of a benzene solution of the pyrrolizine (7) and DMAD a 26% yield of the 1 : 1 photoadduct (10) was obtained. The n.m.r. spectrum of the adduct (10) was similar to that of adduct (4). One signal due to the cyclobutene hydrogen atoms was visible at δ 4·15 p.p.m. (*J* 5 Hz), the other being masked by the methyl signals due to the ester groups; the two methyl groups at position 2 were observed as separate singlets at δ 1·40 and 1·48 p.p.m. A similar adduct from methoxyindene and DMAD has been shown[4] to open thermally and photochemically to give a benzocycloheptatriene. The azatricyclo-derivative (10), heated at 180—200° for 1·5 h, gave the aza-azulene (11) (61%). The aza-azulene (11) was pale yellow ($\lambda_{max.}$ 366 nm) and showed n.m.r. signals δ 6·22, 6·71, and 6·88 (three pyrrole protons), 1·61 (s, 2 × Me), 6·34(s), and 7·71(s) p.p.m. (H-6 and H-9). The mass spectrum showed the base peak at *m/e* 260 ($M^+ - 15$), corresponding to the stable azonia-azulenium ion (12). Although no aza-azulene was present in the original photoaddition mixture, the compound (10) was submitted to irradiation in a cyclohexane solution (13 h); no ring opening occurred, the only product isolated being shown by mass spectroscopy to be a dimer. If one assumes the usual arrangement for such a dimerisation a plausible structure would be (13); the n.m.r. spectrum showed the presence of two pairs of non-equivalent ester groups and two pairs of non-equivalent C–Me groups. The aza-azulene (11) was unstable, reverting to the tricyclic compound (10).

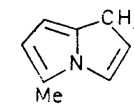
An obvious candidate for an improved yield of photochemical adduct would be 5-methyl-3*H*-pyrrolizine (14), in which electrophilic attack at position 5 would be completely suppressed. When 5-methylpyrrole-2-carbaldehyde was treated with vinyltriphenylphosphonium bromide and sodium hydride, a mixture of three products was obtained, in a ratio of 10 : 46 : 44. All three products showed an *m/e* value of 119 (obtained on a linked g.l.c.–mass spectrometer system), and were therefore methylpyrrolizines. Of the four possibilities (14)—(17), only one, 3-methyl-3*H*-pyrrolizine (15)



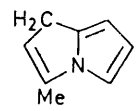
(14)



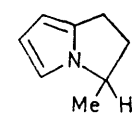
(15)



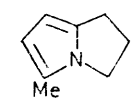
(16)



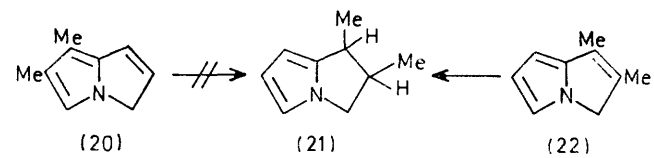
(17)



(18)



(19)



(20) (21) (22)

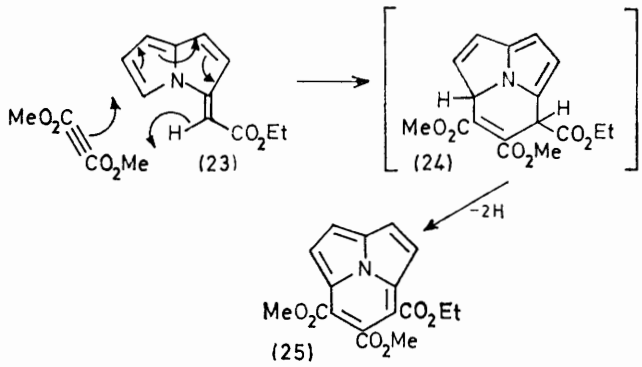
has a methyl group attached to an sp^3 carbon atom; a signal in the n.m.r. spectrum of the mixture at δ 1·29 p.p.m. (d, *J* 6 Hz) could be assigned to the methyl group of compound (15) and integration showed it to represent *ca.* 10% of the total mixture. The n.m.r. spectrum also showed two signals, at δ 3·13 and 4·02 p.p.m., which could be assigned to methylene protons; since the 3*H*-pyrrolizine methylene absorption is normally at δ 4·0 p.p.m. we can assume that one of the products is the anticipated 5-methyl-3*H*-pyrrolizine (14), and the third product is then a 1*H*-pyrrolizine. Hydrogenation of the mixed pyrrolizines gave a two-component mixture (*ca.* 1 : 1 by g.l.c.). The hydrogenation products were separated by preparative g.l.c.; their n.m.r. spectra showed that they were 2,3-dihydro-3-methyl-1*H*-pyrrolizine (18) and 2,3-dihydro-5-methyl-1*H*-pyrrolizine (19). The approximately equal proportions of compounds (18) and (19) obtained from the pyrrolizine mixture prove that the third component was 3-methyl-1*H*-pyrrolizine (17) [hydrogenation of a mixture of (14), (15), and (16) in the proportions 45 : 10 : 45 would

[3] E. E. Schweizer and K. K. Light, *J. Org. Chem.*, 1966, **31**, 2912.
[4] T. W. Doyle, *Canad. J. Chem.*, 1970, **48**, 1629.

have given a ratio of hydrogenated derivatives (18) and (19) of 90 : 10]. This appears to be the first example of a 1*H*-pyrrolizine yet reported. Schweizer and Light [3] probably obtained the same mixture in their attempts to synthesise 3-methyl-3*H*-pyrrolizine from allyltriphenylphosphonium bromide and pyrrole-2-carbaldehyde. The evident ease of interconversion of the various pyrrolizines under basic conditions (shown also in our deuteriation experiments [2]) caused us to re-examine our supposed 6,7-dimethyl-3*H*-pyrrolizine (20). The dimethylpyrrolizine showed only a single peak on g.l.c. and gave a single product on hydrogenation. However, this hydrogenation product was clearly 1,2-dimethyl-2,3-dihydro-1*H*-pyrrolizine (21), since the shifts of the two methyl signals in the n.m.r. spectrum indicated that they were attached to sp^3 carbon atoms, and hence our original compound was 1,2-dimethyl-3*H*-pyrrolizine (22). Our suggested mechanism for the formation of the 1 : 1 thermal adducts must still be correct because of the deuteriation experiments (Part I), but the isolation of the adduct (2b) from what is now shown to be 1,2-dimethyl-3*H*-pyrrolizine (22) indicates that isomerisation of the pyrrolizine must be possible under the conditions of the thermal reaction. There are now a number of reports of the isolation of unexpected isomers in the base-catalysed pyrrolizine syntheses. The thermodynamically favoured products (since all are made under equilibrium conditions) so far isolated are the 6-alkoxycarbonyl- [5,6] and 7-ethoxycarbonyl-3*H*-pyrrolizines,[7] and a mixture of 2- and 6-benzoyl-3*H*-pyrrolizines [6] (all from synthetic procedures which should have produced pyrrolizines substituted in positions 1 or 2), but there appears as yet to be no obvious explanation of the isomer distribution.

Attempted reactions between 3*H*-pyrrolizine and acetylenes other than acetylenedicarboxylates were unsuccessful. Under all photochemical and thermal conditions used there was no reaction between 3*H*-pyrrolizine and methyl propiolate or diphenylacetylene. With dicyanoacetylene, 3*H*-pyrrolizine reacted without irradiation to give a low yield of an unstable 1 : 1 adduct (mass spectrum) too insoluble for a satisfactory n.m.r. spectrum to be obtained.

Since the publication of Part I, we have prepared the 3-ethoxycarbonylmethylene-3*H*-pyrrolizine (23) reported by Flitsch [8] and treated it with dimethyl acetylenedicarboxylate. As anticipated, it is intermediate in reactivity between 3-diphenylmethylene-3*H*-pyrrolizine and our adduct (2a); the monoester (23) reacted slowly to give a mixture of products from which we isolated in 12% yield the cycl[3,2,2]azine (2b). The anticipated product would be a dihydrocyclazine (24) but the aromatic delocalisation energy associated with the peripheral π-electron system of the cyclazine probably provides the driving force for a disproportionation; the yield of cyclazine would probably be improved by the addition of palladium–charcoal during the thermal addition.



The cyclazine (25) showed four downfield proton absorptions in the n.m.r. spectrum (δ 7·58—7·80 p.p.m.) in keeping with the increased delocalisation, and the spectroscopic evidence was in good agreement with that reported for other cycl[3,2,2]azine esters.[9]

EXPERIMENTAL

M.p.s were determined on a Kofler hot-stage apparatus. Column chromatography was performed on Woelm alumina, activity III. Preparative layer chromatography (p.l.c.) was performed on 40 cm plates coated with Merck Silica Gel PF_{254}. Analytical g.l.c. was performed on a Pye series 104 instrument (1·5 m × 4 mm glass column packed with 3% OV101 on Chromosorb W) and preparative g.l.c. on a Pye series 105 Automatic Preparative Chromatograph (5 m × 1 cm column, packed with 15% SE30 on Chromosorb W). Photochemical reactions were carried out under an atmosphere of nitrogen, with a Hanovia medium-pressure mercury lamp. All n.m.r. shifts are in p.p.m. from internal tetramethylsilane; u.v. spectra were determined for solutions in 95% ethanol.

Photochemical Reaction between 3H-*Pyrrolizine* (1) *and DMAD.*—A solution of 3*H*-pyrrolizine [10] (1) (550 mg), acetophenone (1 g), and DMAD (7·1 g) in benzene (1 l) was purged with nitrogen and then irradiated (Pyrex, 7 h). Evaporation left a brown oil, which was chromatographed on alumina (300 g). The fractions eluted were (*a*) acetophenone (petroleum–toluene, 9 : 1), (*b*) compound (2) (638 mg; petroleum–toluene, 1 : 1), (*c*) compound (4) (274 mg; toluene), (*d*) compound (3) (153 mg; toluene), (*e*) compounds (5) and (6) (295 mg; toluene). Fraction (*c*) was purified by p.l.c. (ether–petroleum, 35 : 65) to give *dimethyl 7-azatricyclo*[5,3,0,$0^{2,5}$]*deca*-1(10),3,8-*triene*-3,4-*dicarboxylate* (4) as a yellow gum (60 mg, 5%) (Found: C, 63·2; H, 5·7; N, 5·2. $C_{13}H_{13}NO_4$ requires C, 63·15; H, 5·3; N, 5·65%), $\lambda_{max.}$ 219 nm (log ε 4·11); $\nu_{max.}$ ($CHCl_3$) 1710 cm^{-1}; δ (CCl_4) 3·73 (6H, s, $O{\cdot}CH_3$), 4·1br (4H, CH_2 + cyclobutene H), 5·8 (1H, d, *J* 3 Hz), 6·01 (1H, t, *J* 3 Hz), and 6·35 p.p.m. (1H, m); *m/e* 247 (M^+, 39%), 216 (16),

[5] V. Carelli, M. Cardellini, and F. Morlacchi, *Ann. Chim. (Italy)*, 1963, **53**, 309.
[6] W. Flitsch and R. Heidhues, *Chem. Ber.*, 1968, **101**, 3843.
[7] S. Brandänge and C. Lundin, *Acta Chem. Scand.*, 1971, **25**, 2447.
[8] W. Flitsch, personal communication.
[9] A. Galbraith, T. Small, R. A. Barnes, and V. Boekelheide, *J. Amer. Chem. Soc.*, 1961, **83**, 453; M. A. Jessep and D. Leaver, *Chem. Comm.*, 1970, 790.
[10] E. E. Schweizer and K. K. Light, *J. Amer. Chem. Soc.*, 1964, **86**, 2963.

188 (53), 143 (50), 129 (30), 115 (66), and 105 (100). Fraction (*e*) on p.l.c. (petroleum–ether, 2 : 3) gave two main products. *Dimethyl* 3,4-*bismethoxycarbonyl*-7-*azatricyclo*[5,3,0,$0^{2,5}$]*deca*-1(10)3,8-*triene*-8-*maleate* (5), m.p. 155—160° (from carbon tetrachloride–petroleum), was obtained in yields of up to 14% (Found: C, 58·6; H, 4·7; N, 3·7. $C_{19}H_{19}NO_8$ requires C, 58·6; H, 4·9; N, 3·6%), $\lambda_{max.}$ 221 and 341 nm (log ε 4·15 and 4·30); $\nu_{max.}$ ($CHCl_3$) 1700, 1710, and 1725 cm^{-1}; δ ($CDCl_3$) 3·4—4·1 (12H, m, $O{\cdot}CH_3$), 4·2br (4H, CH_2 + cyclobutene H), 5·88 (1H, s, maleate H), 6·12 (1H, d, *J* 4 Hz), and 6·43 p.p.m. (1H, d, *J* 4 Hz); *m/e* 389 (M^+, 100%), 357 (67), 342 (79), 330 (55), 298 (30), 270 (68), 247 (17), 215 (68), and 187 (53). The 8-*fumarate* (6), was obtained as a red oil, in a maximum yield of 3%, and proved too unstable for analysis; *m/e* 389 (M^+, 70%), 357 (52), 342 (57), 330 (61), 298 (37), 270 (61), 247 (52), 215 (100), and 187 (65); $\nu_{max.}$ ($CHCl_3$) 1710 cm^{-1}; δ (CCl_4) 3·5—4·4 (16H, m, $O{\cdot}CH_3$, CH_2, and cyclobutene H), 5·93 (1H, d, *J* 4 Hz), 6·3 (1H, d, *J* 4 Hz), and 6·1 p.p.m. (1H, s, fumarate H).

Dimethyl 3,3-*Dimethyl*-3H-*pyrrolizin*-5-*yl*-*fumarate* (8) *and maleate* (9).—(*a*) A solution of 3,3-dimethyl-3*H*-pyrrolizine [3] (7) (800 mg) and DMAD (850 mg) in methanol (100 ml) was boiled for 22 h. Evaporation left a red oil, which was chromatographed on alumina (75 g). The following fractions were eluted: (i) 3,3-dimethyl-3*H*-pyrrolizine (20 mg; petroleum–toluene, 9 : 1), (ii) crude fumarate (8) [461 mg; petroleum–toluene (4 : 1) and toluene (early fractions)], (ii) crude maleate (9) (235 mg; toluene, later fractions). Fraction (ii) was purified by p.l.c. (ether–petroleum, 1 : 1) to give the *fumarate* (8) as a red oil (423 mg, 26%) (Found: C, 65·6; H, 6·6; N, 5·1. $C_{15}H_{17}NO_4$ requires C, 65·4; H, 6·25; N, 5·1%); $\lambda_{max.}$ 209, 287·5, and 391 nm (log ε 4·19, 3·88, and 3·25); $\nu_{max.}$ ($CHCl_3$) 1710 cm^{-1}; δ (CCl_4) 1·31 (6H, s, CMe_2), 3·50 (3H, s, $O{\cdot}CH_3$), 3·65 (3H, s, $O{\cdot}CH_3$), 5·74 (1H, d, *J* 4 Hz, H-6), 6·0 (2H, m), 6·38 (1H, d, *J* 6 Hz, H-1), and 6·87 p.p.m. (1H, s, fumarate); *m/e* 275 (M^+, 48%), 260 (10), 243 (16), 215 (64), 200 (55), 184 (26), 156 (100), and 141 (64). Fraction (iii) was purified by p.l.c. (petroleum–ether, 60 : 40) to give the *maleate* (9), as an unstable yellow oil, isomerising readily to the fumarate (8); *m/e* 275 (M^+, 49%), 260 (12), 243 (16), 215 (65), 200 (64), 184 (26), and 156 (100); δ (CCl_4) 1·65 (6H, s, CMe_2), 3·68 (3H, s, $O{\cdot}CH_3$), 3·80 (3H, s, $O{\cdot}CH_3$), 5·85 (1H, d, *J* 4 Hz), 6·13 (1H, s, maleate H), 6·14 (1H, d, *J* 6 Hz), 6·35 (1H, d, *J* 4 Hz), and 6·35 p.p.m. (1H, d, *J* 6 Hz).

(*b*) The fumarate (8) was obtained from a similar reaction in boiling toluene (56 h).

Photochemical Reaction between 3,3-*Dimethyl*-3H-*pyrrolizine* (7) *and DMAD*.—A solution of the pyrrolizine (7) (665 mg), DMAD (7·1 g), and acetophenone (1·0 g) in benzene (1 l) was irradiated (Pyrex, 7 h). The residual brown oil obtained by evaporation of the benzene was chromatographed on alumina (240 g). The oil was applied to the column [made up with petroleum (b.p. 60—80°)] in a small volume of petroleum–toluene, and eluted with petroleum to remove acetophenone and unchanged pyrrolizine (7). Further elution with petroleum–toluene (1 : 1) gave a yellow solution yielding crude photoproduct. The crude product was further purified by p.l.c. [twice; first with chloroform–benzene (60 : 40), then with ether–petroleum (70 : 30)]. The purified *dimethyl* 6,6-*dimethyl*-7-*azatricyclo*[5,3,0,$0^{2,5}$]*deca*-1(10),3,8-*triene*-3,4-*dicarboxylate* (10) was a yellow gum (363 mg, 26%) (Found: C, 65·6; H, 6·0; N, 4·9. $C_{15}H_{17}NO_4$ requires C, 65·4; H, 6·25; N, 5·1%); $\lambda_{max.}$ 218 nm (log ε 4·22); $\nu_{max.}$ ($CHCl_3$) 1695 cm^{-1}; δ (CCl_4) 1·40 (3H, s), 1·48 (3H, s), 3·7—3·9 (7H, m, $O{\cdot}CH_3$ and cyclobutene), 4·15 (1H, d, *J* 5 Hz), 5·77 (1H, d, *J* 3 Hz), 6·00 (1H, t, *J* 3 Hz), and 6·33 p.p.m. (1H, m); *m/e* 275 (M^+, 48%), 260 (95), 243 (24), 216 (44), 184 (88), 156 (56), 142 (36), and 133 (100).

Dimethyl 5,5-*Dimethyl*-5H-*pyrrolo*[1,2-a]*azepine*-7,8-*dicarboxylate* (11).—A glass tube (5 mm diam.) containing the photoproduct (10) (127 mg) under nitrogen was heated in an oil bath (180—200°; 1·5 h). The cooled tube was crushed and the product extracted with chloroform. The black residue obtained by evaporation of the chloroform solution was purified by p.l.c. (petroleum–ether, 1 : 1). The major bands yielded unchanged photoproduct (10) (27 mg, 21%) and the *pyrrolo*[1,2-a]*azepine* (11) as a yellow oil (77 mg, 61%) (Found: C, 65·4; H, 6·35; N, 4·8. $C_{15}H_{17}NO_4$ requires C, 65·4; H, 6·25; N, 5·1%); $\lambda_{max.}$ 205, 227sh, 247·5, 283, and 366 nm (log ε 4·09, —, 3·76, 3·71, and 4·07); $\nu_{max.}$ ($CHCl_3$) 1705 cm^{-1}; δ (CCl_4) 1·61 (6H, s, CMe_2), 3·64 (3H, s, $O{\cdot}CH_3$), 3·72 (3H, s, $O{\cdot}CH_3$), 6·34 (1H, s, H-6), 6·22 (1H, t, *J* 3 Hz), 6·54 (1H, m), 6·88 (1H, m), and 7·71 p.p.m. (1H, s, H-9); *m/e* 275 (M^+, 45%), 260 (100), 243 (37), 216 (29), 184 (69), 156 (37), and 142 (24).

Photochemical Dimerisation of the Azatricyclodecatriene (10).—A solution of compound (10) (363 mg) in redistilled cyclohexane (1 l) was purged with nitrogen and then irradiated (Pyrex, 13 h). After evaporation of the cyclohexane the product was purified by p.l.c. (petroleum–ether, 1 : 1); the only materials isolated were the starting material (21 mg, 6%) and the *dimer* (13) (55 mg, 15%), m.p. 64—67° [from petroleum (b.p. 40—60°)]; *m/e* 550 (M^+, 46%), 519 (5), 491 (9), 459 (5), 431 (6), 326 (52), 204 (60), and 133 (100); δ (CCl_4) 1·22 (6H, s), 1·46 (6H, s), 3·30 (2H, d, *J* 6 Hz), 3·40 (6H, s, $O{\cdot}CH_3$), 3·55 (2H, d, *J* 6 Hz), 3·8 (6H, s, $O{\cdot}CH_3$), 5·6 (2H, d, *J* 3 Hz), 6·03 (2H, t, *J* 3 Hz), and 6·4 p.p.m. (2H, m); $\nu_{max.}$ ($CHCl_3$) 1720 cm^{-1}; $\lambda_{max.}$ 221 nm (log ε 4·16).

Attempted Synthesis of 5-*Methyl*-3H-*pyrrolizine* (14).—Pyrrole-2-carbaldehyde (21 g) was reduced by the method used by Acheson and Vernon [11] on 1-methyl-2-formylpyrrole. The yield of 2-methylpyrrole, b.p. 146—149° at 750 mmHg (lit.,[12] 148° at 755 mmHg) was 12 g (67%). The 2-methylpyrrole was formylated by the procedure used to formylate pyrrole.[13] The crude product was not distilled but chromatographed on an alumina column, prepared in petroleum (b.p. 40—60°) and eluted with benzene–petroleum (1 : 1), giving a yellow solid. Three recrystallisations from petroleum (b.p. 40—60°) (charcoal) gave 5-methylpyrrole-2-carbaldehyde, m.p. 72—73° (lit.,[14] 70°).

A mixture of 5-methylpyrrole-2-carbaldehyde (8·3 g), sodium hydride (3·24 g; 50% dispersion in paraffin), ether (74 ml), and vinyltriphenylphosphonium bromide (29·4 g) was treated as described for the synthesis of 3*H*-pyrrolizine.[10] A mixture of methylpyrrolizines (5·4 g, 60%) was obtained, b.p. 78—80° at 16 mmHg. Analytical g.l.c. showed 3 peaks (at 115°, 40 ml min^{-1} of N_2) with

[11] R. M. Acheson and J. M. Vernon, *J. Chem. Soc.*, 1963, 1008.
[12] H. Fischer, H. Beller, and A. Stern, *Ber.*, 1928, **61**, 1078.
[13] R. M. Silverstein, E. E. Ryskiewicz, and C. Willard, *Org. Synth.*, 1963, Coll. Vol. 4, p. 831.
[14] H. Fischer, H. Beyer, and E. Zaucker, *Annalen*, 1931, **486**, 68.

retention times of 72, 100, and 111 s (approximate composition 10 : 46 : 44). G.l.c.–mass spectral analysis of the mixture showed the following results: peak (i), compound (15), *m/e* 119 (M^+, 89%), 118 (100), and 104 (91); peak (ii), *m/e* 119 (M^+, 100%), 118 (66), and 104 (53); peak (iii), *m/e* 119 (M^+, 100%), 118 (61), and 104 (58). The mixture showed δ (CCl_4) 1·29 (d, *J* 7 Hz), 2·08br (s), 3·13br (s), 4·02br (s), 5·26br (s), 5·6—5·97 (m), 6·05 (m), and 6·49 p.p.m. (m).

2,3-*Dihydro*-3-*methyl*-1H-*pyrrolizine* (18) *and* 2,3-*Dihydro*-5-*methyl*-1H-*pyrrolizine* (19).—A solution of the mixed pyrrolizines (just described) (250 mg) in dry ether (30 ml), with palladium–charcoal (50 mg; 10%), was hydrogenated at atmospheric temperature and pressure until uptake ceased. The filtered solution was evaporated, leaving a brown oil. Analytical g.l.c. showed two peaks (at 115°, 40 ml min^{-1} of N_2) at 66 and 96 s retention times (ratio *ca.* 53 : 47). Preparative g.l.c. (160°, 100 ml min^{-1} of N_2) gave pure samples of the two components. Fraction (i) was 2,3-dihydro-3-methyl-1*H*-pyrrolizine (18), *m/e* 121 (M^+, 52%), 120 (47), and 106 (100); δ (CCl_4) 1·30 (3H, d, *J* 6 Hz), 2·0—2·9 (4H, m), 4·07 (1H, q, *J* 6 Hz), 5·57 (1H, d, *J* 3 Hz), 5·98 (1H, t, *J* 3 Hz), and 6·34 p.p.m. (m). Fraction (ii) was 2,3-dihydro-5-methyl-1*H*-pyrrolizine (19); *m/e* 121 (M^+, 77%), 120 (100), and 106 (33); δ (CCl_4) 2·11 (3H, s), 2·2—2·9 (4H, m), 3·64 (2H, t, *J* 6 Hz), 5·45 (1H, d, *J* 4 Hz), and 5·65 p.p.m. (1H, d, *J* 4 Hz).

2,3-*Dihydro*-1,2-*dimethyl*-1H-*pyrrolizine* (21).—A solution of dimethylpyrrolizine (22) [1] was hydrogenated as just described. Evaporation of the filtered solution gave virtually pure *dihydropyrrolizine* (21) (quant.), *m/e* 135 (M^+, 36%), 134 (20), 120 (100); δ (CCl_4) 0·8—1·3 (6H, m, 2 × CH*Me*), 2·4—4·0 (4H, m), 5·57 (1H, d, *J* 3 Hz), 5·95 (1H, t, *J* 3 Hz), and 6·3 p.p.m. (1H, m).

Dimethyl 7-*Ethoxycarbonylpyrrolo*[2,1,5-cd]*indolizine*-5,6-*dicarboxylate* (25).—A solution of 3-(ethoxycarbonylmethylene)-3*H*-pyrrolizine (23) (203 mg) [prepared from 3*H*-pyrrolizin-3-one [15] by a Wittig reaction [8]] and DMAD (710 mg) in toluene (50 ml) was boiled until t.l.c. showed the disappearance of most of compound (23) (22 h). The residue obtained by evaporation of the toluene was chromatographed on alumina (50 g), with petroleum (b.p. 60—80°)–benzene (1 : 1) to remove unchanged compound (23), and then benzene–chloroform (1 : 1) to remove products. The red gum (281 mg) was separated by p.l.c. [petroleum (b.p. 40—60°)–ether (1 : 1)] into twelve bands, only two of which gave appreciable quantities of material. An orange band yielded unchanged compound (23) (36 mg) and a deep red band gave orange needles of the *cyclazine triester* (25), m.p. 129—130° [from petroleum (b.p. 60—80°)] (44 mg, 12%) (Found: C, 61·6; H, 4·85; N, 4·3. $C_{17}H_{15}NO_6$ requires C, 62·0; H, 4·6; N, 4·25%); $\lambda_{max.}$ 218, 263·5, 283, 322·5, and 470 nm (log ε 4·44, 4·46, 4·51, 3·77, and 3·20), $\nu_{max.}$ 1717 cm^{-1}; δ ($CDCl_3$) 1·52 (3H, t, $CH_2{\cdot}CH_3$), 4·10 (6H, s, $O{\cdot}CH_3$), 4·59 (2H, q, $O{\cdot}CH_2{\cdot}CH_3$), 7·58 (1H, d, *J* 2 Hz), 7·67 (1H, d, *J* 2 Hz), and 7·80 p.p.m. (2H); *m/e* 329 (M^+, 93%), 298 (16), 285 (22), 270 (9), and 238 (100).

We thank the S.R.C. for a Studentship (to D. J.) and Professor W. Flitsch for information.

[15] W. Flitsch and U. Neumann, *Chem. Ber.*, 1971, **104**, 2170.

[2/1112 *Received*, 17*th May*, 1972]