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α-Lithiation of *N*-Alkylcarbazoles: Preparation of *N*-(*E*)-Styrylcarbazole

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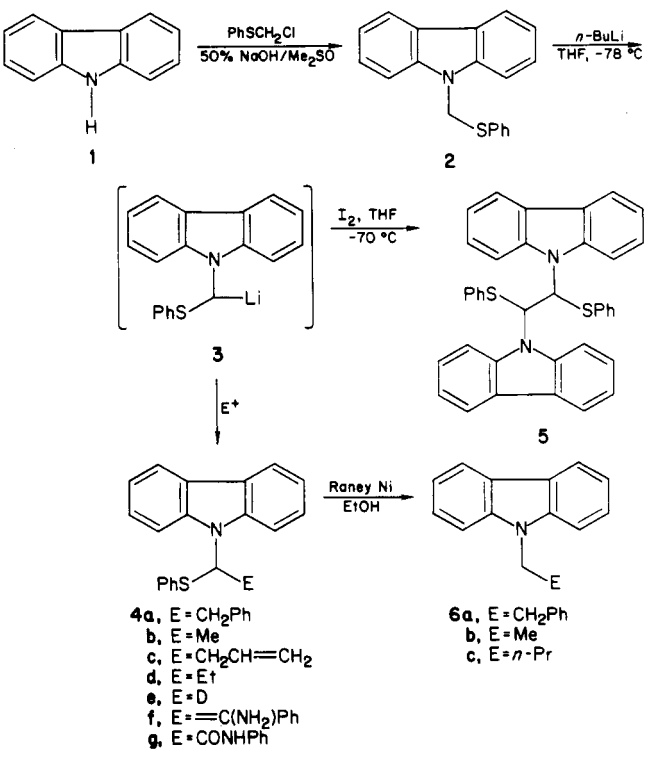
Alkylation of carbazole with [(chloromethyl)thio]benzene gave the key intermediate *N*-[(phenylthio)-methyl]carbazole (**2**). Treatment of **2** with *n*-butyllithium at low temperature gave an α-lithio derivative **3**, which reacted with a variety of electrophiles, affording *N*-[(phenylthio)alkyl]carbazoles **4a–g**. Removal of the activating phenylthio group in **4a–g** was achieved by Raney nickel desulfurization. Three successful routes to the novel *N*-(*E*)-styrylcarbazole (**10**) are described. ^{1}H NMR and ^{13}C NMR assignments of *N*-alkylcarbazoles are discussed.

There are numerous synthetic methods using α-substituted organometallic reagents.[1] While ring metalation of azoles is well-known,[2a] reports of N–C_α metalation in simple azoles are rather less common.[2b] Recently, several examples of α-metalation of *N*-alkylazoles have been reported.[3-8] We now report successful α-metalations in *N*-alkylcarbazoles, together with ensuing synthetic transformations.

Julia[7] has demonstrated that *N*-allylcarbazoles can, by N-C_α lithiation, be used as templates in the synthesis of carbonyl compounds. Despite the relative inertness of carbazoles to C-lithiation,[9,10] 9-ethylarbazole has been shown to lithiate at C-1 rather than at N-C_α.[11] Thus, an activating group is required, and since orthothioesters can be readily methylated,[11b] we chose the thiophenyl group which permitted preparations of new *N*-alkyl- and *N*-alkenylcarbazoles.

We reasoned that *N*-[(phenylthio)methyl]carbazole (**2**) would readily and specifically lithiate at N-C_α, giving the derivative **3** which would undergo electrophilic substitution to yield carbazoles of the form **4**. The latter could be expected to yield novel *N*-alkyl- and *N*-alkenylcarbazoles by reductive and oxidative desulfurization, respectively.

Scheme I



4a, E = CH_2Ph
b, E = Me
c, E = $CH_2CH{=}CH_2$
d, E = Et
e, E = D
f, E = $=C(NH_2)Ph$
g, E = CONHPh

6a, E = CH_2Ph
b, E = Me
c, E = *n*-Pr

The present studies form part of a wider strategy in which the aim is to develop general procedures for the synthesis and transformation of N-substituted azoles.

Results and Discussion

N-[(Phenylthio)methyl]carbazole (**2**) was readily obtained in one step from [(chloromethyl)thio]benzene and carbazole (**1**) by employing a known method for the alkylation of active nitrogen.[12] The thioether **2** thus ob-

(1) Krief, A. *Tetrahedron* **1980**, *36*, 2531.
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Table I. Preparation and Physical Characteristics of *N*-Substituted Carbazoles

no.	electrophile	CH_2 subst	reaction time, h	mp, °C	α-CH δ	yield, %
4a	D_2O	D	0.1	63–65[a]		89
4b	CH_3I	CH_3	0.5	96–97[a]	6.15	86
4c	C_2H_5I	C_2H_5	0.5	116–118[a]	5.95	79
4d	CH_2=$CHCH_2Br$	CH_2=$CHCH_2$	0.5	79–81[a]	5.90	69
4e	$PhCH_2Br$	$PhCH_2$	1	67–69[a]	6.15	62
4f	PhCN	=C(NH_2)Ph	8	96–98[a]		77
4g	PhNCO	CONHPh	1	183–185[a]		66
5	I_2	(dimer)	0.1	189–194[b]		38
6a		CH_3	4	51–53[a,c]	4.50	88[f]
6b		C_3H_7	5	55–57[a,d]	4.15	86[f]
6c		$PhCH_2$	4	110–112[e]	4.30	93[f]

[a] Recrystallized from MeOH. [b] Recrystallized from DMF. [c] Recrystallized from EtOH. [d] Nishi, H.; Kohno, H.; Kano, T. *Bull. Chem. Soc. Jpn.* **1981**, *54*, 1897 mp 52–53 °C. [e] Compounds **6a–c** (1 mmol) were hydrogenated with W-2 Raney nickel (1.9, 2.5, and 1.9 g, respectively). [f] Kricka, L. J.; Ledwith, A. *J. Chem. Soc. Perkin Trans. 1* **1972**, 2292 mp 57–58 °C. [g] Satisfactory analytical data (±0.4% for C, H, N) were obtained for all compounds.

Table II. ^{13}C NMR Spectra of Carbazoles[a]

C	1[b]	2	4a[c]	4b	4c[d]	4d[e]	6a	16	17	18[f]	19[g]
α		49.7	66.1	59.8	64.4	66.3	44.7	49.6	49.0	37.1	
β			40.4		38.3	27.8	35.1			13.5	
			108.0[h]	110.6[h]	108.8[h]	108.8[h]					
1	111.0	109.3	113.3[h]	113.0[h]	113.0[h]	113.0[h]	108.5	109.3	111.6	108.2	113.0
2	125.6	125.6	125.3	125.3	125.3	125.3	125.6	125.4	122.3	125.4	128.6
3	118.6	119.7	119.7	119.3	119.3	119.3	118.8	119.5	142.0	118.6	111.1
4	120.1	120.2	120.3	120.0	120.0	120.1	120.3	120.0	118.3	120.2	123.5
10	139.9	139.7	141.1[i]	139.1	139.3[i]	140.9	140.1	139.6	144.4	139.7	138.8
11	122.6	123.3	123.4	123.4	123.1[i]	123.6	122.9	123.2	122.7	122.8	123.2
1′		133.3	132.9[i]	133.0	133.7[i]	133.1	138.6	129.7	131.9		
2′		134.5	133.6[i]	133.7	133.7	133.7	128.7[i]	134.4	134.4		
3′		128.9[j]	128.6[j]	128.5[j]	128.5[j]	128.5[j]	128.5	129.5[j]	128.9[j]		
4′		128.5	128.1	128.0	128.0	128.0	126.6	138.4	129.1		

[a] Solvent $CDCl_3$, reference Me_4Si. [b] Reference 17. In Me_2SO-d_6. [c] Comparison with toluene allowed these assignments: C-1″, 137.2; C-2″, 128.8; C-3″, 128.3; C-4″, 126.8. [d] γ at 132.9; δ at 118.4. [e] γ at 11.7. [f] Johnson, L. F.; Jankowski, W. C. In "Carbon-13 NMR Spectra"; Wiley-Interscience: New York, 1972; p 458. [g] Partial assignments of **21** were made as follows: C-1, 113.0; C-2, 129.1; C-3, 111.0; C-10, 138.5; C-2′, 134.9. [h] Broad signal. [i] Assigned by multiplicity. [j] A brace indicates signals may be interchanged.

tained proved to be a versatile synthetic intermediate. Thus, with *n*-butyllithium in THF at −78 °C thioether **2** underwent α-metalation at the doubly activated methylene group. Reactions of lithium derivative **3** with a variety of electrophiles proceeded smoothly, giving functionalized compounds **4a–g** in good yields (48–87%); in all cases except carbazole **4f** the reactions were complete in 0.5–1 h. The reaction to give enamine **4f** required 12 h. The structure of compound **4f** was confirmed by ν NH_2 at 3360 cm^{-1} (symmetric stretch) and 3450 cm^{-1} (asymmetric stretch) and by the broad singlet of two exchangeable NH_2 protons at δ 4.7 in the ^1H NMR spectrum.

Reaction of alkyllithium **3** with iodine gave dicarbazolylethane **5** (Scheme I). Carbazoles **5** and **4a–g** here reported are new and have been fully characterized by their IR, ^1H NMR, and ^{13}C NMR data (Tables I and II).

Compounds **4a–c** were reductively desulfurized with Raney nickel in boiling ethanol, furnishing derivatives **6a–c** in good yields (86–93%). Desulfurization of compound **4c**, however, even using a sample of catalyst partially deactivated by washing with acetone was accompanied by reduction of the C=C double bond and led to *N*-butylcarbazole **6c** (Scheme I).

The plan for the synthesis of the novel *E* isomer of *N*-styrylcarbazole (**10**) was based on the eliminative desulfurization of intermediate **9**. We envisaged that sulfoxide **9** could be prepared either by benzylation of alkyllithium **3** to give sulfide **4a** and subsequent oxidation of the latter (Method A) or by benzylation of sulfoxide **8** (Method B).

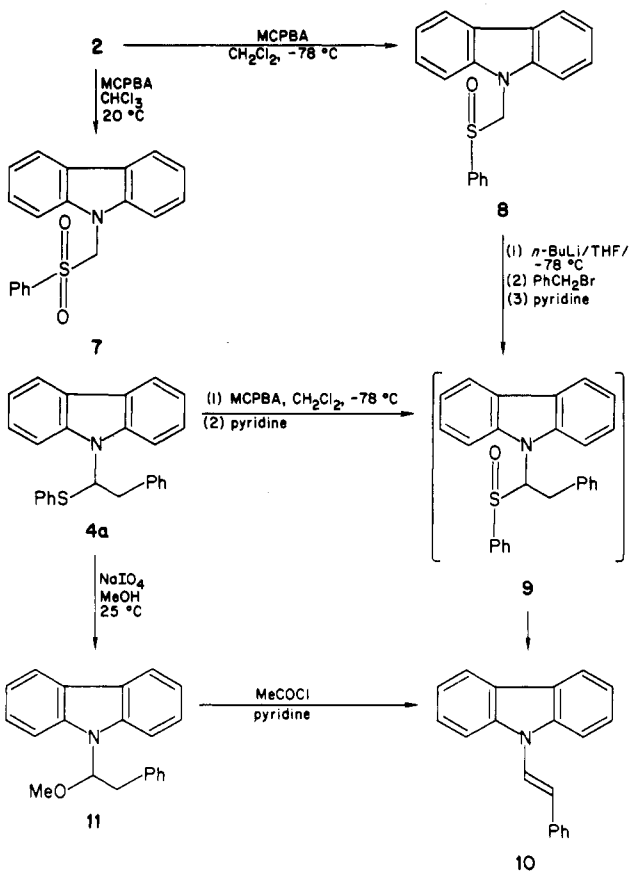
Method A was attempted as follows. Oxidation of sulfide **4a** with $NaIO_4$ in benzene/methanol under standard conditions unexpectedly gave the α-methoxy analogue **11** in 79% yield. However, oxidation of sulfide **4a** with *m*-chloroperbenzoic acid (MCPBA) in CH_2Cl_2 at −78 °C was successful; subsequent addition of pyridine enabled *N*-(*E*)-styrylcarbazole to be isolated in excellent yield (84%) in a one-pot preparation. In such a manner, both the ready hydrolysis of carbazole **10** into carbazole and phenylacetaldehyde **12** and the facile decomposition of sulfoxide **9** were avoided. Pyridine (2 equiv) acted as a trap for the benzenesulfenic acid produced.

The formation of carbazole **11** is believed to proceed via sulfoxide **9**, which could not be isolated owing to thermal instability, and decomposes to *N*-(*E*)-styrylcarbazole (**10**), which undergoes addition of methanol under reaction conditions.

For the alternative synthesis of compound **10**, the key intermediate **2** was first oxidized to sulfoxide **8** by reaction with MCPBA in CH_2Cl_2 solution at −78 °C. Interestingly, the same reaction performed at 20 °C gave sulfone **7**. Lithiation of sulfoxide **8** was readily accomplished by treatment with *n*-butyllithium at −78 °C; addition of benzyl bromide induced α-alkylation, and the resulting sulfoxide **9** was allowed to react in situ with pyridine; thermal decomposition of sulfoxide **9** was achieved by allowing the reaction mixture to warm to 20 °C. The conversion of sulfoxide **8** into styrylcarbazole **10** proceeded in 40% yield (Scheme II).

^1H NMR data were particularly revealing in identifying the products derived from the oxidation of thioether **2**. Thus, the methylene group of compound **2** (δ 5.55) resonated as a singlet, but that of sulfoxide **8** (δ 5.30) appeared as a double doublet, on account of the chirality at the sulfoxide sulfur atom. However the sulfone **7**, also prepared by using MCPBA but at higher temperature, showed

Scheme II

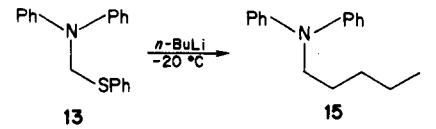


a singlet methylene resonance (δ 5.65) owing to the prochiral sulfur atom. The ^{1}H NMR of *N*-styrylcarbazole (**10**) was also diagnostic; the vicinal coupling constant of 15 Hz is typical for such an *E* configuration, whereas the corresponding *J* value for the *Z* isomer is reported[13] by Filimonov as 8.6 Hz.

A different method for preparing *N*-(*E*)-alkenylcarbazoles has been reported[14] by Filimonov, in which *N*-(α-methoxyalkyl) derivatives are reacted with acetyl chloride in the presence of pyridine, which induces β-elimination of methoxide, affording the corresponding alkene. We found that reaction of ether **11** with acetyl chloride and pyridine (Method C) gave styrylcarbazole **10** in 68% yield. Thus, two significant results have emerged in regard to this third method of preparing *N*-(*E*)-alkenylcarbazoles; first, that thioethers of the form **4a** readily undergo formal substitution to give ethers of the form **11**, and second, that the method of Filimonov can be applied to (arylalkenyl)carbazoles.

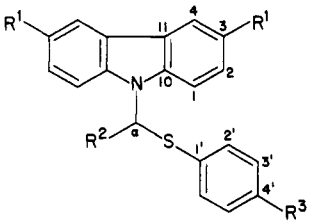
The significance of α-metalation of 9-substituted carbazoles is enhanced by the failure of related systems to react with alkyllithiums. Thus, several attempts to metalate diphenylamine **13** and *N*-[(phenylthio)methyl]-benzamide (**14**) with *n*-butyllithium or lithium diisopropylamide (LDA) did not afford a stable metalated product (Scheme III). Compound **13** underwent nucleophilic displacement to afford the *n*-pentyl derivative **15**, whereas amide **14** did not react with *n*-butyllithium or LDA below −20 °C, and only decomposition products were detected at 0 °C. The former result is in agreement with Lepley[15] who showed that treatment of a mixture of *n*-

Scheme III

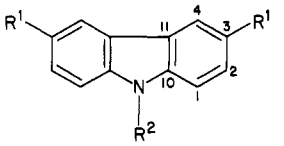


propyl iodide and *N*-methyldiphenylamine with *n*-butyllithium afforded a mixture of *N*-butyl- and *N*-pentyldiphenylamines.

^{13}C NMR Assignments. ^{13}C NMR data of various carbazoles are reported in Table II. While the literature reveals a majority opinion[16-18] for the assignment of carbazole resonances, other conflicting assignments have been made.[14,19] The former group of authors ascribe the lines at ca. 111, 118, 120, 123, 125, and 140 ppm to positions 1, 3, 4, 11, 2, and 10, respectively, of the carbazole ring, an analysis in excellent agreement with the assignments herein reported. However, in view both of the complexities encountered in our own spectra, in particular an anomalous line at ca. 134 ppm, and also the doubtful assignments already existing in the literature, we sought further confirmation. Accordingly, carbazoles **16**, **17**, and **21** were prepared, which enabled substituent effects on both carbazole and phenylthio rings to be studied. In all cases, observed substituent effects were in reasonable agreement with those calculated from a simple monosubstituted benzene[20] (see paragraph at the end of paper about supplementary material), thereby confirming the veracity of the assignments made in Table II.



4a-g, R^1=H; R^2=alkyl; R^3=H
16, R^1=H; R^2=H; R^3=Me
17, R^1=NO$_2$; R^2=H; R^3=H



18, R^1=H; R^2=Et
19, R^1=Br; R^2=H
20, R^1=NO$_2$; R^2=H
21, R^1=Br; R^2=CH$_2$SPh

A line at ca. 134 ppm was observed in all of the spectra of carbazoles bearing a phenylthio group attached to the N-C$_\alpha$ carbon atom. That line, which varied by less than 1.0 ppm in the series studied (vide Table II), has not been previously observed. The consistency in the chemical shifts of all the carbazole carbon atoms strongly implies that the line at ca. 134 ppm is due to one of the carbon atoms of the phenylthio group; C-1′, resonating as a singlet, can be eliminated on grounds of multiplicity. C-4′ is ruled out because it is found, as expected, at 138.4 ppm in thioether **16**, while a line at 134.4 ppm is also present. Of the two remaining positions, C-2′ and C-3′, the former is the preferred assignment of the anomalous line at 134.4 ppm for two reasons: first, C-3′ suffers the expected small shift on account of the methyl group ortho to it in thioether **16**, and second, steric interaction of C-1 (of the carbazole nucleus) is more likely with C-2′ rather than with the less proximate C-3′ of the phenyl ring. The observed line

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(20) Ewing, D. F. *Org. Magn. Reson.* **1979**, *12*, 499.

broadening of C-1 in all the thioethers containing branching at N-C_α (line broadening which is absent in the unbranched thioethers, presumably because of less severe nonbonding interactions) is believed to arise from restricted rotation of the bulky 9-substituent about the N-C_α bond thereby inducing the observed nonequivalence of C-1 and C-8. However, the chirality at the N-C_α carbon atom of the branched thioethers did not lead to complexity in the spectra, which admitted of an otherwise straightforward analysis.

Conclusions

The problem of directed lithiation of N-C_α of carbazoles may be readily overcome by employing the activating phenylthio group, which can be readily removed by reductive desulfurization as described above. The scope for electrophilic substitution at C_α via lithio derivatives has been shown herein to be wide, and also of consequence, as demonstrated by the preparation of the previously unknown *N*-(*E*)-styrylcarbazole. Analysis of ^{13}C NMR data of various carbazoles revealed an anomalous line in cases where severe steric interaction can occur, and also clarified the considerable confusion existing in the literature over carbazole assignments. It is hoped that the ^{13}C data presented herein may find use in natural product interpretation, perhaps along a line previously reported.[17]

Experimental Section

Melting points were determined on a Hoover Uni-melt capillary apparatus and are uncorrected. IR spectra were recorded on a Perkin-Elmer 297 spectrophotometer. ^1H NMR spectra were recorded with a Varian EM 360L spectrophotometer and ^{13}C NMR spectra were recorded on a JEOL FX-100 spectrophotometer. Solvents and all reagents were carefully dried, THF being distilled over Na/Ph_2CO. Reagents were routinely distilled and stored over 4A molecular sieves.

Preparation of Starting Materials. [(Chloromethyl)thio]benzene was prepared by the methods of Dolman[21] or Goralski:[22] bp 90–94 °C (4 mmHg) [lit.[22] bp 83 °C (1.5 mmHg)]. 4-[(Chloromethyl)thio]toluene was prepared by the method of Bordwell:[23] bp 89–92 °C (4 mmHg) [lit.[23] bp 125–126 °C (15 mmHg)]. *N*-[(Phenylthio)methyl]diphenylamine (**13**) was prepared by the method of Abel and Rowley:[24] mp 78–80 °C (lit.[24] mp 59–60 °C); ^1H NMR ($CDCl_3$) δ 5.40 (s, 2 H, *N*-methylene), 7.00–7.65 (m, 15 H, arom). 3,6-Dibromocarbazole (**19**) was prepared by the method of Pielichowski and Kyziol:[25] mp 211–213 °C (lit.[25] mp 212–213 °C). 3,6-Dinitrocarbazole (**20**) was prepared by the method of Grotta:[26] mp >360 °C (lit.[26] mp 386–387 °C).

***N*-[(Phenylthio)methyl]carbazole (2).** A suspension of carbazole (19.2 g, 0.115 mol) in a solution of Me_2SO (18 mL) and aqueous sodium hydroxide (50%, 67 mL) was stirred 5 min at 20 °C, before adding dropwise [(chloromethyl)thio]benzene (25 g, 0.158 mol) with vigorous stirring. The temperature rose to 55 °C and was then kept at 35–40 °C for 2 h, with continuous stirring. The reaction mixture was poured into water (200 mL) and extracted with Et_2O (2 × 100 mL). The ethereal layer was washed with water, dried over anhydrous magnesium sulfate, and evaporated under reduced pressure to yield an oil. Addition of MeOH (400 mL) to the oil and cooling to −5 °C gave 20.5 g (62%) of **2** as plates: mp 64–65 °C; IR ($CHBr_3$) 1959, 1485, 1450, 1320, 1260, 1060, 750, 720, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.55 (s, 2 H, methylene), 7.00–7.55 (m, 11 H, arom), 8.00–8.25 (m, 2 H, 1,8-carbazole hydrogen). Anal. Calcd for $C_{19}H_{15}NS$: C, 78.85; H, 5.22; N, 4.84. Found: C, 79.06; H, 5.38; N, 4.66.

General Procedure for Reacting Carbazole 2 with Electrophiles. Synthesis of Carbazoles 4a–g. To a stirred solution of carbazole **2** (0.80 g, 2.8 mmol) in dry THF (10 mL) under nitrogen at −78 °C was added *n*-butyllithium (2.7 mmol, Aldrich); after 5 min the yellow solution was treated with an equimolar amount of electrophile. Stirring at −78 °C was continued for 1 h before allowing the solution to warm to 20 °C. Evaporation of the solvent under reduced pressure, addition of water (10 mL) to the residue, and extraction with diethyl ether (2 × 20 mL) gave an organic phase which was dried over anhydrous magnesium sulfate. Evaporation of the ether under reduced pressure gave a residue which was recrystallized from MeOH.

Melting points and yields of carbazoles **4a–g** are given in Table I.

General Procedure for the Reductive Desulfurization of Carbazoles 4a–c. A mixture of the carbazole **4a** (0.8 g, 2.1 mmol) and W-2 Raney nickel (4.0 g) was refluxed in 95% EtOH (20 mL) for 4 h. The catalyst was filtered and washed with hot EtOH (10 mL) and the filtrate allowed to cool to 20 °C. The precipitate was filtered and recrystallized from EtOH to give **6a**: IR ($CHBr_3$) 3050, 2830, 1630, 1595, 1480, 1450, 1350, 1325, 1240, 1140, 840, 750 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.10 (t, 2 H, J = 7.5 Hz, benzylic methylene), 4.50 (t, 2 H, J = 7.5 Hz, *N*-methylene), 7.15–7.90 (m, 11 H, arom), 8.20–8.60 (m, 2 H, 1,8-carbazole hydrogen).

The same preparation gave **6b**: IR ($CHBr_3$) 3060, 1595, 1480, 1450, 1325, 1260, 1210, 1150 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.77 (t, 3 H, methyl), 4.15 (q, 2 H, J = 7 Hz, methylene), 7.05–7.80 (m, 6 H, arom), 8.20–8.50 (m, 2 H, 1,8-carbazole hydrogen).

The same conditions also afforded **6c**: IR ($CHBr_3$) 3050, 2970, 2930, 2880, 1625, 1595, 1480, 1445, 1330, 1135, 810 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.70–2.05 (m, 7 H, $CH_3CH_2CH_2$), 4.30 (t, 2 H, *N*-methylene), 7.20–7.80 (m, 6 H, arom), 7.20–7.50 (m, 2 H, 1,8-carbazole hydrogen).

Melting points and yields of carbazoles **6a–c** are given in Table I.

1,2-Dicarbazolyl-1,2-bis(phenylthio)ethane (5). A stirred solution of carbazole **2** (0.80 g, 2.8 mmol) in THF (10 mL) at −70 °C under nitrogen was treated with *n*-butyllithium (2.7 mmol). After 5 min a solution of iodine (0.8 g, 3.1 mmol) in THF (5 mL) was added dropwise over 3 min. The mixture was stirred at −70 °C for 20 min and then treated with water (10 mL). Extraction of the mixture with CH_2Cl_2 (3 × 30 mL) gave an organic phase which was washed with a solution of saturated sodium thiosulfate (20 mL) and dried over anhydrous magnesium sulfate. Evaporation of solvent under reduced pressure and recrystallization from DMF gave 0.31 g (38%) of **5** as prisms: mp 189–194 °C; IR ($CHBr_3$) 3050, 1595, 1480, 1320, 1235, 1140, 745, 720 cm^{-1}; ^1H NMR could not be obtained owing to insolubility. Anal. Calcd for $C_{38}H_{28}N_2S_2$: C, 79.19; H, 4.89; N, 4.85. Found: C, 78.96; H, 4.93; N, 4.44.

***N*-[(Phenylsulfonyl)methyl]carbazole (7).** A solution of carbazole **2** (1.0 g, 3.5 mmol) in $CHCl_3$ (20 mL) was cooled to 0 °C and treated with a solution of 85% *m*-chloroperbenzoic acid (MCPBA) (1.3 g, 7.6 mmol) in $CHCl_3$ (10 mL). The mixture was stirred at 20 °C for 3 h, filtered to remove *m*-chlorobenzoic acid, and the latter washed with a solution of saturated Na_2CO_3. The organic layer of the filtrate was separated and dried over anhydrous magnesium sulfate. Removal of solvent under reduced pressure gave a residue which was extracted with hot EtOH (50 mL). On cooling a precipitate appeared, which was collected and recrystallized from EtOH to give 0.29 g (26%) of **7** as prisms: mp 120–124 °C dec; IR ($CHBr_3$) 1600, 1485, 1450, 1325, 1080, 740, 650 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.65 (s, 2 H, methylene), 7.1–8.0 (m, 11 H, arom), 8.15–8.35 (m, 2 H, 1,8-carbazole hydrogen).

Anal. Calcd for $C_{19}H_{15}NO_2S$: C, 71.00; H, 4.70; N, 4.36. Found: C, 70.64; H, 4.42; N, 3.99.

***N*-[(Phenylsulfinyl)methyl]carbazole (8).** A stirred solution of carbazole **2** (1.0 g, 3.5 mmol) in CH_2Cl_2 (15 mL) was cooled to −78 °C and a solution of *m*-chloroperbenzoic acid (0.65 g, 3.5 mmol) in CH_2Cl_2 (10 mL) was added over 5 min. After stirring a further 10 min, the mixture was allowed to warm to 20 °C and filtered to remove *m*-chlorobenzoic acid, and the latter washed with a solution of saturated sodium carbonate. The organic layer of the filtrate was separated and dried over anhydrous magnesium sulfate. Removal of solvent under reduced pressure gave a residue

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which was extracted with hot EtOH (35 mL). On cooling a precipitate appeared, which was collected and recrystallized from EtOH to give 0.38 g (36%) of **8** as prisms: mp 134–136 °C; IR ($CHBr_3$) 1600, 1485, 1455, 1325, 1240, 1085, 1015, 750 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.20 (d, 1 H, J = 13 Hz, CH_A methylene), 5.30 (d, 1 H, J = 13 Hz, CH_B methylene), 7.10–7.65 (m, 11 H, arom), 7.15–8.25 (m, 2 H, 1,8-carbazole hydrogen). Anal. Calcd for $C_{19}H_{15}NOS$: C, 74.72; H, 4.95; N, 4.58. Found: C, 74.91; H, 4.87; N, 4.34.

***N*-(*E*)-Styrylcarbazole (10). Method A.** A stirred solution of carbazole **4a** (1.0 g, 2.7 mmol) in CH_2Cl_2 (20 mL) was cooled to −78 °C and treated with a solution of *m*-chloroperbenzoic acid (0.45 g, 2.6 mmol) in CH_2Cl_2 (10 mL) added over 2 min. The suspension so obtained was stirred at −78 °C for 5 min before adding dry piperidine (0.70 mL, 8.6 mmol). After a further 30 min, the reaction mixture was allowed to warm to 20 °C. Removal of solvent under reduced pressure gave a residue which was treated with a saturated solution of Na_2CO_3 (20 mL) before extracting with Et_2O (2 × 20 mL). Separation of the organic layer and removal of Et_2O at 20 °C gave a residue which was dissolved in hot MeOH (10 mL). Cooling to 0 °C gave, after 4 h, 0.60 g (83%) of **10** as plates: mp 90–92 °C; IR ($CHBr_3$) 3060, 1645, 1600, 1480, 1445, 1360, 1335, 1150, 940, 745 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.20 (d, 1 H, J = 15 Hz, β-CH), 7.40–8.00 (m, 12 H, α-CH and arom), 8.10–8.35 (m, 2 H, 1,8-carbazole hydrogen). Anal. Calcd for $C_{20}H_{15}N$: C, 89.18; H, 5.61; N, 5.20. Found: C, 88.91; H, 5.70; N, 4.96.

Method B. A stirred solution of carbazole **8** (1.0 g, 3.3 mmol) in THF (20 mL) under nitrogen was cooled to −78 °C and treated with a solution of *n*-butyllithium (3.3 mmol). After the reaction was stirred 5 min, benzyl bromide (0.54 g, 3.3 mmol) was added and the mixture stirred at −78 °C for 1 h. Pyridine (0.26 g, 3.3 mmol) was then added and the reaction mixture was allowed to warm to 20 °C. Removal of solvent under reduced pressure gave a residue which was extracted with Et_2O (25 mL). The ethereal layer was washed with water (25 mL) and dried over anhydrous magnesium sulfate. Removal of the Et_2O at 20 °C gave an oil, which upon treatment with cold MeOH gave 0.69 g (79%) of **10** as plates: mp 89–91 °C. Spectral data were identical with those described under Method A.

Method C. A solution of compound **11** (1.0 g, 3.3 mmol) in a mixture of dry dioxane (5 mL) and pyridine (2.5 mL) was treated with a solution of acetyl chloride (0.75 mL) in dioxane (1 mL) at room temperature. The reaction mixture was stirred at 70 °C for 1 h and filtered and the filtrate evaporated under reduced pressure. The oily residue was dissolved in MeOH (5 mL) and cooled to −5 °C. After several hours the precipitate so obtained was filtered and recrystallized from MeOH to give 0.60 g (68%) of **10** as plates: mp 89–92 °C. Methods A, B, and C gave samples of **10** each of which gave identical spectral data.

***N*-(1-Methoxy-2-phenylethyl)carbazole (11).** A solution of carbazole **4a** (0.5 g, 1.3 mmol) in a mixture of benzene (1 mL) and MeOH (19 mL) was cooled to 0 °C, treated with sodium periodate (0.28 g, 1.3 mmol), and stirred at 20 °C for 12 h. The precipitate of sodium iodate was filtered off and the filtrate evaporated to an oil under reduced pressure. The oil was dissolved in hot MeOH (10 mL) and the solution cooled to 0 °C. The resulting precipitate was recrystallized from MeOH to give 0.32 g (79%) of **11** as prisms: mp 77–78 °C; IR ($CHBr_3$) 1595, 1480, 1445, 1325, 1235, 1060, 1020, 745, 715, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.15 (s, 3 H, methoxy), 3.30–3.60 (m, 2 H, β-methylene), 5.85 (t, 1 H, J = 7 Hz, α-methine), 7.00–7.75 (m, 11 H, arom), 8.00–8.30 (m, 2 H, 1,8-carbazole hydrogen). Anal. Calcd for $C_{21}H_{19}NO$: C, 83.69; 6.35; N, 4.65. Found: C, 83.38; H, 6.12; N, 4.92.

***N*-[(Phenylthio)methyl]benzanilide (14).** A suspension of benzanilide (5 g, 25 mmol) in a solution of Me_2SO (3 mL) and 50% aqueous NaOH (12 mL) was stirred 5 min at 20 °C before adding dropwise [(chloromethyl)thio]benzene (4.7 g, 30 mmol) with vigorous stirring. The temperature of the reaction mixture was kept at 40 °C for 3 h with continuous stirring. The resulting suspension was poured into water (50 mL) and extracted with Et_2O (2 × 20 mL). The ethereal layer was washed with water (2 × 20 mL), dried over anhydrous magnesium sulfate, and evaporated under reduced pressure to yield an oily residue. Addition of MeOH (20 mL) and cooling to 0 °C gave 4.3 g (53%) of **14** as prisms: mp 79–81 °C; IR ($CHBr_3$) 3030, 1655, 1630, 1595, 1490, 1365, 1315, 1260, 950, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.5 (s, 2 H, α-methylene), 7.05–7.65 (m, 15 H, arom). Anal. Calcd for $C_{20}H_{17}NOS$: C, 75.20; H, 5.36; N, 4.28. Found: C, 75.49; H, 5.53; N, 4.26.

***N*-[[(4-Methylphenyl)thio]methyl]carbazole (16).** A suspension of carbazole (4.0 g, 24 mmol) in a solution of Me_2SO (3 mL) and aqueous NaOH (50%; 12 mL) was stirred 5 min at 20 °C before adding dropwise 4-[(chloromethyl)thio]toluene (5.69 g, 33 mmol) with vigorous stirring. After stirring 2 h at 30 °C, the reaction mixture was poured into water (40 mL) and extracted with Et_2O (2 × 20 mL). The ethereal layer was washed with water, dried over anhydrous magnesium sulfate, and evaporated under reduced pressure; the residue was recrystallized from MeOH (80 mL) to give 6.4 g (88%) of **16** as needles: mp 95–97 °C; IR ($CHBr_3$) 2920, 1595, 1480, 1445, 1340, 1320, 1260, 1190, 1060 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.13 (s, 3 H, methyl), 5.40 (s, 2 H, methylene), 6.70–7.40 (m, 10 H, arom), 8.03 (m, 2 H, 1,8-carbazole hydrogen). Anal. Calcd for $C_{20}H_{17}NS$: C, 79.17; H, 5.65; N, 4.62. Found: C, 79.63; H, 5.94; N, 4.52.

3,6-Dinitro-9-[(phenylthio)methyl]carbazole (17). A suspension of 3,6-dinitrocarbazole (4.0 g, 24 mmol) in a solution of Me_2SO (10 mL) and aqueous NaOH (50%, 20 mL) was stirred 30 min at 50 °C before adding dropwise [(chloromethyl)thio]-benzene (5.23 g, 33 mmol) with vigorous stirring. After stirring 2 h at 30 °C, the reaction mixture was poured into water (40 mL) and extracted with Et_2O (2 × 20 mL). The ethereal layer was washed with water, dried over anhydrous magnesium sulfate, and evaporated under reduced pressure; the residue was recrystallized from DMF/MeOH (5:1) to give 4.46 g (49%) of **17** as prisms: mp 234–236 °C; IR ($CHBr_3$) 3120, 1670, 1600, 1585, 1510, 1335, 905, 790, 750 cm^{-1}; the ^1H NMR spectrum could not be readily obtained although ^{13}C NMR data (DMF/Me_2SO-d_6) are reported in Table III (supplementary material). Anal. Calcd for $C_{19}H_{13}N_3O_4S$: C, 60.15; H, 3.45; N, 11.08. Found: C, 59.81; H, 3.53; N, 11.24.

3,6-Dibromo-9-[(phenylthio)methyl]carbazole (21). A suspension of 3,6-dibromocarbazole (3.0 g, 10.4 mmol) in a solution of Me_2SO (5 mL) and aqueous NaOH (50%, 10 mL) was stirred 5 min at 20 °C before adding dropwise [(chloromethyl)thio]-benzene (2.26 g, 14.3 mmol) with vigorous stirring. After stirring 2 h at 30 °C, the reaction mixture was poured into water (30 mL) and extracted with Et_2O (2 × 20 mL). The ethereal layer was washed with water, dried over anhydrous magnesium sulfate, and evaporated under reduced pressure; the residue was recrystallized from EtOH to give 4.1 g (89%) of **21** as prisms: mp 124–126 °C; IR ($CHBr_3$) 1570, 1465, 1430, 1340, 1285, 1260, 1195, 795, 745 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.50 (s, 2 H, methylene), 7.00 (d, 2 H, J = 9 Hz, 1,8-carbazole hydrogen), 7.23 (s, 5 H, phenyl hydrogen), 7.52 (dd, 2 H, J = 2 Hz and 9 Hz, 2,7-carbazole hydrogen), 8.13 (d, 2 H, J = 2 Hz, 4,5-carbazole hydrogen). Anal. Calcd for $C_{19}H_{13}Br_2NS$: C, 51.03; H, 2.93; N, 3.13. Found: C, 51.06; H, 2.85; N, 2.96.

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Supplementary Material Available: ^{13}C NMR data (and correlation of substituents) for carbon atoms of the phenylthio ring of carbazoles **16**, **17**, **19**, and **21** (1 page). Ordering information is given on any current masthead page.