was sublimed in vacuo to give the pure amide: mp 149 °C (lit.[37] mp 151–152 °C); MS *m/e* 137 (M).

Anal. Calcd for $C_6H_7N_3O$: C, 52.54; H, 5.15. Found: C, 52.66; H, 5.12.

Method B. Into a solution of 3-aminopyridine-4-carboxylic acid azide (**19**, 0.15 g) in ethanol (5 mL) hydrogen sulfide was introduced for 30 min. The precipitated sulfur was filtered off, and the solution was evaporated to dryness to give the amide, mp 148 °C. The compound was found to be identical in all respects with the product obtained as described in method A.

Pyrido[3,4-*d*]-*v*-triazin-4(3*H*)-one (22). A solution of the above amide (**21**, 0.137 g) in glacial acetic acid (5 mL) was treated with sodium nitrite (69 mg) in a little water while stirring. The product which separated was filtered off and had mp 251 °C dec; ^{1}H NMR (Me_2SO-d_6) δ 8.14 (dd, H_5, $J_{5,6}$ = 5.1, $J_{5,8}$ = 0.9 Hz), 9.11 (d, H_6), 9.64 (d, H_8); MS *m/e* 148 (M).

Anal. Calcd for $C_6H_4N_4O$: C, 48.65; H, 2.72. Found: C, 49.03; H, 2.99.

Reaction between 2-Aminopyridine-3-carboxylic Acid Hydrazide and Ethyl Acetoacetate to Give 23. 2-Aminonicotinic acid hydrazide (**1**, 0.5 g), ethyl acetoacetate (0.43 g), ethyl acetate (60 mL), and a drop of triethylamine were heated under reflux for 3 h. The reaction mixture was evaporated to dryness in vacuo, the residue was treated with benzene, and the separated product was filtered off and crystallized from benzene: yield 0.45 g; mp 99–101 °C; ^{1}H NMR (Me_2SO-d_6) δ 7.75 (dd, H_4, $J_{4,5}$ = 8.0, $J_{4,6}$ = 1.8 Hz.), 6.60 (dd, H_5, $J_{5,6}$ = 5.0 Hz), 8.17 (dd, H_6), 2.0 (s, Me), 3.40 (s, CH_2CO_2Et).

Anal. Calcd for $C_{12}H_{16}N_4O_3$: C, 54.55; H, 6.10; N, 21.10. Found: C, 55.01; H, 6.47; N, 21.01.

Reaction between 2-Aminopyridine-3-carboxylic Acid Hydrazide and Ethyl Benzoylacetate. A mixture of the hydrazide (**1**, 0.5 g), ethyl benzoylacetate (0.65 g), and diethylene glycol dimethyl ether (10 mL) was heated at 160 °C for 2 h. After about 1 h of heating, crystals started to separate. The product was filtered off and had mp over 290 °C (yield 0.11 g). The tricyclic product (**24**) showed the following spectrum: ^{1}H NMR (Me_2SO-d_6, 147 °C) δ 6.45 (s, H_3), 8.85 (dd, H_6, $J_{6,7}$ = 4.0, $J_{6,8}$ = 1.8 Hz), 8.40 (dd, H_7, $J_{7,8}$ = 8.0 Hz), 8.70 (dd, H_8), 8.10 and 7.5 (m, Ph).

Anal. Calcd for $C_{15}H_{10}N_4O$: C, 68.69; H, 3.84; N, 21.37. Found: C, 68.51; H, 4.30; N, 21.19.

The filtrate was evaporated in vacuo to dryness, and the residue was suspended in *n*-hexane, filtered, and washed with ethanol. The product (**25**) was crystallized from ethanol: yield 0.45; mp 209–212 °C; ^{1}H NMR (Me_2SO-d_6) δ 7.85 (dd, H_4, $J_{4,5}$ = 7.5, $J_{4,6}$ = 1.8 Hz), 6.75 (dd, H_5, $J_{5,6}$ = 4.5 Hz), 8.10 (dd, H_6), 2.30 (s, Me), 7.85 and 7.4 (m, Ph).

Anal. Calcd for $C_{14}H_{14}N_4O$: C, 66.12; H, 5.55; N, 22.04. Found: C, 65.99; H, 5.08; N, 21.65.

Registry No.—1 (R_1 = R_2 = H), 5327-31-1; 1 (R_1R_2 = CHPh), 64189-07-7; **2**, 64189-06-6; **3**, 16328-62-4; **4**, (R_1 = R_2 = H), 64189-05-5; **4** (R_1R_2 = $CHNMe_2$), 64189-04-4; **5** (R = H), 37554-48-6; **5** (R = HCO), 64189-03-3; **7**, 13438-65-8; **8**, 64189-01-1; **9**, 3303-28-4; **10**, 64201-58-7; **11**, 37554-49-7; **12**, 64189-02-2; **13**, 64189-10-2; **14**, 64189-09-9; **15**, 64189-08-8; **16**, 64188-99-4; **17**, 64189-00-0; **18** (R = H), 64201-55-4; **18** (R = HCO), 64201-57-6; **19**, 64188-98-3; **20**, 7397-68-4; **21**, 64188-97-2; **22**, 64188-96-1; **23**, 64188-95-0; **24**, 64188-94-9; **25**, 64188-93-8; *N,N*-dimethylformamide dimethyl acetal, 4637-24-5; formic acid, 64-18-6; anthranilamide, 88-68-6; triethyl orthoformate, 122-51-0; 9-dimethylaminomethylene derivative, 64188-92-7; benzenediazonium tetrafluoroborate, 369-57-3; benzaldehyde, 100-52-7; ethyl 3-aminopyridine-4-carboxylate, 14208-83-4; ethyl acetoacetate, 141-97-9; ethyl benzoylacetate, 94-02-0.

References and Notes

(1) Heterocycles. Part 168.
(2) B. Stanovnik and M. Tišler, *Synthesis*, 120 (1974).
(3) B. Stanovnik and M. Tišler, *Croat. Chem. Acta*, **44**, 243 (1972).
(4) W. J. Irwin and D. G. Wibberley, *Adv. Heterocycl. Chem.*, **10**, 149 (1969).
(5) K. Babič, S. Molan, S. Polanc, B. Stanovnik, J. Stres-Bratoš, M. Tišler, and B. Verček, *J. Heterocycl. Chem.*, **13**, 487 (1976).
(6) B. Jenko, B. Stanovnik, and M. Tišler, *Synthesis*, 833 (1976).
(7) J. Faganeli, S. Polanc, B. Stanovnik, and M. Tišler, *Croat. Chem. Acta*, **48**, 161 (1976).
(8) M. Zupan, V. Pirc, A. Pollak, B. Stanovnik, and M. Tišler, *J. Heterocycl. Chem.*, **11**, 525 (1974).
(9) S. Polanc, B. Verček, B. Šek, B. Stanovnik, and M. Tišler, *J. Org. Chem.*, **39**, 2143 (1974).
(10) S. Gorjan, B. Klemenc, M. Starič, B. Stanovnik. and M. Tišler, *Monatsh. Chem.*, **107**, 1199 (1976).
(11) S. Polanc, B. Stanovnik, and M. Tišler, *J. Org. Chem.*, **41**, 3152 (1976).
(12) For a review on the utility of heterocyclic diazo compounds in organic synthesis see M. Tišler and B. Stanovnik, *Heterocycles*, **4**, 1115 (1976).
(13) B. Stanovnik, M. Tišler, S. Polanc, V. Kovačič-Bratina, and B. Špicer-Smolnikar, *Tetrahedron Lett.*, 3193 (1976).
(14) M. Kočevar, D. Kolman, H. Krajnc, S. Pólanc, B. Porovne, B. Stanovnik, and M. Tišler, *Tetrahedron*, **32**, 725 (1976).
(15) M. Jurgec, M. Kovačič, B. Stanovnik, M. Tišler, and M. Volk, *J. Heterocycl. Chem.*, **12**, 253 (1975).
(16) M. Kovačič, S. Polanc, B. Stanovnik, and M. Tišler, *J. Heterocycl. Chem.*, **11**, 949 (1974).
(17) A. Gorup, M. Kovačič, B. Kranjc-Škraba, B. Mihelčič, S. Simonič, B. Stanovnik, and M. Tišler, *Tetrahedron*, **30**, 2251 (1974).
(18) D. Fortuna, B. Stanovnik, and M. Tišler, *J. Org. Chem.*, **39** 1933 (1974).
(19) For a review on some aspects of azido–tetrazolo isomerizations and previous references see M. Tišler, *Synthesis*, 123 (1973).
(20) T. J. Batterham, "NMR Spectra of Simple Heterocycles", Wiley, New York, N.Y., 1973, p 483.
(21) A. Hetzheim and K. Möckel, *Adv. Heterocycl. Chem.* **7**, 183 (1966).
(22) R. W. Leiby and N. D. Heindel, *J. Org. Chem.*, **42**, 161 (1977).
(23) M. Vincent, J. Maillard, and M. Benard, *Bull. Soc. Chim., Fr.*, 1580 (1962).
(24) B. Stanovnik and M. Tišler, *Org. Prep. Proced. Int.*, **4**, 55 (1972).
(25) T. Curtius, *J. Prakt. Chem.*, **50**, 281 (1894).
(26) R. Stolle, *Ber. Dtsch. Chem. Ges.*, **46**, 260 (1913).
(27) P. W. Wiley, *J. Am. Chem. Soc.*, **76**, 5176 (1954).
(28) L. Horner and H. Fernekess, *Chem. Ber.*, **94**, 712 (1961).
(29) B. Stanovnik, M. Tišler, S. Polanc, and J. Žitnik, *Synthesis*, 491 (1977).
(30) G. Heller, *J. Prakt. Chem.*, **111**, 36 (1925).
(31) G. Heller, *J. Prakt. Chem.*, **116**, 9 (1927).
(32) K. H. Menzel, R. Pütter, and G. Wolfrum, *Angew. Chem.*, **74**, 839 (1962).
(33) V. Oakes, R. Pascoe, and H. N. Rydon, *J. Chem. Soc.*, 1045 (1956).
(34) D. Harrison and A. C. B. Smith, *J. Chem. Soc.*, 3157 (1959).
(35) E. C. Taylor and A. J. Crovetti, *J. Org. Chem.*, **19**, 1633 (1954).
(36) G. B. Barlin, *J. Chem. Soc. B*, 285 (1966).
(37) H. H. Fox, *J. Org. Chem.*, **17**, 542 (1952).

Stable Arene Imines

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Received June 13, 1977

The syntheses of stable *N*-alkyl arene imines are described. The general route to 1-butyl-, 1-cyclohexyl-, and 1-benzyl-1a,9b-dihydrophenthr[9,10-*b*]azirine includes the reaction of phenanthrene 9,10-oxide with the appropriate amine followed by cyclodehydration of the amino alcohol with PPh_3–CCl_4 reagent. The preparation of 1-acetyl-1a,11b-dihydrochrysen[5,6-*b*]azirine from *trans*-6-acethoxy-5-acetylamino-5,6-dihydrochrysene and NaH is described as an example of an unstable arene imine that rearranges at room temperature to the corresponding *N*-acetyl aryl amine.

It is widely accepted that polycyclic aromatic hydrocarbons exert their carcinogenic properties through metabolically induced binding to tissue constituents.[1] Arene oxides are generally described as the primary intermediates that alkylate amino acid and nucleic acid residues to form hydrocarbon-bound cell substances with new C–O, C–S, or C–N linkages.[2]

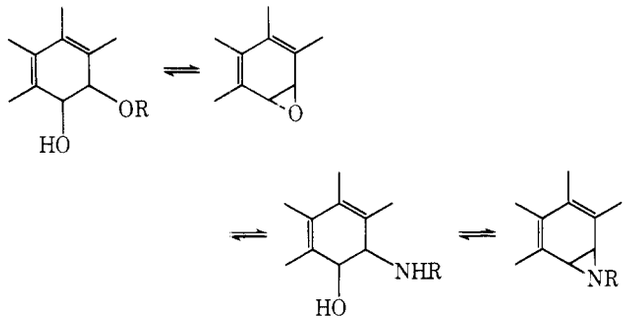
0022-3263/78/1943-0397$01.00/0

Table I. ^{1}H NMR Spectra of some 10-Alkylamino-9,10-dihydrophenanthr-9-ols (2)[a,b]

Compd 2, R =	Registry no.	Chemical shifts, δ (ppm)		
		$H_{(9)}$	$H_{(10)}$	Alkyl protons
n-Butyl[c]	64188-67-6	4.62 (d)	3.74 (d, $J_{9,10}$ = 7 Hz)	2.50 (t, J = 8 Hz, N-CH_2), 1.10–1.68 [m, $(CH_2)_2$], 0.88 (t, J = 5 Hz, CH_3)
tert-Butyl	64188-57-4	4.10 (d)	3.52 (d, $J_{9,10}$ = 10 Hz)	1.50 (s, CH_3)
Cyclohexyl	64188-68-7	4.36 (d)	3.72 (d, $J_{9,10}$ = 10 Hz)	2.42 (m, N-CH), 0.85–1.92 (m, cyclohexyl)
Benzyl	64188-69-8	4.52 (d)	3.68 (d, $J_{9,10}$ = 8 Hz)	3.81 (s, N-CH_2)

[a] In $CDCl_3$ + Me_4Si. [b] The NH and OH protons appear as broad signals between 2.40 and 2.80 ppm. [c] This compound has been reported by Dey and Neumeyer (ref 18).

Chart I

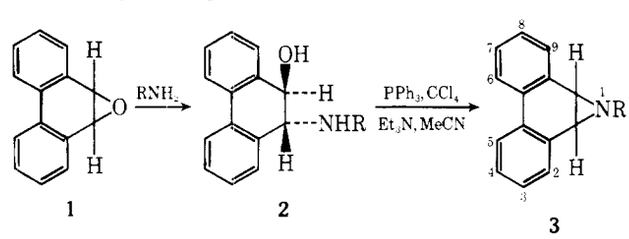


R = peptide or nucleic acid residue

Thus, upon reversing these alkylations there may be formed not only the original arene oxides, but also the analogous arene imines (Chart I). This hypothesis concerning the existence of aziridines as transient intermediates in chemical carcinogenesis finds some support in the observation that β-amino alcohols can be metabolized to aziridines.[3]

Recently,[4] we announced briefly the synthesis of the first *N*-acetylphenanthrene imine and Shudo and Okamoto[5] reported the corresponding *N*-tosyl derivative. Imines of higher polycyclic hydrocarbons were prepared as well (vide infra). However, these compounds which have electron-attracting groups attached to the nitrogen atom proved to rearrange readily at ambient temperature to aromatic amines and are therefore unsuitable for biological tests. In this study, we find that arene imines which have electron-donating substituents on the aziridine nitrogen are perfectly stable. The synthesis is accomplished simply by reacting an arene oxide with an appropriate amine followed by PPh_3–CCl_4–Et_3N cyclodehydration[6] of the *trans*-amino alcohol[7] intermediate.

The application of this method to 1-butyl-, 1-cyclohexyl-, and 1-benzyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine is illustrated by the sequence of transformations **1** → **2** → **3**.

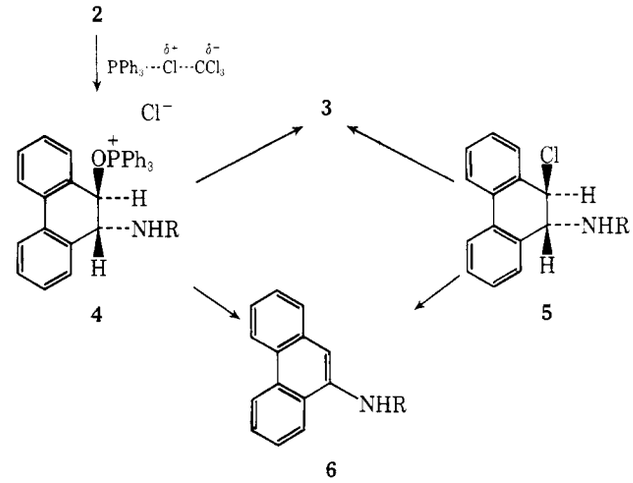


a, R = *n*-butyl
b, R = cyclohexyl
c, R = benzyl

While the first step seems to be hardly affected by the geometry of the amine, conversion of **2** into **3** is very sensitive to steric effects so that 10-*tert*-butylamino-9,10-dihydrophenanthr-9-ol [**2**, R = $C(CH_3)_3$] fails to cyclize to the respective aziridine.

Attempts to obtain **3** by a stepwise transformation of **2** to haloamine **5**, followed by cyclodehydrohalogenation, resulted in rapid aromatization to the substituted 9-aminophenanthrene (**6**). This provides support for the mechanism proposed by Appel and Kleinstück[6] which does not include a 10-halogeno-9-amine-9,10-dihydrophenanthrene intermediate (Chart II). Small amounts of *N*-alkyl-9-aminophenanthrenes (**6**) that were obtained as side products are assumed to be formed by HCl addition to **3** or, more likely, by loss of triphenylphosphine oxide from intermediate **4**.

Chart II



The structures of the amino alcohols **2** and the imines **3** were deduced from the elementary and spectral analyses. The most indicative feature of the mass spectra of both compounds **2** and **3** is the intense fluorenyl peak (usually base peak) *m/e* 165. This ion is characteristic for 9,10-dihydrophenanthrene derivatives but is absent in the fully aromatic system.[8] While the aziridines **3** form distinctive molecular ions, the amino alcohols readily loose water and give $[M - H_2O]^{+\cdot}$ ions which are more abundant than $M^{+\cdot}$.

Some ^{1}H NMR data for compounds **2** and **3** are listed in Tables I and II. As expected, the chemical shift of $H_{(9)}$ in **2** is sensitive to the geometry of the polycyclic system. The magnetic anisotropy effect is less pronounced in the distorted *N*-*tert*-butyl- and *N*-cyclohexylamino alcohols than in **3a** and **3c**.

The ring protons in the rigid arene imines **3** resonate at lower field than those of flexible aziridines. While, e.g., *cis*-1-ethyl-2,3-diphenylaziridine shows up at ~2.79 ppm,[9] the peaks of $H_{(1a)}$ and $H_{(9b)}$ of **3a–c** are below 2.97 ppm. This deshielding is somewhat smaller than reported[10] for the corresponding oxiranes (the oxirane protons of phenanthrene 9,10-oxide and *cis*-stilbene oxide resonate at 4.67 and 4.19 ppm, respectively[10]) owing to the greater interaction of the nitrogen lone pair with the aromatic π electrons.

The aromatic protons in phenanthrene-9,10-imines (**3**) show two well-separated multiplets of which the low-field complex is assigned to $H_{(5)}$ and $H_{(6)}$.

The high-field absorption (2.05 ppm) of the α-*N*-cyclohexyl

Table II. ^{1}H NMR, UV, and Mass Spectra of some 1-Alkyl-1a,9b-dihydrophenanthr[9,10-*b*]azirines (3)

Compd	Registry no.	^{1}H NMR, δ (ppm)[a]	UV λ_{max}, nm (log ε)[b]	Major fragment ions *m/e* (rel intensity)
3a	64188-66-5	0.88 (t, J = 5 Hz, CH_3), 1.20–1.72 [m, $(CH_2)_2$], 2.54 (t, J = 8 Hz, N-CH_2), 2.97 (s, $H_{(1a,9b)}$) 7.94 (m, $H_{(5,6)}$)	239 (3.82), 271 (3.99), 277 (4.01), 281 (4.00), 288 (3.68), 295 (3.67), 306 (3.58)	249 (60), 206 (100), 178 (31), 165 (30)
3b	64188-65-4	1.00–2.00 (m, cyclohexyl), 2.05 (m, N-CH_2), 3.03 (s, $H_{(1a,9b)}$), 7.96 (m, $H_{(5,6)}$)	242 (3.58), 269 (3.99), 274 (4.00), 280 (3.99), 287 (3.86), 292 (3.69), 305 (3.50)	275 (76), 232 (38), 178 (62), 165 (100)
3c	64188-64-3	3.19 (s, $H_{(1a,9b)}$), 3.75 (s, N-CH_2), 8.04 (m, $H_{(5,6)}$)	225 (4.10), 239 (3.86), 272 (3.96), 275 (3.97), 281 (3.95), 288 (3.80), 295 (3.64), 305 (3.49)	283 (100), 192 (86), 178 (77), 165 (94)

[a] In $CDCl_3$ + Me_4Si. [b] Compound **3a** and **3c** were recorded in cyclohexane and **3b** in $CHCl_3$.

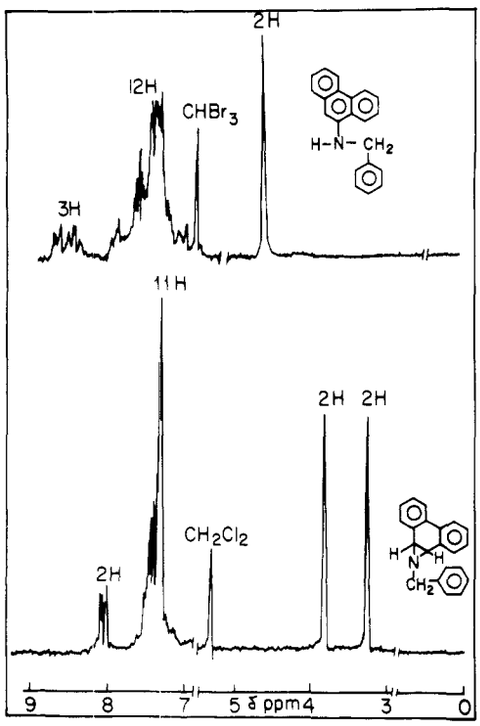


Figure 1. 100-MHz ^{1}H NMR spectra of 1-benzyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine (**3c**) at 31 °C in CD_2Cl_2, and (after rearrangement) at 140 °C in $CDBr_3$.

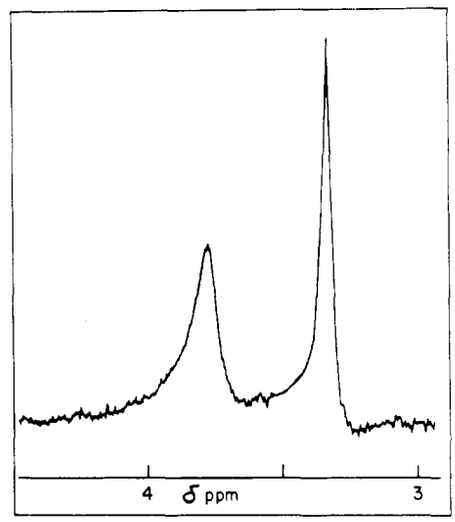
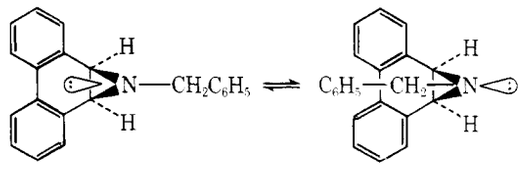


Figure 2. ^{1}H NMR signals of $H_{1a}H_{9b}$ (narrow line) and benzylic protons (broad peak) of **3c** at −98 °C.

proton of **3b** exceeds the upper-field limit for an equatorial cyclohexylamine hydrogen.[11] Since the flexibility of the heavily substituted cyclohexane ring is rather restricted, it may be suggested that the nitrogen (and the aziridine ring) is virtually equatorial.

The assignment of the two singlets (3.19 and 3.75 ppm) in the ^{1}H NMR spectrum of 1-benzyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine (**3c**) (Figure 1) was accomplished by the aid of ^{13}C NMR spectroscopy. The aziridine ring and methylene carbon atoms resonate at δ 48.97 and 67.75 ppm, respectively. On off-resonance decoupling $C_{(1a)}$ and $C_{(9b)}$ appear as a doublet, while the benzylic CH_2 carbon forms a triplet. Thus, by off-resonance decoupling techniques at various decoupler offsets the ^{1}H NMR peak at 3.75 ppm is found, unequivocally, to arise from the methylene, and the singlet at 3.19 ppm arises from the vicinal aziridine-ring protons. Further confirmation to this assignment is obtained from the ^{1}H NMR spectra of **3a** and **3b** which have only one singlet in the vicinity of 3 ppm.

The CH_2 signals of **3c** in both ^{1}H and ^{13}C NMR spectra broaden upon lowering the temperature. The effect on the ^{1}H NMR singlet is larger than on the ^{13}C peak (see Figure 2). This phenomenon is attributed to inversion of the aziridine nitrogen by which a mixture of the two invertomers **7** and **8** result.



7 **8**

Owing to symmetry factors associated with the *cis*-aziridine structure, the $CH_{(1a)}$ and $CH_{(9b)}$ peaks remain almost unchanged. It may thus be concluded that the reason for the line broadening is not just a viscosity effect. The chemical shift (3.75 ppm) reflects, therefore, the relative contribution of the exo and endo structures **7** and **8** to the equilibrium mixture.

Solvent effect on the ^{1}H NMR spectrum of **3c** has been studied and deserves some attention. Deuterated benzene, toluene, as well as CS_2 that have high π-electron densities are assumed to be repelled by the aziridine nitrogen lone pair.[12] Thus, an approach of the solvent from the opposite direction shields the aziridine protons (see Table III). The effect is largest in $CD_3C_6D_5$ (hyperconjugation) and smallest in the relative π-electron poor CS_2. The opposite effect of C_5D_5N can

Table III. ^{1}H NMR Spectra of 1-Benzyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine (3c) in Various Solvents at 100 MHz

Solvent	$H_{(1a,9b)}$[a]	$\Delta H_{(1a,9b)}$[b]	CH_2[a]	ΔCH_2[b]	$H_{(5,6)}$[a]	$\Delta H_{(5,6)}$[b]
CCl_4	300.9	0	370.2	0	797.0	0
$CDCl_3$	318.8	+17.9	382.1	+11.0	795.9	−1.1
CD_2Cl_2	318.0	+17.1	375.1	+4.9	801.1	+4.1
CS_2	296.4	−5.6	364.5	−5.7	786.6	−10.4
C_6D_6	277.6	−22.3	345.1	−24.7	783.3	−13.7
C_7D_8	274.6	−25.3	343.6	−26.6	773.1	−23.9
C_5D_5N	328.8	+27.3	377.1	+6.9	812.2	+15.2

[a] Chemical shifts in Hz from Me_4Si internal reference. [b] As compared with CCl_4.

be rationalized by the considerable accumulation of positive charge on $C_{(2)}$ and $C_{(6)}$ of the pyridine molecule. This causes attraction of the solvent by the aziridine lone pair and deshielding of the ring protons. The effect of $CDCl_3$ on aziridine ^{1}H NMR has been well documented.[13] The CCl_3 group is linked via a D bond to the nonbonding orbital and causes moderate deshielding. A similar effect is observed in CD_2Cl_2.

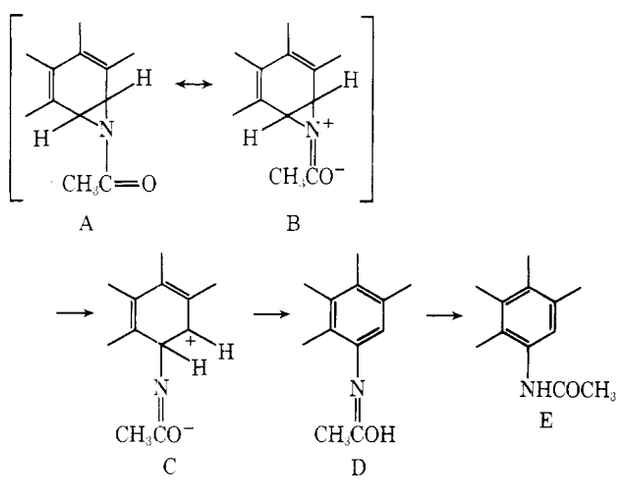
As noted, the *N*-alkyl arene imines **3a–c** are stable and do not rearrange below 100 °C. However, at 114 °C (in $CDBr_3$) the ^{1}H NMR indicates slow conversion into 9-aminophenanthrenes. At 140 °C the aromatization is instantaneous (see Figure 1).

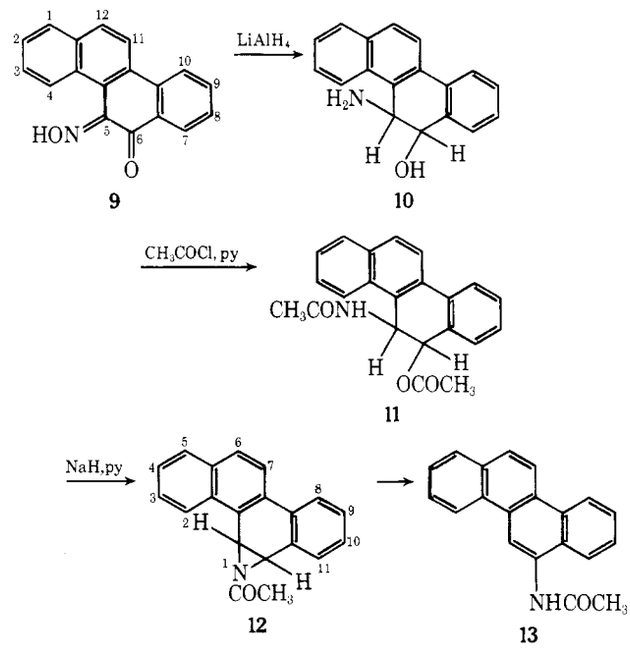
It is remarkable that the *N*-alkyl arene imines are also stable toward strong acids. ^{1}H NMR measurements conducted in $CDCl_3/CF_3COOH$ at room temperature indicate protonation of the nitrogen atom without ring opening. The corresponding chemical shifts for (a) *N*-butyl- and (b) *N*-cyclohexyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine are (a) δ 0.95 (t, 3, J = 4 Hz), 1.17–1.96 (m, 4), 3.36 (m, 2), 4.59 (d, J = 3 Hz), 6.33 (1, m), 7.32–8.12 (m, 8); and (b) 1.14–2.36 (m, 10), 2.74 (m, 1), 4.59 (s, 2), 6.55 (m, 1), 7.42–8.07 (m, 8) ppm. The main changes that occur in the UV spectra of imines **3** upon protonation is the disappearance of the 305-nm band and the appearance of a strong absorption at 255–265 nm.

In contrast to *N*-alkyl arene imines, the *N*-acetyl analogues readily rearrange to aromatic *N*-acetylamines. We assume that the difference in stability is associated with the existence of the mesomeric form B shown in Chart III, in which the high order of the imine carbonyl N–C bond has a weakening effect on the ring N–C linkages. In aliphatic aziridines, intermediates of type C usually undergo cyclization to oxazoline derivatives.[14] In the aromatic series, rearrangement to D (tautomers of the *N*-acetyl aryl amine E) predominates due to obvious thermodynamic reasons.

In addition to 1-acetyl-1a,9b-dihydrophenanthr[9,10-*b*]-azirine, which has been announced in our preliminary communication,[4] we attempted the preparation of some higher polycyclic *N*-acetyl arene imines; for example, chrysene-5,6-quinone 5-monoxime (**9**) was reduced with lithium aluminum hydride to 5-amino-5,6-dihydrochrysen-6-ol (**10**). The *N*-acetylamino acetate **11** was then treated at 25 °C with sodium hydride, but the resulting 1-acetyl-1a,11b-dihydrochrysen[5,6-*b*]azirine (**12**) proved to rearrange under these conditions to 6-acetylaminochrysene (**13**) of mp 301 °C[15] (free of any 5-acetylamino isomer of mp 250 °C[16]). The best evidence for the formation of imine **12** was obtained from an experiment in which the cyclodeacetylation of **11** → **12** was carried out in pyridine-d_5 in an NMR tube, and the spectrum of the reaction mixture was recorded on a CFT-20 instrument every 30–70 min. The characteristic bands of **11** at 1.39, 2.42, 2.86, and 6.21 ppm gradually disappeared and the imine spectrum, δ 2.50, 4.33, and 4.55 ppm, was built up. The highest intensities of the peaks of **12** were obtained after 70 min. After this period the spectrum of 6-acetylaminochrysene (**13**) prevailed.

Chart III





The structure of the starting oxime **9** was established by virtue of the significant peak m/e 152 $[C_{10}H_6N]^+$ in the mass spectrum. The second possible isomer, viz., chrysene-5,6-quinone 6-oxime would, by similar fragmentation, give rise to ion $[C_6H_4CN]^+$ of m/e 102 which, however, is not present in the spectrum. It is thus interesting to note that the nitrogen atom migrates from $C_{(5)}$ in the oxime to $C_{(6)}$ in the final acetyl amine derivative. This migration doubtlessly occurs via the cyclic arene imine intermediate.

Experimental Section

General. Melting points were taken either on a Buchi capillary melting point apparatus or on a Fisher hot plate instrument and are

not corrected. Infrared and ultraviolet spectra were obtained on a Perkin-Elmer Model 157 and a Unicam SP-800 spectrophotometer, respectively. Proton magnetic resonance spectra were run using Varian EM-360, HA-100D, and CFT-20 spectrometers. The latter instrument, equipped with a Fourier transformer, was also used for the recording of ^{13}C magnetic resonance spectra. Mass spectra were obtained with the aid of a Varian MAT-311 instrument at 70 eV. Preparative thin-layer chromatography was performed with plates precoated with Merck alumina type T.

10-Benzylamino-9,10-dihydrophenanthr-9-ol (2c). A mixture of 1.94 g (10 mmol) of phenanthrene 9,10-oxide (**1**)[17] and 2.14 g (20 mmol) of benzylamine was stirred at 80–90 °C under N_2 for 6 h. The reaction mixture was left at room temperature for 16 h and excess benzylamine removed in vacuo. The oily residue proved by NMR analysis (see Table I) to be essentially pure. The major fragment ions in the mass spectrum are: *m/e* (rel intensity) 301 (M^+, 19), 283 (69), 194 (59), 165 (100).

When a solution of the amino alcohol in a tenfold volume of EtOH was treated with gaseous HCl, the colorless hydrochloride separated in quantitative yield, mp 226 °C (from acetonitrile). Anal. Calcd for $C_{21}H_{20}ClNO$: C, 74.7; H, 5.9; Cl, 10.5; N, 4.1. Found: C, 74.9; H, 5.9; Cl, 10.5; N, 4.4.

10-*n*-Butylamino-,[18] 10-cyclohexylamino-, and 10-tert-butylamino-9,10-dihydrophenanthr-9-ol were obtained in the same manner by heating **1** in the appropriate amine for 5 h at 75 °C, 5 h at 90 °C, and 48 h at 43 °C, respectively.

1-Benzyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine (3c). To a solution of 301 mg (1 mmol) of **2c** in 1 mL of acetonitrile were added succesively 270 mg (1.2 mmol) of freshly crystallized PPh_3, 0.2 mL of Et_3N, and 0.5 mL of CCl_4 (all solvents were dried and freshly distilled). The mixture was stirred under N_2 at 70 °C for 3 h, and then cooled and left to stand at room temperature for 16 h. Cold water was added to dissolve excess triethylamine and its hydrochloride. The organic layer was diluted with 15 mL of $CHCl_3$, washed twice with cold water, dried (K_2CO_3), and concentrated. Upon addition of ether to the residue, 113 mg of colorless imine separated immediately. A second crop of pale yellow compound was further purified by preperative TLC on Merck alumina type T (hexane–ether mixture, 5:1, served as eluent). The total yield of pure **3c** was 42%, mp 128 °C (from methylcyclohexane). Anal. Calcd for $C_{21}H_{17}N$: C, 89.0; H, 6.0; N, 4.9. Found: C, 89.0; H, 6.3; N, 4.7.

1-Butyl-1a,9b-dihydrophenanthr[9,10-b]azirine (3a) was obtained in 40% yield by the same method, mp 87 °C (from methylcyclohexane). Anal. Calcd for $C_{18}H_{19}N$: C, 86.7; H, 7.6. Found: C, 86.4; H, 7.5. Conversion of **2c** into **1-cyclohexyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine (3b)** was affected similarly but 100% excess PPh_3 and 6 h heating were required, mp 123 °C (from methylcyclohexane). Anal. Calcd for $C_{20}H_{21}N$: C, 87.3; H, 7.6; N, 5.1. Found: C, 87.3; H, 7.4; N, 4.8.

Additional physical data of **3a–c** are listed in Table II.

***trans*-5-Amino-5,6-dihydrochrysen-6-ol (10).** Powdered chrysene-5,6-quinone 5-oxime (**9**)[19] (2.73 g, 10 mmol) was added in small portions under N_2 to a stirred suspension of 1.14 g (30 mmol) of lithium aluminum hydride in 200 mL of dry ether. After the initial exothermic reaction ceased the mixture was refluxed for 6 h, during which the color changed from bright green to dark tan. Excess reagent was decomposed with 5 mL of acetone followed by 100 mL of aqueous sodium tartarate (2 M). The aqueous layer was extracted twice with 100 mL of benzene. The combined organic layers were washed with water, dried (K_2CO_3) and concentrated to a volume of 20 mL. Addition of 25 mL of hexane afforded 1.93 g (74%) of colorless amino alcohol **10**. The analytical sample was recrystallized from a mixture of benzene–hexane: mp 123 °C; IR (Nujol) 3300, 3280, 3200 cm^{-1} (NH, OH); ^1H NMR ($CDCl_3$) δ 2.58 (br s, 3), 4.50 (m, 1), 5.60 (d, 1 J = 5 Hz), 7.60–8.62 ppm (m, 10); MS *m/e* (rel intensity) 261 (M^+, 13), 246 (100), 228 (28), 215 (57). Anal. Calcd for $C_{18}H_{15}NO$: C, 82.8; H, 5.8; N, 5.4. Found: C, 82.5; H, 6.0; N, 5.1.

***trans*-6-Acetoxy-5-acetylamino-5,6-dihydrochrysene (11).** A mixture of 10 mL of acetic anhydride and 15 mL of dry pyridine was refluxed for 15 min and added to a cold solution of 1.30 g (50 mmol) of **10** in 15 mL of pyridine. The mixture was stirred at room temperature for 24 h. The cream-colored precipitate was recrystallized from toluene to yield 1.72 g (100%) of **11**: mp 301 °C; IR (Nujol) 3250 (NH), 1760 (ester carbonyl), 1640 cm^{-1} (amide); UV λ_{max} (log ε)(CH_3CN) 256 (4.68), 266 (4.84), 294 (4.06), 305 (4.13), 317 (4.03), 340 nm (2.83); ^1H NMR (pyridine-d_5) δ 1.39 (s, 3), 2.42 (s, 3), 2.86 (m, 1) 4.73 (br s, 2), 6.21 (d, 1 J = 5 Hz), 7.19–8.69 ppm (m, 10); MS *m/e* (rel intensity) 345 (M^+, < 1), 285 (77), 243 (100), 215 (82). Anal. Calcd for $C_{22}H_{19}NO_3$: C, 76.5; H, 5.5; N, 4.1. Found: C, 76.0; H, 5.5; N, 4.2.

Reaction of 11 with Sodium Hydride. (a) A mixture of 345 mg (1 mmol) of **11**, 2 mmol of NaH (freshly washed with pentane to remove mineral oil), and 50 mL of pyridine was stirred under N_2 at room temperature for 8 h. Ethanol was added to the green solution to decompose excess NaH. A small amount of solids was removed by filtration, and the filtrate was evaporated under reduced pressure to dryness. The residue was recrystallized from acetic acid to yield 240 mg (84%) of 6-acetylaminochrysene (**13**), mp 300–301 °C (lit.[15] 299.5–301 °C); IR (Nujol) 3240 (NH), 1640 cm^{-1} (amide); ^1H NMR (pyridine-d_5) δ 2.56 (s, 3), 7.56–8.77 ppm (m, 11); MS *m/e* (rel intensity) 285 (M^+ 37), 243 (100), 219 (90). The same result was also obtained when the above reaction mixture was refluxed for 5 min.

(b) A high-precision NMR tube was charged with 2 mg of **11**, 1 mL of pyridine-d_5, and 1 mg of sodium hydride (80% in mineral oil) and sealed under N_2. The ^1H NMR spectrum was recorded on a CFT-20 instrument (with Fourier transformer)(31 °C) every 30–70 min. The initial spectrum consisted of the bands of **11** (vide supra) and those of mineral oil. The second recording indicated new peaks at δ 2.50, 4.33, and 4.55 ppm which are attributed to the acetyl and aziridinering protons of **1-acetyl-1a,11b-dihydrochrysen[5,6-*b*]azirine (12)**, as well as small peaks of **13**. After 70 min the spectrum of **12** diminished and that of **13** prevailed. Finally (3 h), only the spectrum of 6-acetylaminochrysene could be observed.

***trans*-9-Acetoxy-10-acetylamino-9,10-dihydrophenanthrene.** *trans*-10-Amino-9,10-dihydrophenanthr-9-ol[4,5] was converted in quantitative yield into the corresponding acetoxyacetylamine by the method described above for **11**: mp 176 °C (from aqueous MeOH); IR (Nujol) 3270 (NH), 1732 (ester carbonyl) 1645 cm^{-1} (amide); UV λ_{max} (log ε)(EtOH) 220 (4.72), 273 (4.30), 285 nm (4.08); ^1H NMR ($CDCl_3$) δ 2.10 (s, 6), 5.62 (d, 1 J = 4 Hz), 5.82 (m, 1), 6.10 (d, 1 J = 4 Hz), 7.33–7.93 ppm (m, 8); (C_6D_6) δ 1.28 (s, 3), 1.39 (s, 3), 4.98 (d, 1 J_{CHCH} = 5 Hz), 5.62 (dd, 1 J_{CHCH} = 5, J_{CHNH} = 9 Hz), 6.22 (d, 1 J_{CHCH} = 5 Hz), 7.00–7.60 ppm (m, 8); (pyridine-d_5) δ 0.86 (s, 3), 1.62 (s, 3), 4.23 (br s, 1), 5.37 (dd, 1 J_{CHCH} = 4, J_{CHNH} = 9 Hz), 5.65 (d, 1 J_{CHCH} = 4 Hz), 6.36–7.32 ppm (m, 8); MS *m/e* (rel intensity) 235 (M − CH_3CO_2H, 60), 193 (100), 165 (57). Anal. Calcd for $C_{18}H_{17}NO_3$: C, 73.2; H, 5.8; N, 4.7. Found: C, 73.1; H, 5.7; N, 4.8.

1-Acetyl-1a,9b-dihydrophenanthr[9,10-*b*]azirine. (a) Cyclodeacetylation with NaH. Small-scale synthesis was carried out in an NMR tube in which 2 mg of the above acetoxyacetylamine was treated with 1 mg of NaH (80%) and 1 mL of pyridine-d_5 as described for the chrysene derivative. The solvent was removed in vacuo immediately after the bands of the starting material have disappeared. The *N*-acetyl protons of the imine show up as a singlet at 1.63 ppm, and the aziridine protons as doublets at 4.10 and 4.93 ppm (J = 4 Hz).[20]

On 1-mmol scale preparation a mixture of 295 mg of the diacetylated amino alcohol, 2 mmol of NaH, and 5 mL of pyridine was stirred for 48 h at room temperature under N_2. However, workup as above afforded the arene imine together with some 9-acetylaminophenanthrene.[21] Anal. Calcd for $C_{16}H_{13}NO$: C, 81.7; H, 5.5; N, 6.0. Found: C, 81.6; H, 5.4; N, 5.5.

(b) Cyclodeacetylation with CH_3Li. At −60 °C under N_2 atmosphere there was injected 1.2 mL of a 1 M solution of CH_3Li in ether into a stirred mixture of 295 mg (1 mmol) of the acetoxyacetylamine in 5 mL of dry THF. The green solution was gradually warmed to room temperature, and the solvents were removed in vacuo. The residue was extracted with $CHCl_3$, dried (K_2CO_3), and concentrated. As in method a, the resulting imine was accompanied with varying amounts of 9-acetylaminophenanthrene.

Acknowledgments. We thank the Ber-Lehmsdorf Foundation for Cancer Research and the Central Fund of the Hebrew University for financial support.

Registry No.—**1**, 585-08-0; **2c** HCl, 64188-63-2; **9**, 14140-05-7; **10**, 64188-62-1; **11**, 64188-61-0; **12**, 64188-60-9; **13**, 63018-97-3; 9-benzylaminophenanthrene, 64188-59-6; benzylamine, 100-46-9; *n*-butylamine, 109-73-9; cyclohexylamine, 108-91-8; *tert*-butylamine, 75-64-9; acetic anhydride, 108-24-7; *trans*-9-acetoxy-10-acetylamino-9,10-dihydrophenanthrene, 64188-58-5; *trans*-10-amino-9,10-dihydrophenanthr-9-ol, 60883-94-5; 1-acetyl-1a,9b-dihydrophenanthr[9,10*b*]azinine, 59310-28-0.

References and Notes

(1) See, e.g., D. Avnir and J. Blum, *J. Heterocycl. Chem.*, **13**, 619 (1976), and references 1 and 2 therein.
(2) P. Sims and P. L. Grover, *Adv. Cancer Res.*, **20**, 165 (1974).
(3) U. Bicker and W. Fischer, *Nature (London)*, **249**, 344 (1974); U. Bicker, *Arch. Geschwulstforsch.*, **44 (4)**, 312 (1974).
(4) J. Blum, Y. Ittah, and I. Shahak, *Tetrahedron Lett.*, 4607 (1975).
(5) K. Shudo and T. Okamoto, *Chem. Pharm. Bull.*, **24**, 1013 (1976).

(6) R. Appel and R. Kleinstück, *Chem. Ber.*, **107**, 7 (1974).
(7) Cf., P. Y. Bruice, T. C. Bruice, P. M. Dansette, H. G. Selander, H. Yagi, and D. M. Jerina, *J. Am. Chem. Soc.*, **98**, 2965 (1976).
(8) J. H. D. Eland and C. J. Danby, *J. Chem. Soc.*, 5935 (1965).
(9) E. Breuer, L. Somekh, and I. Ringel, *Org. Magn. Reson.*, **9**, 328 (1977).
(10) Cf., H. Yagi and D. M. Jerina, *J. Am. Chem. Soc.*, **97**, 3185 (1975); M. H. Gianni, E. L. Stagryn, and C. M. Orlands, *J. Phys. Chem.*, **67**, 1385 (1963).
(11) Cf., e.g., B. P. Daily, A. Gawer, and W. C. Neikam, *Discuss. Faraday Soc.*, **34**, 18 (1962).
(12) T. Yonezawa, I. Morishima, and K. Fukuta, *Bull. Chem. Soc. Jpn.*, **41**, 2297 (1968); J.-L. P. Baret and P. Arnaud, *Bull. Soc. Chim. Fr.*, 3619 (1971).
(13) H. Saito, K. Nukada, T. Kobayashi, and K. Morita, *J. Am. Chem. Soc.*, **89**, 6605 (1967).
(14) P. E. Fanta and E. N. Walsh, *J. Org. Chem.*, **31**, 59 (1966); H. W. Heine and M. S. Kaplan, *J. Org. Chem.*, **32**, 3069 (1967).
(15) M. S. Newman and J. A. Cathcart, *J. Org. Chem.*, **5**, 618 (1940).
(16) J. W. Cook and R. Schoental, *J. Chem. Soc.*, 288 (1945).
(17) The oxide was obtained by the method of M. S. Newman and S. Blum, *J. Am. Chem. Soc.*, **86**, 5598 (1964). Direct conversion of phenanthrene into **1** according to K. Ishikawa, H. C. Charles, and G. W. Griffin, *Tetrahedron Lett.*, 427 (1977), proved to give an impure compound on large-scale preparation.
(18) A. S. Dey and J. L. Neumeyer, *J. Med. Chem.*, **17**, 1095 (1974).
(19) H. M. Haender and G. McP. Smith, *J. Am. Chem. Soc.*, **61**, 2624 (1939).
(20) The chemical shift (in $CDCl_3$) of the aziridine-ring protons given in ref 4 should be read 4.30 instead of 2.30 ppm.
(21) G. H. Keyes and L. G. S. Brooker, *J. Am. Chem. Soc.*, **59**, 74 (1937).

Synthesis and Chemical Properties of α-Alkyl(aryl)thiovinyl Isocyanates

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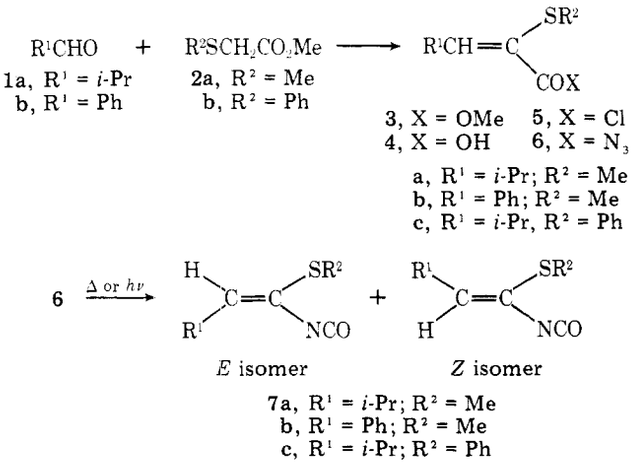
Received June 28, 1977

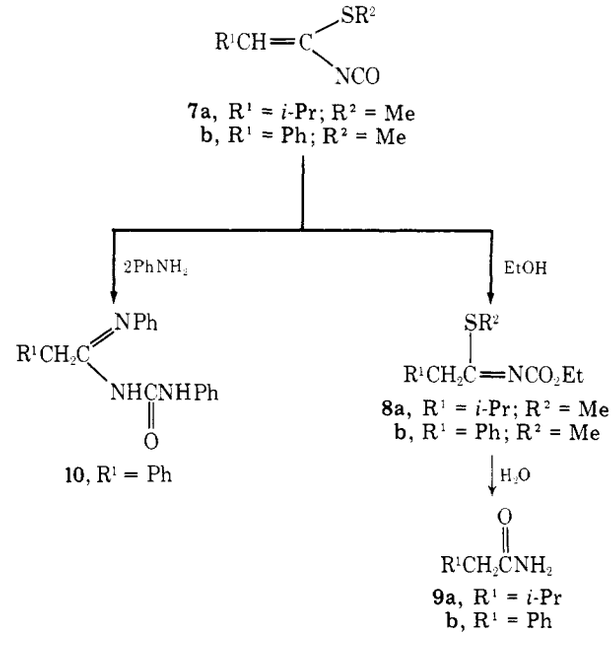
Thermolysis or photolysis of α-alkyl(aryl)thioacrylyl azides **6** gave α-alkyl(aryl)thiovinyl isocyanates **7** in good yields. The isocyanates **7** reacted with aromatic hydrazines to give the triazoles **11** and the triazolinone **12**. In the reaction of **7a** with enamines, the pyridone **15a** or the azadecalin **15b** were isolated. Thermolysis of **7a** gave 4-methylthio-5-isopropyluracil (**16**) quantitatively, while **7b** led to 3-methylthioisocarbostyril (**17**). 3-Methylthio-4-chloroisocarbostyril (**19a**) and 3-methylthio-4-bromoisocarbostyril (**19b**) were obtained by the treatment of **17** with $CuCl_2$–CuO and Br_2–CuO, respectively.

In recent years, the chemical properties of acyl isocyanates have been widely investigated and many heterocyclic compounds were derived from them.[1] In spite of their great synthetic utility, difficulty in the preparation of aliphatic acyl isocyanates[2] and instability of aromatic acyl isocyanates have restricted the utilization of acyl isocyanates. The synthesis of reagents equivalent to acyl isocyanates has been undertaken to overcome these limitations.

Since the vinyl sulfide group is easily converted to the carbonyl group,[3] α-alkyl(aryl)thiovinyl isocyanates are expected to be potentially useful in place of acyl isocyanates in organic synthesis. We also expect them to provide new routes for the synthesis of various heterocyclic compounds containing the sulfide group, since α,β-unsaturated isocyanates have been used in the synthesis of heterocyclic compounds.[4] From these points of view, we wish to report here the synthesis and some chemical properties of α-alkyl(aryl)thiovinyl isocyanates.

Thermolysis or photolysis of a mixture of (*E*)- and (*Z*)-α-alkyl(aryl)thioacrylyl azides **6**, prepared from aldehydes **1** and methyl methyl(phenyl)thioacetates **2**, gave α-alkyl(aryl)-thiovinyl isocyanates **7** in good yields. The structures of **7** were established by spectral data and chemical evidence. The IR spectrum of **7a** displays characteristic absorption bands at 2240 and 1620 cm^{-1} assignable to NCO and olefinic linkage, respectively. The NMR spectrum shows two doublets at 5.17 and 5.40 ppm in the ratio of 87:13. The peak at higher field would be assignable to the vinyl proton of the *E* isomer and the other to that of the *Z* isomer. Treatment of **7a** and **7b** with ethanol gave the amides **9** which were formed from the imino sulfides **8** by hydrolysis. Only **8a** as intermediate was isolated. With aniline, **7b** led to the amidine **10**.





The isocyanate **7a** reacted with *p*-nitrophenylhydrazine at room temperature to give 1-*p*-nitrophenyl-3-hydroxy-5-

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