# N-Quaternary Compounds. Part XL.[1] Syntheses of 1a,6a-Dihydroindeno[1,2-b]azirin-6(1H)-ones and Isomerisation to Isoquinolinium Derivatives

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Isoquinolinium-4-olates (5) have been synthesised from the valence isomeric 1a,6a-dihydroindeno[1,2-b]azirin-6(1H)-ones (4) by photochemical ring-opening. The thermally disallowed conrotatory ring-opening proceeded less readily. The N-arylaziridines (4; R = Ar) were prepared by photolysis of 3-aryl-3a,8a-dihydroindeno-[1,2-d]triazol-8(3H)-one derivatives (3); 3-alkyl derivatives did not react. Thermolysis was less successful and may yield the isomeric indan-1,3-dione monoimine. The triazolones (3) were formed by addition of azide to inden-1-one.

TRI- AND TETRA-PHENYL substituted 4,5-epoxycyclopent-2-enone and 2,3-epoxy-2,3-diphenylindan-1-one undergo reversible thermal valence isomerisation to the corresponding pyrylium-3-olate and benzopyrylium-4-olate.[2,3] A corresponding isomerisation between 6-azabicyclo-[3.1.0]hex-3-en-2-one (B) and the pyridinium-3-olate isomer (A) (Scheme 1) would seem feasible; such a process would also appear to explain the relatively high volatility of pyridinium-3-olates in the mass spectrometer.[4,5] We therefore initiated a project to synthesise some valence isomer pairs for comparative mass spectrometric studies.[6,7] During our work it was reported that 1,1a,6,6a-tetrahydro-6-iminoindeno[1,2-b]azirines undergo the thermally disallowed valence isomerisation to the corresponding isoquinolinium imides;[8] the conrotatory ring opening is not formally permitted by the geometry of the system since the aziridine ring is constrained in a bicyclic structure of medium size at the 2,3-bond.[8] Further evidence for this isomerisation was provided by the trapping of the carbonyl ylide from a dihydroindeno[1,2-b]azirin-6-one in a 1,3-dipolar cyclo-addition reaction.[9]

(A)   (B)
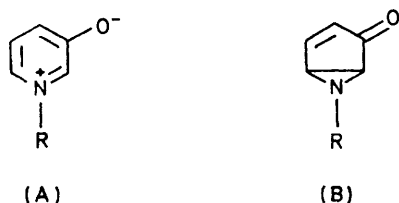
SCHEME 1

The bicyclic valence isomer (B) is expected to be chemically unstable as cyclopentenone and especially cyclopentadienone are highly reactive compounds.[10,11] By incorporating the double bond in an aromatic system, however, stabilisation and protection of the double bond is achieved during the synthesis. Our studies were therefore carried out on indanone derivatives

(Scheme 2). The isomeric isoquinolinium compounds (5) were expected to be preparatively available by the allowed disrotatory photochemical ring-opening of the aziridines (4).

a; R = Ph
b; R = p-MeOC$_6$H$_4$
c; R = p-NO$_2$C$_6$H$_4$
d; R = CH$_2$Ph
e; R = Me
f; R = Bu^n

SCHEME 2

Δ^2-1,2,3-Triazolines can be transformed into aziridines photochemically or pyrolytically.[12] Synthesis of the indeno[1,2-d]triazole (3) required easy access to inden-1-one; the latter has been synthesised from indan-1-one

[1] Part XXXIX, M. Gacek and K. Undheim, Tetrahedron, in the press.
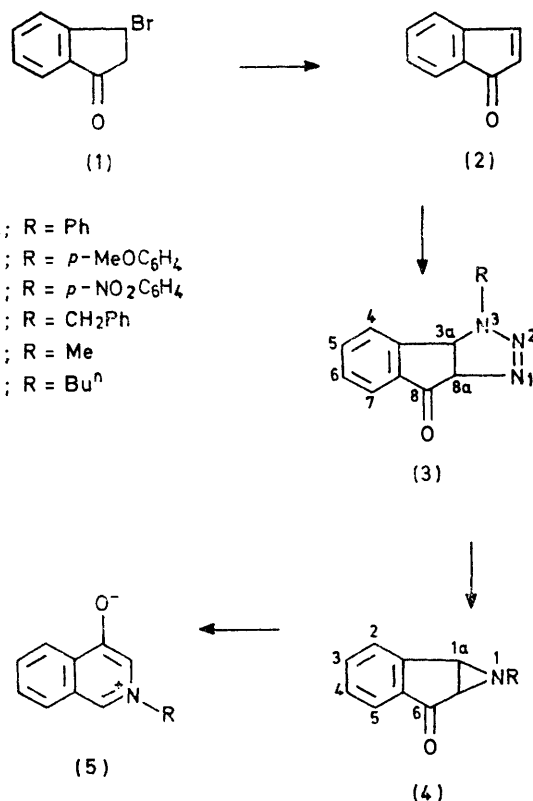
[2] E. F. Ullman, J. Amer. Chem. Soc., 1963, 85, 3529.

[3] E. F. Ullman and J. E. Milks, J. Amer. Chem. Soc., 1964, 86, 3814.

[4] T. Grønneberg and K. Undheim, Acta Chem. Scand., 1971, 25, 2807.

[5] K. Undheim and T. Hurum, Acta Chem. Scand., 1972, 26, 2385.

[6] K. Undheim and P. E. Hansen, Chemica Scripta, 1973, 3, 113.

[7] P. E. Hansen and K. Undheim, Acta Chem. Scand., 1973, 27, 1112.

[8] J. W. Lown and K. Matsumoto, J. Org. Chem., 1971, 36, 1405.

[9] D. L. Garling and N. H. Cromwell, J. Org. Chem., 1973, 38, 654.

[10] C. H. Depuy, B. W. Ponder, and J. D. Fitzpatrick, J. Org. Chem., 1964, 29, 3508.

[11] O. L. Chapman and C. L. McIntosh, Chem. Comm., 1971, 770.

[12] P. Scheiner, in 'Selective Organic Transformations,' ed. B. S. Tyagarajan, Wiley–Interscience, New York, 1970, vol. 1, p. 327.

by free radical bromination followed by elimination of hydrogen bromide in the presence of triethylamine.[7,13] Inden-1-one is unstable and tends to polymerise on distillation; in our best purification procedure the crude indenone was dissolved in n-hexane and crystallised at −70 °C.

The cycloaddition of azides with dipolarophiles occurs by a concerted 1,3-dipolar mechanism.[12,14,15] Polymerisation of inden-1-one was avoided by running the reaction at 0 °C in the dark in hexane or chloroform solution, or without a solvent. The reaction rate was lowest in n-hexane (low dielectric constant) suggesting that the two new σ-bonds formed are not developed to the same extent during the course of the reaction.[16]

The structural assignment of the adducts (3) is in accordance with the regioselectivity observed in related reactions; simple α,β-unsaturated carbonyl and nitrile derivatives yield $Δ^2$-1,2,3-triazolines with the electron-attracting group in the 4-position as predicted from electronic effects.[14,17,18] gem-Disubstitution in the substrate, however, may affect the orientation.[14,18] The n.m.r. spectra of the adducts formed are also in accord with the structural assignment. Thus 3a- and 8a-H appear as two doublets; the coupling (J 10 Hz) shows that the cis-adduct has been formed. The lower field signal is broadened, presumably due to long-range interannular coupling ($J < 0.5$ Hz) with an aromatic indan proton;[19] the signal is therefore ascribed to 3a-H. The α-proton (8a-H) in the aryl series (3a—c) and in the alkyl derivatives (3d—f) appears at τ ca. 4·5 and 5·0, respectively; the β-proton in the alkyl derivatives is at τ ca. 4·5 while the shifts in the aryl series varies (τ 4·1—4·5) according to the electronic properties of the phenyl substituent. These observations suggest that the triazoline substituent is close to the indanone β-proton, in agreement with the structural assignment of the adducts (3).
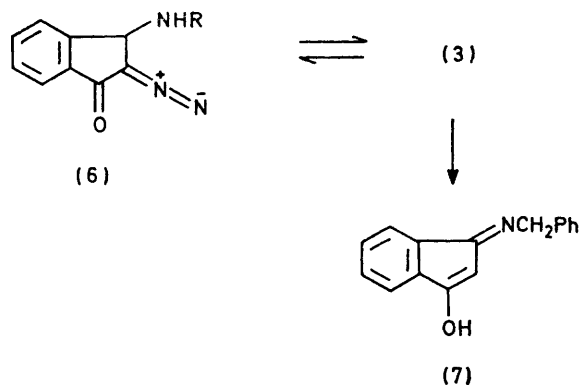
SCHEME 3

Certain indeno[1,2-d]triazol-8-ones exist in equilibrium with their amino-azo-isomers (Scheme 3).[14,17] The spectra in the present series, however, showed only one

isomer (3); nor was the azo-amino-isomer seen by n.m.r. after treatment of (3a) with cold triethylamine for 2 weeks.

Triazolines can be converted into aziridines by photolysis or thermolysis;[12] the former method is most often preferable, provided the aziridine formed does not absorb light in the wavelength region used in the photolysis. In the present work a cold solution of the triazoline (3) in a Pyrex flask was illuminated by a 300 W lamp; the aryltriazolines (3a—c) were converted almost quantitatively into the respective aziridines while the alkyl derivatives were recovered unchanged. The u.v. spectra of (3) contain a strong absorption at ca. 245 nm; the aryl derivatives in addition have a second strong absorption band at 285 nm which extends into the region used in the photolysis. Irradiation of the alkyl derivatives (3d—f) in the 245 nm region also led to expulsion of nitrogen, but a mixture of products was formed.

Thermolysis of the benzyltriazoline (3d) for a short time at reduced pressure gave among other products the aziridine (4d) together with some of the isomeric imine (7). The methyl- and butyl-triazolines failed to react in this way. The imine (7) was the major product from the benzyl derivative (3d) on heating in bromobenzene. The i.r. spectrum of the product formed shows OH absorption and no carbonyl absorption. The n.m.r. data also agree with enolisation. Treatment with aqueous hydrochloric acid gave indan-1,3-dione.

The mass spectra of the arylaziridines contain the molecular ion and show the same type of fragmentation pattern as reported for the benzyl analogue (4d).[6] In the n.m.r. spectra the two 2,3-protons of the indanone system are seen as two doublets; the lower field signal is broadened due to long range interannular coupling as discussed above for the triazolines. The broad signal is therefore ascribed to the β-proton (1a-H). The shifts for both protons were affected in the expected manner by the nature of the phenyl substituent. The coupling constant was ca. 3·5 Hz. This low value agrees with previous observations that normal $J_{vic} \geqslant 6$ Hz in aziridines is decreased on fusion to another ring system.[20]

The aziridine, 2,3-fused to a five-membered ring, is not formally allowed a thermal conrotatory ring opening to the isoquinoline valence isomer (5), as previously pointed out. Disrotatory photochemical opening, however, is allowed; thus irradiation of an ethereal solution of the aziridine with a mercury quartz lamp rapidly gave a strongly coloured solution. The colour faded on extermination of the irradiation, without any isoquinolinium betaine being precipitated. Imine analogues have been reported to behave similarly.[8] Irradiation apparently results in reversible isomerisation of a carbonyl ylide structure [(8) ⬌ (5)] and the aziridine

[13] W. Treibs and W. Schroth, Annalen, 1961, **639**, 204.
[14] R. Huisgen, G. Szeimies, and L. Möbius, Chem. Ber., 1966, **99**, 475.
[15] R. Huisgen, J. Org. Chem., 1968, **33**, 2291.

[16] P. K. Kadaba, Synthesis, 1973, 71.
[17] F. Texier and R. Carrié, Bull. Soc. chim. France, 1971, 4119.
[18] W. Broeckx, N. Overbergh, C. Samyn, G. Smets, and G. L'Abbé, Tetrahedron, 1971, **27**, 3527.
[19] E. Lustig and E. P. Ragelis, J. Org. Chem., 1967, **32**, 1398.
[20] R. W. Franck and J. Auerbach, J. Org. Chem., 1971, **36**, 31.

(Scheme 4). The ylide was trapped and precipitated as its hydrochloride salt when the photolysis was carried out in cis-1,2-dichloroethylene. The slow photolytic elimination of hydrogen chloride from this solvent [8] avoids acidic decomposition of unchanged aziridine. The assignment of the isoquinolinium structure to the product is confirmed by the u.v. spectra which show a bathochromic shift to ca. 340 nm for the longest wavelength absorption band.[6] Intense molecular ion peaks are present in the mass spectra, with mass numbers corresponding to the isoquinolinium betaines; they differ from their isomeric aziridines (5) in fragmentation and ionisation potential values.[21]
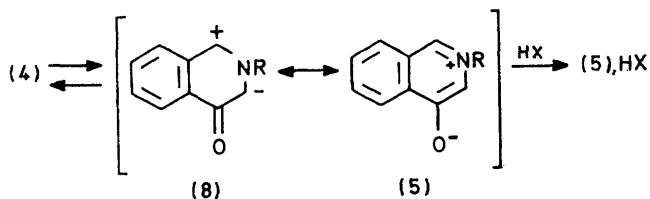
SCHEME 4

The formally disallowed thermal isomerisation of the arylaziridines was attempted by heating them in deoxygenated toluene; ammonium chloride was used for trapping of the intermediate ylide. The desired products were obtained, albeit in much lower yields than from photolysis. The aryltriazolines (3a—c) in the same way were convertible into the isoquinolinium derivatives. The latter reaction presumably goes via the aziridine intermediate. As previously pointed out, thermally disallowed valence isomerisations have been reported for other closely related systems. It has been suggested that a substantial driving force for the process is provided by the relief of ring strain and the gain in resonance energy of the ylide. A symmetry-allowed conrotatory process in the ylide would result in a non-permissible trans-fused aziridine; this factor also contributes to the stability of the ylide.[8]

EXPERIMENTAL

N.m.r. spectra were recorded with a Varian A-60A instrument and u.v. spectra with a Cary 14 instrument.

Inden-1-one (2).—Indan-1-one (10·6 g, 0·08 mol) was brominated in the 3-position with N-bromosuccinimide as previously described.[7] The crude bromo-product was dissolved in ether (100 ml), and triethylamine (10·1 g, 0·1 mol) in ether (10 ml) was added dropwise to the stirred solution at ca. 0 °C. The precipitate was filtered off after 2 h at this temperature and the filtrate evaporated in the cold at reduced pressure. The residual oil was dissolved in the minimum amount of hexane and some thick residual oily material removed by decantation. The hexane solution was then cooled to −70 °C. The indenone slowly crystallised out and was collected by filtration at this temperature; yield 65%.

3-Substituted 3a,8a-Dihydroindeno[1,2-d]triazol-8(3H)-ones

[21] P. E. Hansen and K. Undheim, *Acta Chem. Scand.*, in the press.

(3).—The aromatic azides required for this reaction were prepared as described for phenyl azide [22] and the aliphatic azides as for benzyl azide.[23] The azide (0·02 mol) and inden-1-one (2·6 g, 0·02 mol) were dissolved in n-hexane (20 ml) and kept in the dark at 0 °C for 7 days. The reaction mixture was then heated to 50 °C for 8 h. The triazoline formed was precipitated on cooling and was recrystallised from n-hexane. Data for the individual compounds are given below.

3-*Phenyl-* (3a); yield 70%, m.p. 132 °C (decomp.) (Found: C, 72·5; H, 4·8; N, 16·6. $C_{15}H_{11}N_3O$ requires C, 72·15; H, 4·45; N, 16·8%); τ (CDCl$_3$) 4·5 (d, J 9·7 Hz, 8a-H), 4·3br (d, 3a-H), and 2·1—2·8 (9H, ArH); $\lambda_{max.}$ (EtOH) 248 (log ε 3·71) and 286 nm (3·36); $\nu_{max.}$ (KBr) 1725 cm^{-1} (C=O).

3-p-*Methoxyphenyl-* (3b); yield 75%, m.p. 140 °C (decomp.) (Found: C, 69·05; H, 4·7; N, 15·4. $C_{16}H_{13}N_3O_2$ requires C, 68·8; H, 4·7; N, 15·05%); τ (CDCl$_3$) 6·2 (3H, s, OMe), 4·6 (d, J 10·0 Hz, 8a-H), 4·4br (d, 3a-H), and 2·1—3·2 (8H, ArH); $\lambda_{max.}$ (EtOH) 245 (log ε 3·87) and 283 nm (3·51); $\nu_{max.}$ (KBr) 1720 cm^{-1} (C=O).

3-p-*Nitrophenyl-* (3c); yield 60%, m.p. 200 °C (decomp.) (Found: C, 61·2; H, 3·5; N, 19·35. $C_{15}H_{10}N_4O_3$ requires C, 61·2; H, 3·4; N, 19·05%); τ (CDCl$_3$) 4·2 (d, J 9·5 Hz, 8a-H), 4·0br (d, 3a-H), and 2·0—3·1 (8H, ArH); $\lambda_{max.}$ (EtOH) 251 (log ε 3·79), 290 (3·58) and 365 nm (2·39); $\nu_{max.}$ (KBr) 1730 cm^{-1} (C=O).

3-*Benzyl-* (3d); yield 82%, m.p. 146 °C (decomp.) (Found: C, 73·15; H, 5·25; N, 15·9. $C_{16}H_{13}N_3O$ requires C, 3·0; H, 4·95; N, 15·95%); τ (CDCl$_3$) 5·1 (d, J 9·5 Hz, 8a-H), 4·5br (d, 3a-H), 4·7 and 5·2 (2H, ABq, J 16 Hz, CH_2Ph), and 2·1—2·8 (9H, ArH); $\lambda_{max.}$ (EtOH) 245 nm (log ε 4·06); $\nu_{max.}$ (KBr) 1725 cm^{-1} (C=O).

3-*Methyl-* (3e); yield 53%, m.p. 115 °C (decomp.) (Found: C, 64·0; H, 4·6; N, 22·6. $C_{10}H_9N_3O$ requires C, 64·15; H, 4·85; N, 22·45%); τ (CDCl$_3$), 6·5 (NMe), 5·1 (d, J 10·0 Hz, 8a-H), 4·6br (d, 3a-H), and 2·1—2·7 (4H, ArH); $\lambda_{max.}$ (EtOH) 245 nm (log ε 4·03); $\nu_{max.}$ 1720 cm^{-1} (C=O).

3-n-*Butyl-* (3f); yield 46%, m.p. 70 °C (decomp.) (Found: C, 68·0; H, 6·3; N, 18·45. $C_{13}H_{13}N_3O$ requires C, 68·1; H, 6·6; N, 18·35%); τ (CDCl$_3$) 5·8—6·6 and 7·9—9·1 (NBu), 5·0 (d, J 10·1 Hz, 8a-H), 4·6br (d, 3a-H), and 2·1—2·7 (4H, ArH); $\lambda_{max.}$ (EtOH) 245 nm (log ε 4·01); $\nu_{max.}$ (KBr) 1715 cm^{-1} (C=O).

1-*Aryl-*1a,6a-*dihydroindeno*[1,2-b]*azirin*-6(1H)-*ones* (4).—The triazoline (3) (0·004 mol) was dissolved or suspended in benzene (50 ml) and the solution water-cooled by means of a cold-finger immersed in the solution during the illumination. The light source was a 300 W Philips HP 3202 u.v. lamp which was placed ca. 10 cm from the reaction flask. Illumination was stopped when evolution of nitrogen had almost ceased. This required ca. 1 h for the phenyl and p-methoxyphenyl derivatives and ca. 8 h for the p-nitrophenyl derivative. The solution was then evaporated at reduced pressure and the residual material crystallised from n-hexane. Data for the individual compounds are given below.

1-*Phenyl-* (4a); yield 65%, m.p. 88 °C (Found: C, 81·65; H, 5·0; N, 6·05. $C_{15}H_{11}NO$ requires C, 81·45; H, 5·0; N, 6·35%); τ (CDCl$_3$) 6·6 (d, J 3·5 Hz, 6a-H), 6·1br (d, 1a-H), and 2·4—3·4 (9H, ArH); $\lambda_{max.}$ (EtOH) 240

[22] R. O. Lindsay and C. F. Allen, *Org. Synth.*, Coll. Vol. III, 1955, p. 710.
[23] T. Curtius and G. Ehrhart, *Chem. Ber.*, 1922, **55**, 1559.

(log ε 4·01) and 292 nm (1·60); $v_{max.}$ (KBr) 1725 cm^{-1} (C=O).

1-p-*Methoxyphenyl-* (4b); yield 73%, m.p. 142 °C (Found: C, 76·6; H, 5·2; N, 5·35. $C_{16}H_{13}NO_2$ requires C, 76·5; H, 5·2; N, 5·55%); τ (CDCl$_3$) 6·3 (OMe), 6·5 (d, J 3·7 Hz, 6a-H), 6·0br (d, 1a-H), and 2·4—3·5 (8H, ArH); $\lambda_{max.}$ (EtOH) 236 (log ε 4·35) and 290 nm (1·63); $v_{max.}$ (KBr) 1720 cm^{-1} (C=O).

1-p-*Nitrophenyl-* (4c); yield 35%, m.p. 192 °C (Found: C, 68·0; H, 3·5; N, 10·65. $C_{15}H_{10}N_2O_3$ requires C, 67·65; H, 3·8; N, 10·5%); τ (CDCl$_3$) 6·3 (d, J 3·4 Hz, 6a-H), 5·7br (d, 1a-H), and 1·9—3·2 (8H, ArH); $\lambda_{max.}$ (EtOH) 242 (log ε 4·05) and 315 nm (1·81); $v_{max.}$ (KBr) 1730 cm^{-1} (C=O).

2-*Arylisoquinolinium-4-olate* (5) *Hydrochlorides.*—The 1-arylaziridine (4) (0·0015 mol) was dissolved in absolute ether (200 ml)· containing *cis*-1,2-dichloroethylene (15 ml). The solution was irradiated using a Möller apparatus containing a 250 W mercury lamp in the centre enclosed in a quartz vessel with the solution circulating past the irradiated region by means of a centrifugal pump. A rapid circulation is advantageous. A precipitate started to form shortly after irradiation was initiated; the reaction was complete after *ca.* 30 min. The solid was recrystallised from absolute ethanol. Data for the individual compounds are summarised below.

2-*Phenyl-* (5a); yield 52%, m.p. 208 °C (Found: C, 69·7; H, 4·5; N, 5·7. $C_{15}H_{11}NO$,HCl requires C, 69·9; H, 4·7; N, 5·45%); τ (CD$_3$OD) 2·3 (5H, Ph), 1·3—2·0 (5H, 3- and 5—8-H), and 0·9 (1-H); $\lambda_{max.}$ (EtOH) 227 (log ε 4·32), 243 (4·31), 258 (4·28), and 338 nm (4·53).

2-p-*Methoxyphenyl-* (5b); yield 63%, m.p. 222 °C (Found: C, 66·95; H, 5·15; N, 4·55. $C_{16}H_{13}NO_2$,HCl requires C, 66·8; H, 4·9; N, 4·85%); τ (CD$_3$OD) 6·08 (3H, s, OMe), 2·3—2·9 (4H, Ph), 1·3—2·1 (5H, 3- and 5—8-H), and 0·4 (1-H); $\lambda_{max.}$ (EtOH) 235 (log ε 4·70), 293 (4·27), and 339 nm (4·19).

2-p-*Nitrophenyl-* (5c); yield 35%, m.p. 253 °C (Found:

C, 59·8; H, 3·45; N, 9·05. $C_{15}H_{10}N_2O_3$,HCl requires C, 59·5; H, 3·65; N, 9·25%); τ (CD$_3$OD) 2·2—2·8 (4H, Ph), 1·3—2·0 (5H, 3- and 5—8-H), and 0·5 (1-H); $\lambda_{max.}$ (EtOH) 247 (log ε 3·89), 283 (4·21), and 352 nm (4·01).

Pyrolyses of the Triazolines (3).—The 3-aryltriazolines were pyrolysed in refluxing xylene until nitrogen evolution had ceased. The product was a mixture, but some of the 1-arylaziridine (4) could be isolated after silica gel chromatography using hexane–ethyl acetate (2 : 1) as eluant.

The 3-alkyltriazolines (3e) and (3f) were pyrolysed without a solvent at 145 °C and 0·05 mmHg, but no aziridine could be isolated. The benzyl derivative (3d), however, gave some of the corresponding aziridine which was isolated by silica gel chromatography using the above eluant. Physical data for the benzylaziridine (4d) have previously been reported.[6]

3-*Benzyliminoindan-1-one* (7).—The 3-benzyltriazoline (3d) (0·4 g, 0·0015 mol) dissolved in bromobenzene (50 ml) was heated under reflux for 4 h; cooling gave the *imine* as a yellow precipitate, m.p. 170 °C (from chloroform); yield 0·2 g (50%) (Found: C, 81·45; H, 5·7; N, 5·7. $C_{16}H_{13}NO$ requires C, 81·7; H, 5·55; N, 5·95%); τ (CDCl$_3$) 7·3 (s, OH), 5·3 and 5·5 (2H, s, C=NCH$_2$), 5·1 (H, s, vinyl H), and 2·3—2·7 (9H, ArH); $\lambda_{max.}$ (EtOH) 231 (log ε 4·31) and 264 nm (3·97); no C=O band in the i.r. spectrum (KBr).

Photolysis of the Triazoline (3).—The triazoline (0·0015 mol) was dissolved in absolute ether (200 ml) containing *cis*-1,2-dichloroethylene (15 ml) and irradiated in the Möller apparatus as described for the aziridines. The product was a mixture.

The 3-aryltriazolines gave mixtures of the 2-arylisoquinolinium salts and the respective aniline hydrochloride. The aniline was extracted from a weakly alkaline solution and the isoquinolinium salt precipitated by neutralisation with hydrochloric acid.

The 3-alkyltriazolines under these conditions only gave the corresponding amine hydrochlorides.