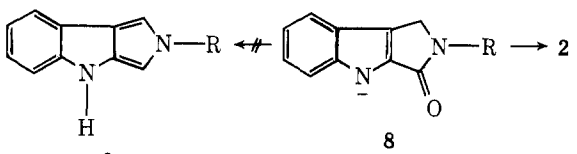
efficient abstraction of the C(1) proton by soluble base. It is of interest to note that energetic requirements for operation of either mechanism appear to be high, since our attempted reductions at lower temperatures were unsuccessful. The reduction of α,β-unsaturated γ-lactones to the corresponding furans with dialkylaluminum hydrides has been reported[3] to proceed at low (−20 to −25 °C) temperatures in good yield. This difference most likely reflects the energy differences between formation of the pseudoaromatic furan ring and disruption of the indole nucleus to form **5**.

It is of interest to note that Southwick did not report formation of dihydropyrrolo[3,4-*b*]indoles **9** from N(4) unsubstituted pyrrolo[3,4-*b*]indolones **1**, although yields of the tetrahydro species and conditions of reduction were comparable. Owing to the relative acidity of indole nitrogen protons, it is quite likely that generation of the N(4) anion (i.e., **8**) in Southwick's series would prevent abstraction of a proton from C(1) and hence the elimination sequence envisioned in path b above. Also of interest is the stability of these compounds by comparison with that of isoindoles.[4] Clearly the subject compounds resemble disubstituted pyrroles rather than the isoindole type of molecule. This stability and the extended chromophore apparent from our uv data imply (but do not confirm) electronic interaction between the rings of this interesting molecule.



9 8

Experimental Section[5]

2-Benzyl-4-phenylpyrrolo[3,4-*b*]indol-3(2*H*)-one (3). A solution of 11.90 g (63.0 mmol) of 1-benzyl-2,3-pyrrolidinedione in 200 ml of glacial acetic acid was added to a suspension of diphenylhydrazine hydrochloride (13.88 g, 63.0 mmol) in 200 ml of glacial acetic acid and the resulting suspension was heated briefly on a steam bath to effect hydrazone formation. Then 100 ml of concentrated hydrochloric acid was added to the warm solution and heated for a further 20 min. The reaction mixture was diluted slowly with water giving 17.8 g (84%) of crystalline **3**. Recrystallization from ethyl acetate gave colorless crystals, mp 145.5–146.5 °C: ir (KBr) 3.35, 3.52, 5.97, 6.91, 7.25, 8.15, 13.17, 13.40 μ; NMR ($CDCl_3$) δ 4.30 (2 H, s), 4.75 (2 H, s), 7.12–7.76 (9 H, m), 7.30 (5 H, s); uv (MeOH) λ_{max} 246 nm (log ϵ 4.265), 299 nm (4.141); mass spectrum *m/e* 338 (parent ion). Anal. Calcd for $C_{23}H_{18}N_2O$: C, 81.66; H, 5.33; N, 8.28. Found: C, 81.35; H, 5.51; N, 8.24.

2-Benzyl-4-phenyl-1,2,3,4-tetrahydropyrrolo[3,4-*b*]indole (4) and 2-Benzyl-4-phenyl-2,4-dihydropyrrolo[3,4-*b*]indole (5). To a solution of 13.0 g (38.5 mmol) of **3** dissolved in 350 ml of dry toluene (4A molecular sieves) at reflux was added 2.92 g (76.9 mmol) of $LiAlH_4$. The resulting suspension was heated at reflux for 16 h and then cooled to room temperature. After the slow addition of 150 ml of ethyl acetate, 150 ml of water was added and the resulting suspension was filtered. The separated aluminum salts were washed thoroughly with ethyl acetate and the washings combined with the filtrate. The aqueous phase was extracted thoroughly with ethyl acetate, the combined organic extracts were then dried ($MgSO_4$), and the solvent was evaporated to give 17 g of an orange oil. This material was chromatographed on 340 g of Brinkmann silica gel. The benzene eluent consisted of 3.39 g of an oil (R_f 0.75, benzene) and the 1:1 benzene–ethyl acetate fraction was 5.16 g of an oil (R_f 0.11, benzene). Neither product could be induced to crystallize; however, the less polar product, identified below as **5**, yielded a crystalline picrate salt from ethanol whereas the more polar product **4** formed a crystalline hydrochloride salt from ether with dry HCl gas.

2-Benzyl-4-phenyl-1,2,3,4-tetrahydropyrrolo[3,4-*b*]indole Hydrochloride (4): mp 198.0–199.5 °C; mass spectrum *m/e* 324 (parent ion), 323 (M − 1, 100%), 232, 218, 204, 91; NMR ($CDCl_3$) δ 4.47 (4 H, d),[6] 4.69 (2 H, d),[6] 6.94–7.50 (12 H, m), 7.50–7.74 (2 H, m); uv (MeOH) λ_{max} 254 nm (log ϵ 4.159), 287 (3.963).

Anal. Calcd for $C_{23}H_{20}N_2$·HCl: C, 67.54; H, 5.87; N, 7.76. Found: C, 67.23; H, 5.95; N, 7.71.

2-Benzyl-4-phenyl-2,4-dihydropyrrolo[3,4-*b*]indole Picrate (5): mp 134–135 °C; mass spectrum *m/e* 323 (parent ion, 100%); NMR (free base, $CDCl_3$) δ 4.91 (2 H, s), 6.37 (1 H, d, J = 1.5 Hz), 6.73 (1 H, d, J = 1.5 Hz), 6.80–7.67 (14 H, m); uv (MeOH) λ_{max} 250 nm (log ϵ 4.065), 270 (3.807), 282 (3.817), 303 (3.678).

Anal. Calcd for $C_{23}H_{18}N_2$·$C_6H_3N_3O_7$: C, 63.16, H, 3.84; N, 12.70. Found: C, 63.19; H, 3.93; N, 12.85.

Reduction of 3 with $LiAlH_4$ in the Presence of *N*-Ethylpiperidine. A solution of 0.50 g (4.4 mmol) of distilled *N*-ethylpiperidine and 0.50 g (1.48 mmol) of compound **3** in 15 ml of dry toluene was heated to reflux at which time 0.11 g (2.89 mmol) of $LiAlH_4$ was added. Reflux was continued for 16 h. Then the reaction mixture was cooled, worked up, and subjected to column chromatography as outlined above. The benzene eluent yielded 200 mg (42%) of compound **5** and the 1:1 benzene–ethyl acetate fractions contained 218 mg (45%) of compound **4** identical in all respects with the compounds described above.

Acknowledgment. We are grateful to Dr. E. B. Whipple and associates for the proton decoupling experiments and to Mr. R. L. Taylor and Mr. F. C. Kohansky for valuable technical assistance.

Registry No.—**3**, 58485-96-4; **4** HCl, 58485-97-5; **5** picrate, 58485-99-7; 1-benzyl-2,3-pyrrolidinedione, 58485-00-3; diphenylhydrazine HCl, 29666-92-0; *N*-ethylpiperidine, 766-09-6; $LiAlH_4$, 16853-85-3.

References and Notes

(1) P. L. Southwick and R. J. Owellen, *J. Org. Chem.*, **25**, 1133 (1960).
(2) P. L. Southwick and R. T. Crouch, *J. Am. Chem. Soc.*, **75**, 3413 (1953).
(3) H. Minato and T. Nagasaki, *Chem. Ind. (London)*, 889 (1965); H. Minato and T. Nagasaki, *J. Chem. Soc. C*, 377 (1966); P. A. Grieco, C. S. Pognonowski, and S. Burke, *J. Org. Chem.*, **40**, 542 (1975).
(4) For example, see J. D. White and M. E. Mannin, *Adv. Heterocycl. Chem.*, **10**, 113 (1969).
(5) Melting points (uncorrected) were taken with a Thomas-Hoover capillary apparatus. NMR spectra were recorded on Varian A-60 and T-60 spectrometers with Me_4Si as internal standard. Proton decoupling experiments were conducted on a Varian XL-100 spectrometer. Ir spectra were determined with a Perkin-Elmer Model 21 spectrophotometer. Uv spectra were recorded on a Cary Model 14 spectrophotometer. Mass spectra were obtained with a Perkin-Elmer RMU-6E mass spectrometer. Microanalyses were performed by the Pfizer Analytical Department. All evaporations were conducted in vacuo using either a water aspirator or a vacuum pump.
(6) It is apparent that, in the hydrochloride salt, the α and β C(1) and C(3) methylene protons are nonequivalent owing to the quaternary nature of N(2). In NMR spectra of the free base of **4**, this region collapses to a 6 H singlet at δ 4.10.

---

s-Triazines. 1. Reaction of Cyanuric Chloride with Unsaturated Nitrogen Compounds

Koichi Miyashita* and Linus Pauling

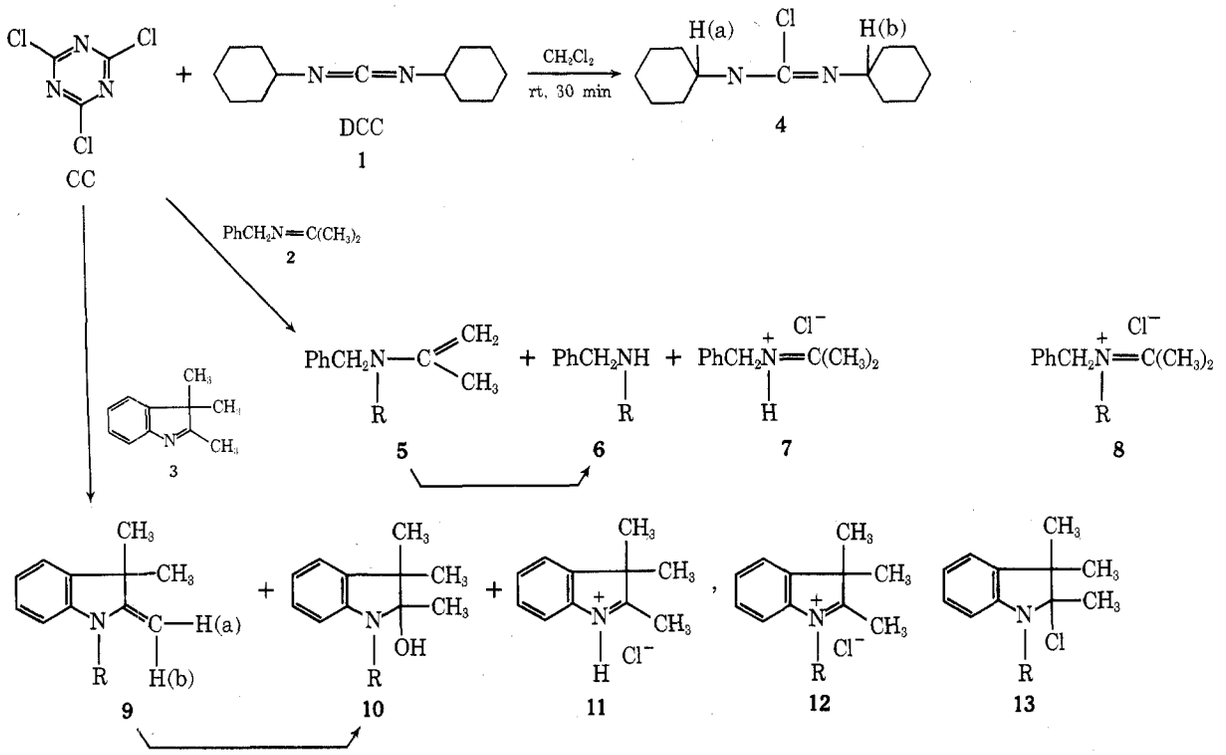
Linus Pauling Institute of Science and Medicine, Menlo Park, California 94025

Received December 22, 1975

Since 1940 applications of *s*-triazine derivatives, especially melamine and its derivatives, have been extended into nearly every industrial field.[1] In addition, many melamine derivatives have been found to exhibit[1,2,3] antineoplastic, antibiotic, antibacterial, and/or insecticidal activity. We believe, therefore, that other hitherto unknown *s*-triazines, especially melamine derivatives, will probably have potential antineoplastic and antibiotic action.

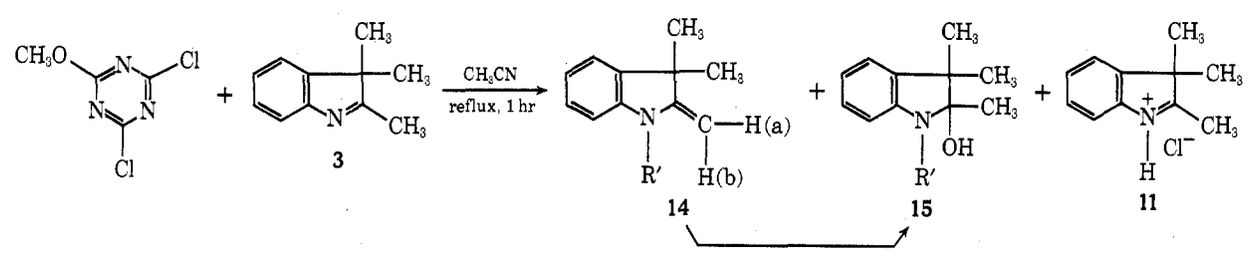
Although several synthetic methods for the preparation of *s*-triazine derivatives from cyanuric halides have been developed,[1] few studies have been reported of the reaction of cyanuric halides with unsaturated nitrogen compounds other than pyridine.[4] In the course of work on potential anticarcinogens we have found that cyanuric chloride (CC) reacts at room temperature with dicyclohexylcarbodiimide (DCC, **1**),

Scheme I



R = 2,4-dichloro-*s*-triazinyl

Scheme II



R′ = 4-chloro-6-methoxy-*s*-triazinyl

N-isopropylidenebenzylamine (**2**), and 2,3,3-trimethylindolenine (**3**).

DCC (**1**, 1 equiv) reacts with CC to form 2,4-dichloro-6-[*N*′-cyclohexyl-*N*′-(*N*′-cyclohexylchloroimino)]-*s*-triazine (**4**) in 95% yield (Scheme I). Also, we obtained a small amount of a pale yellow solid which was amorphous in several solvent systems and showed several bands on TLC.

2,4-Dichloro-6-(*N*′-benzyl-*N*′-isopropenyl)-*s*-triazine (**5**) and 2,4-dichloro-6-benzylamino-*s*-triazine (**6**)[5] were obtained in 11 and 3 yield, respectively, from the base **2** (1 equiv). Also, *N*-isopropylidenebenzylamine hydrochloride (**7**) was obtained in 4 yield. When 2 equiv of the base was used, **5**, **6**, and **7** were obtained in 63, 30, and 94% yield, respectively, calculated on the basis of CC. No compound of structure **8** was isolated from either of the reactions. Pure **5** was converted to **6** at room temperature within 1 day, although **5** was stable enough to be separated by preparative TLC.

From the indolenine **3** (1 equiv), 2,4-dichloro-6-(2′-methylene-3′,3′-dimethylindoline)-*s*-triazine (**9**) and 2,4-dichloro-6-(2′-hydroxy-2′,3′,3′-trimethylindoline)-*s*-triazine (**10**) were obtained in 3.4 and 41% yield, respectively. Also, the hydrochloride **11** was obtained in 50% yield. Neither **12** nor **13**[6] was isolated.

It is of interest that the ratio of **9** and **10**, which was 3:1[7] before isolation by TLC, changed to 1:12 after the procedure, although TLC of pure **9** showed no detectable conversion to **10**, which was checked by NMR spectrum. Compounds **9** and **11** were obtained quantitatively by using 2 equiv of the indolenine **3**, one of which was used as a scavenger of hydrogen chloride produced in the reaction.

It was also found that 2,4-dichloro-6-methoxy-*s*-triazine reacted with the active azomethine (–C=N–) group under more vigorous conditions (in refluxing dry CH_3CN, for 1 h). From **3** (2 equiv), **11**, 2-chloro-4-methoxy-6-(2′-methylene-3′,3′-dimethylindoline)-*s*-triazine (**14**), and 2-chloro-4-methoxy-6-(2′-hydroxy-2′,3′,3′-trimethylindoline)-*s*-triazine (**15**) were obtained in 96, 24, and 48% yield, respectively, calculated on the basis of the *s*-triazine (Scheme II). The indolenine **3** (3%) was recovered. Again, the addition of water to **14** took place. The ratio of **14** and **15** (2:1)[8] changed to 2:5 after isolation and purification. It is not clear at this time what causes these observed ratio changes of **9**/**10** and **14**/**15** during the process.

Experimental Section

All NMR spectra (60 MHz) were determined in $CDCl_3/Me_4Si$. All ir spectra were determined in a KBr mix. Silica gel, GF_{254} (E. Merck), was used for preparative TLC.

General Procedure for the Reactions. To CC (922 mg, 5 mmol) suspended in dry CH_2Cl_2 (5 ml), a solution of the substrate (5 or 10 mmol) in CH_2Cl_2 (2 or 4 ml) was added dropwise at room temperature

over a period of several minutes with vigorous stirring. After 30 min the solvent was removed by an aspirator at room temperature and the residue was purified by usual techniques.

Reaction of CC with DCC (1). The residue obtained from CC and DCC (1.03 g, 5 mmol) was dissolved in *n*-hexane and the amorphous pale yellow solid was filtered off. The solution was condensed and kept in a refrigerator to give colorless prisms of **4** (1.85 g, 95%): mp 101 °C; ir 1690 cm^{-1} (C=N); NMR δ 4.41 [1, m, methyne H(a)], 3.70 [1, m, methyne H(b)], 2.30–1.00 (20, m, dicyclohexyl H); *m/e* 389 ($M^{\cdot+}$, 0.0001), 354 ($M^{\cdot+}$ − ·Cl, 0.01), 308 ($M^{\cdot+}$ − cyclohexenyl radical, 0.11).

Anal. Calcd for $C_{16}H_{22}Cl_3N_5$: C, 49.16; H, 5.63; N, 17.97. Found: C, 48.99; H, 5.62; N, 17.91.

Reaction of CC with *N*-Isopropylidenebenzylamine (2). The residue obtained from CC and the imine (735 mg, 5 mmol) was extracted with anhydrous Et_2O under a nitrogen atmosphere. The insoluble solid was dissolved in dry CH_2Cl_2 and anhydrous Et_2O was added to the solution slowly to give colorless needles of **7** (440 mg, 48%): mp 114–118 °C;[9] ir 2630 and 1690 cm^{-1} (C=N+<); NMR δ 7.60–7.10 (5, m, aromatic H), 4.82 (2, s, $-CH_2Ph$), 2.70 and 2.41 [6, s, $(CH_3)_2C$=].

Anal. Calcd for $C_{10}H_{13}N$·HCl:[10] C, 65.39; H, 7.62; N, 7.62. Found: C, 64.13; H, 7.44; N, 7.73.

The ether filtrate was chromatographed by preparative TLC developed with benzene to give two main bands, which were extracted with CH_2Cl_2. The solution from the upper band was distilled to give **5** as a colorless liquid (162 mg, 11%): bp 125–126 °C (0.15 mm);[11] ir (NaCl) 1665 cm^{-1} (C=C); NMR δ 7.27 (5, s, aromatic H), 5.10 and 4.85 (2, d, J = 1.8 Hz, vinylic H), 4.95 (2, s, $-CH_2Ph$), 1.84 (3, s, $-CH_3$); *m/e* 203 ($M^{\cdot+}$ − $\cdot C_7H_7$, 64.2).

Anal. Calcd for $C_{13}H_{12}Cl_2N_4$: C, 52.88; H, 4.06; N, 18.98. Found: C, 52.63; H, 4.09; N, 19.32.

The product from the other band was crystallized from *n*-hexane to give colorless prisms of **6** (484 mg, 38%), identical with an authentic sample.[5]

From 10 mmol of the imine, the compounds **5** (929 mg, 63%), **6** (383 mg, 30%), and **7** (865 mg, 93%) were obtained by the same procedure as above.

Reaction of CC with 2,3,3-Trimethylindolenine (3). The residue obtained from CC and the indolenine (795 mg, 5 mmol) was extracted with anhydrous Et_2O followed by preparative TLC developed with a mixture of *n*-hexane and benzene (3:1 v/v) to give two main bands, which were extracted with CH_2Cl_2 and crystallized from *n*-hexane, respectively. The upper band was assigned as **9** (52 mg, 3.4%): mp 122–123 °C; ir 1650 cm^{-1} (C=C); NMR δ 8.41 (1, m, $C_{7'}$ H), 7.43–7.10 (3, m, aromatic H), 6.37 [1, d, J = 1.0 Hz, olefinic H(b)], 5.80 [1, d, J = 1.0 Hz, olefinic H(a)], 1.43 [6, 3′,3′-$(CH_3)_2$]; *m/e* 306 ($M^{\cdot+}$, 47.6), 291 ($M^{\cdot+}$ − $\cdot CH_3$, 100).

Anal. Calcd for $C_{14}H_{12}Cl_2N_4$: C, 54.72; H, 3.90; N, 18.24. Found: C, 54.80; H, 4.11; N, 18.24.

The other band was assigned as **10** (674 mg, 41%): mp 128–129.5 °C; ir 3485 cm^{-1} (–OH); NMR δ 8.13 (1, m, $C_{7'}$, H), 7.15–7.05 (3, m, aromatic H), 5.75 (1, s, –OH), 1.75 (3, s, 2′-CH_3), 1.39 and 1.22 [6, s, 3′,3′-$(CH_3)_2$]; *m/e* 324 ($M^{\cdot+}$, 27.5), 306 ($M^{\cdot+}$ − H_2O, 17.7), 291 ($M^{\cdot+}$ − MeOH, 96.5).

Anal. Calcd for $C_{14}H_{14}Cl_2N_4O$: C, 51.69; H, 4.30; N, 17.27. Found: C, 51.66; H, 4.39; N, 17.29.

Also, the ether-insoluble solid **11** (488 mg, 50%) was identical with an authentic sample.

From 10 mmol of the indolenine, **9** (1.534 g, 100%) and **11** (977 mg, 100%) were obtained, respectively, calculated on the basis of CC.

Reaction of 2,4-Dichloro-6-methoxy-*s*-triazine with the Indolenine 3. A mixture of the *s*-triazine (980 mg, 5 mmol) and **3** (1.59 g, 10 mmol) in dry CH_3CN (2 ml) was boiled for 1 h. The solvent was removed at room temperature and the residue was extracted with anhydrous Et_2O followed by preparative TLC developed with benzene to give two main bands, which were extracted with Et_2O and crystallized from *n*-hexane, respectively. The upper band was assigned as **14** (362 mg, 24%): mp 81–82 °C; ir 1650 cm^{-1} (C=C); NMR δ 8.60–8.39 (1, m, $C_{7'}$ H), 7.50–7.10 (3, m, aromatic H), 6.39 [1, d, J = 1.8 Hz, olefinic H(b)], 5.02 [1, d, J = 1.8 Hz, olefinic H(a)], 4.10 (3, s, $-OCH_3$), 1.43 [6, s, 3′,3′-$(CH_3)_2$]; *m/e* 302 ($M^{\cdot+}$, 20.1), 287 ($M^{\cdot+}$ − $\cdot CH_3$, 85.4).

Anal. Calcd for $C_{15}H_{15}ClN_4O$: C, 59.53; H, 4.95; N, 18.51. Found: C, 59.49; H, 4.95; N, 18.64.

The other band contained **15** (769 mg, 48%): mp 132–133 °C; ir 3410 cm^{-1} (–OH); NMR δ 8.23–8.03 (1, m, $C_{7'}$ H), 7.32–7.00 (3, m, aromatic H), 6.27 (1, s, –OH), 4.02 (3, s, $-OCH_3$), 1.57 (3, s, 2′-CH_3), 1.39 and 1.22 [6, s, 3′,3′-$(CH_3)_2$]; *m/e* 320 ($M^{\cdot+}$, 49.7), 305 ($M^{\cdot+}$ − $\cdot CH_3$, 52.1), 304 ($M^{\cdot+}$ − CH_4, 38.4).

Anal. Calcd for $C_{15}H_{17}ClN_4O_2$: C, 56.16; H, 5.30; N, 17.47. Found: C, 56.42; H, 5.62; N, 17.65.

The ether-insoluble solid **11** (939 mg, 96%) was identical with an authentic sample. A band close to the baseline on TLC was also extracted with Et_2O and identified as **3** (24 mg, 3%, crude).

Acknowledgment. The authors are indebted to Professor Eugene E. van Tamelen, Stanford University, and his group for giving us the opportunity to use the facilities for this research. We also thank Dr. Roy Neville for his useful discussions of this investigation.

Registry No.—**1**, 538-75-0; **2**, 1197-48-4; **3**, 1640-39-7; **4**, 58502-52-6; **5**, 58502-53-7; **6**, 30369-82-5; **7**, 58502-54-8; **9**, 58502-55-9; **10**, 58502-56-0; **11**, 17790-92-0; **14**, 58502-57-1; **15**, 58502-58-2; CC, 108-77-0; 2,4-dichloro-6-methoxy-*s*-triazine, 3638-04-8.

References and Notes

(1) E. M. Smolin and L. Rapoport, "The Chemistry of Heterocyclic Compounds", Interscience, New York, N.Y., 1959, Chapter VI, p 309.
(2) J. Doskocil, V. Paces, and F. Sorm, *Biochim. Biophys. Acta*, **145**, 771 (1967).
(3) V. Paces, J. Doskocil, and F. Sorm, *Biochim. Biophys. Acta*, **161**, 352 (1968).
(4) L. Saure, *Chem. Ber.*, **83**, 335 (1950); S. O. Winthrop and G. A. Grant, U.S. Patent 2 767 180 (Oct 16, 1956); *Chem. Abstr.*, **51**, 7444*d* (1957).
(5) G. I. Braz, V. K. Antonov, and K. N. Kurdyumova, *Zh. Obshch. Khim.*, **28**, 2972 (1958); *Chem. Abstr.*, **53**, 9240*i* (1959).
(6) Many *N*-acyl-3,3-di- or 2,3,3-trisubstituted 2-chloro (or other electron attracting group substituted) indolines from corresponding indolenines have been reported: "The Chemistry of Heterocyclic Compounds", Interscience, New York, N.Y., 1954, p 46, and references cited therein.
(7) The ratio was estimated on the basis of the signals of the olefinic and the hydroxy protons in the NMR spectrum. The ratio was not changed in a NMR sample tube kept for 1 week.
(8) The same manner as ref 7 for the estimation.
(9) The compound was extremely unstable and lost weight during weighing in preparation for the microanalysis owing to atmospheric hydrolysis to benzylamine hydrochloride.
(10) The calculated values for the cyanuric chloride salt, $PhCH_2{}^+N(R)$=$C(Cl^-)(CH_3)_2$·$C_{13}H_{13}Cl_3N_4$, are C, 47.58; H, 3.92; N, 16.89.
(11) The liquid was solidified within 30 min, mp 66–68 °C.

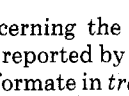
Ethoxycarbonylnitrene Insertion Selectivity. Photolysis of Ethyl Azidoformate in Bicyclo[4.*n*.0]alkanes and in Alkylcyclohexanes

Paolo A. Tardella* and Lucio Pellacani

Istituto di Chimica Organica (I Cattedra) dell'Università, 00185 Roma, Italy

Received February 9, 1976

We first observed the influence of halogenated solvents in lowering the insertion selectivity of ethoxycarbonylnitrene (EtOCON) generated by the thermal decomposition of ethyl azidoformate ($EtOCON_3$) toward the C–H bonds of *cis*- and *trans*-decalins.[1] Assuming stabilization of the singlet nitrene by dichloromethane, a possible explanation is that the triplet nitrene inserts into the tertiary C–H bonds of these hydrocarbons.[2] Later, Brinkmann et al.[3] found by the CIDNP technique during the thermolysis of ethyl azidoformate in *trans*-decalin an emission signal indicating the intermediacy of a radical pair. However, the multiplicity of the reactive intermediate, i.e., whether a triplet or a singlet diradical nitrene generates ·NHCOOEt, remained an open question.



Another case concerning the same effect of the dichloromethane has been reported by Belloli et al.[4] for the thermolysis of ethyl azidoformate in *trans*-1,2-dimethylcyclohexane (TDCH). The proportion of tertiary product to other isomers