2-(*N*-Methylanilino)-2-phenylsulfanylacetonitrile, A Reagent Tested for Electrophilic, Nucleophilic and Radical Reactions

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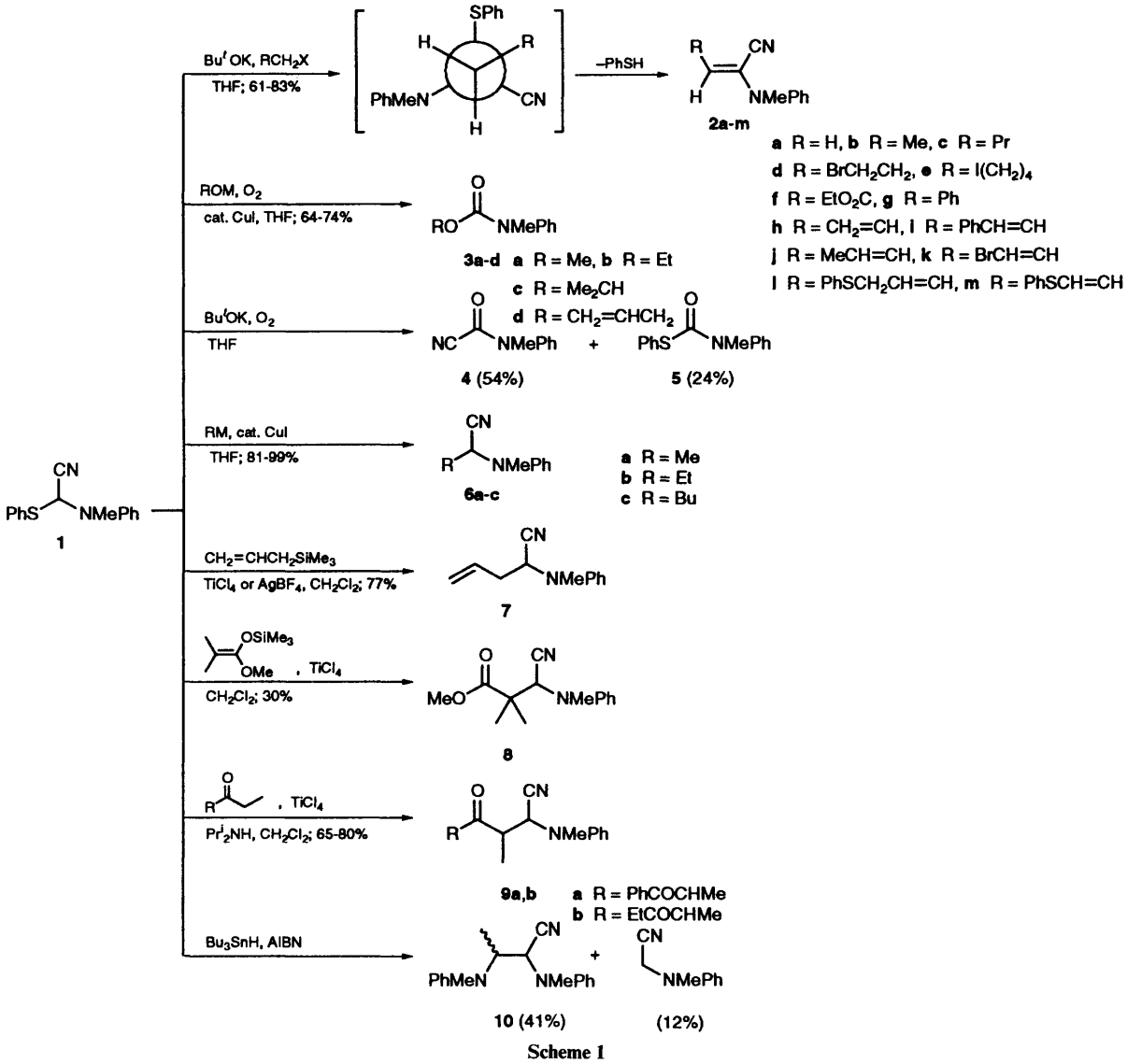
2-(*N*-Methylanilino)-2-phenylsulfanylacetonitrile **1** has been readily prepared from 2-(*N*-methylanilino)acetonitrile and diphenyl disulfide. Alkylation of the anion of **1** with halogenoalkanes resulted in concurrent elimination of benzenethiol to give conjugated α-aminoalkenenitriles of 2*E*-configuration. Autoxidation of **1** in the presence of alkoxide ions afforded alkyl *N*-methyl-*N*-phenylcarbamates. Nucleophilic substitution of **1** with Grignard reagent or appropriate silyl compounds were promoted by CuI or Lewis acids to give varied α-amino nitriles. The 4-oxo-2-amino nitriles **9** obtained by condensation of **1** and titanium enolates can be considered as derivatives of 1,3-dicarbonyl compounds with the aldehyde group being activated to give an amino nitrile umpolung. When **1** was treated with tributylstannane, the corresponding amino nitrile α-radical was formed and the self-coupling product was isolated.

Heteroatom-substituted acetonitriles such as cyanohydrins, amino nitriles and sulfanylacetonitriles are versatile reagents in synthetic chemistry.[1] We reported recently as preliminary communications[2] the properties and use of 2-(*N*-methylanilino)-2-phenylsulfanylacetonitrile **1**. Compound **1**, m.p. 61–61.5 °C, is readily prepared from the reaction of the α-anion



Scheme 1

of 2-(*N*-methylanilino)acetonitrile[3] and diphenyl disulfide. It is stable, and no apparent decomposition occurs after storage for months under a nitrogen atmosphere at room temperature. In addition to the electrophilic reactions, we also studied the nucleophilic and radical reactions of **1**. The results are delineated in Scheme 1 and details are described as follows.

Results and Discussion

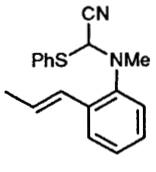
Treatment of **1** with equimolar amounts of Bu^{t}OK and halogenoalkanes in THF solution either at ambient temperature or with gentle heating gave the α-aminoalkenenitriles **2a–m**. The reaction is believed to proceed through the tandem alkylation of **1** α-anion and elimination of the benzenethiol. The *anti* elimination of the benzenethiol molecule can be promoted by the electron-donating amino group[4] to give **2** with the 2*E*-configuration. If allylic bromides or allylic chlorides were used instead of iodoalkanes, the α-amino dienenitriles were obtained.

Compound **1** was converted into the carbamates **3a–d** by autoxidation in the presence of alkoxide ions and CuI. When Bu^{t}OK was used as the base, the autoxidation of **1** gave the cyanoformamide **4** and the thiocarbamate **5** in 54 and 24% yields, respectively. The mechanism for the autoxidation of **1** to **3–5** is not clear, though the reaction may be accounted for by substitution of the α-proton, with an epoxy anion as a postulated intermediate.[5]

To use **1** as an equivalent of the cation of 2-(*N*-methylanilino)acetonitrile, we carried out the nucleophilic substitutions with organometallic or silyl compounds in the presence of CuI or Lewis acid. The reactions of **1** with Grignard reagent or BuLi were promoted by CuI to give amino nitriles **6a–c** in high yields. No further substitution of the cyano group as that occurring in Bruylants reaction[6] was observed. The reaction of **1** with allylsilane was effected by $TiCl_4$ to give 2-(*N*-methylanilino)-pent-4-enenitrile **7** in 77% yield.[7] The allylation was also realized by the catalysis of $AgBF_4$, albeit in lower yield (54%). Substitution of **1** with the titanium enolates generated from the silyl ketene acetal or ethyl ketones gave compounds **8** and **9a, b**.[8] The amino nitrile-substituted ester and ketone have not been prepared by conventional methods. Compounds **9** can be considered as derivatives of 1,3-dicarbonyl compounds with the aldehyde group being activated to give an amino nitrile umpolung[9] that may be used in organic synthesis.

Treatment of **1** with tributyltin hydride yielded 2-(*N*-methylanilino)acetonitrile and 2,3-bis(*N*-methylanilino)butane-1,4-dinitrile **10**. These products are conceivably derived from an amino nitrile α-radical intermediate by hydrogen abstraction or dimerization. Attempts to trap the radical intermediate with alkenes such as hexene, styrene or methyl acrylate failed, presumably the captodative radical[10] being too stable to react with either electron-rich or electron-deficient alkenes.

The amino nitrile α-radical generated from **11**, however, underwent intramolecular cyclization effectively to give the 2-cyanoindoline **12** in 91% yield.



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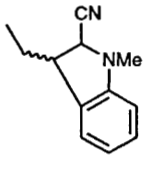

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In summary, the title reagent **1** is useful for the preparation of α-amino nitrile alkenes and dienes *via* tandem alkylation–dehydrosulfanylation. The reaction is initiated by forming an α-carbanion, which can also be trapped with oxygen to give the corresponding carbamate derivatives. Alternatively, **1** is used as an equivalent of an amino nitrile α-cation to react with nucleophiles. The amino nitrile α-radical can be generated from **1**, though its reaction with alkenes failed.

Experimental

Melting points (Yanaco micro melting point apparatus) are uncorrected. Elemental analyses were carried out on a Perkin-Elmer 240c or Hereaus CHN-O-RAPID elemental analyzer. IR spectra were run on a Perkin-Elmer 983G IR spectrophotometer. The ^{1}H NMR spectra were recorded at 200 or 300 MHz (Bruker AC-200 or AM-300WB spectrophotometer). Tetramethylsilane was used as internal standard (*J* values in Hz). ^{13}C NMR spectra were recorded at 50 or 75 MHz. The mass spectra were recorded (using a Finnigan TSQ46c spectrometer) at an ionizing voltage of 70 or 20 eV. The high-resolution mass spectra (HRMS) were recorded on a JEOL JMS-HX 110 spectrometer. HPLC was carried out on a Hitachi L-6200 chromatograph using a μ-Porasil column (7 mm, 25 × 0.78 cm) with 5 cm^3 min^{-1} flow rate of elution.

2-(N-*Methylanilino*)-2-*phenylsulfanylacetonitrile* **1**.—A solution of LDA was prepared by addition of BuLi (1.33 mol dm^{-3} of hexane solution; 5 mmol, 3.75 cm^3) to diisopropylamine (5 mmol, 0.75 cm^3) in THF (10 cm^3). A THF solution (3 cm^3) of 2-(*N*-methylanilino)acetonitrile (730 mg, 5 mmol) was then added dropwise at −40 °C to the preceding solution and the mixture was stirred for 20 min; a THF solution (3 cm^3) of diphenyl disulfide (1.2 g, 5 mmol) was then added to it. After 45 min, the reaction was quenched by addition of saturated aqueous NH_4Cl. The volatile components of the mixture were removed by rotary evaporation, and the residue was extracted with EtOAc. The combined extracts were washed with 5% aqueous NaOH, dried (Na_2SO_4) and concentrated and the residue was purified by silica-gel column chromatography (EtOAc–hexane, 1:9) to give **1** (1.17 g, 91%) as colourless crystals, m.p. 61–61.5 °C (from hexane); ν_{max}(KBr)/cm^{-1} 2237 (CN); δ_H($CDCl_3$) 3.05 (s, NCH_3), 5.80 (s), 6.78–7.02 (3 H, m), 7.18–7.42 (5 H, m) and 7.48–7.62 (2 H, m); δ_C($CDCl_3$) 35.5 (q), 61.7 (d), 116.5 (s, CN), 121.5 (d), 129.5 (d), 129.6 (d), 129.9 (d), 135.7 (s) and 146.7 (s); *m/z* 254 (M^+, 2%), 145 (100) (Found: C, 70.8; H, 5.6; N, 11.05. $C_{15}H_{14}N_2S$ requires C, 70.83; H, 5.55; N, 11.01%).

(N-*Methylanilino*)*prop*-2-*enenitrile* **2a**.[11]—To a solution of Bu^{t}OK (113 mg, 1 mmol) in THF (8 cm^3) was added a solution of 2-(*N*-methylanilino)-2-phenylsulfanylacetonitrile (254 mg, 1 mmol) in THF (2 cm^3) at room temperature. After 20 min, the resulting pale yellow solution was treated with iodomethane (1.1 mmol, 0.07 cm^3). The brownish yellow turbid mixture was stirred at room temperature for 1–12 h and then quenched with saturated aqueous NH_4Cl. After removal of THF from the mixture under reduced pressure, the residue was extracted with EtOAc. The combined extracts were concentrated and passed through a column of silica gel to give the desired product **2a** (131 mg, 83%). The spectral data were previously described.[11]

2-(N-*Methylanilino*)*but*-2-*enenitrile* **2b**.—The reaction of **1** and iodoethane, by a procedure similar to that for **2a**, gave **2b** in 82% yield. A mixture of *E*- and *Z*-isomers (6:1); liquid, TLC (EtOAc–hexane, 2:98) R_f 0.2; ν_{max}(neat)/cm^{-1} 2213 (CN); *m/z* 172 (M^+, 100%), 163 (10) and 157 (50); δ_H($CDCl_3$) 1.98/1.72 (3 H, d, *J* 7.2), 3.06 (3 H, s), 5.94/6.31 (1 H, q, *J* 7.2), 6.85–7.05 (3 H, m) and 7.20–7.40 (2 H, m); δ_C($CDCl_3$) 14.7/13.5 (C-4), 39.6/37.6 (NCH_3), 114.4/114.1 (CN), 116.2 (*Z*), 118.4, 119.6 (*Z*), 120.3 (*Z*), 121.6 (*E*), 121.7 (*Z*), 122.3 (*E*), 126.4 (*E*), 127.6 (*E*), 128.9

(*E*), 129.0 (*Z*), 129.1 (*Z*) 129.3 (*E*), 129.8 (*E*), 139.8 (*Z*), 145.8 and 146.5 (Found: M^+, 172.0984. Calc. for *M*, 172.1000).

2-(N-*Methylanilino*)*hex*-2-*enenitrile* **2c**.[12]—The reaction of **1** and iodobutane, by a procedure similar to that for **2a**, gave **2c** (*E*-configuration) as a liquid in 61% yield. The spectral data were previously described;[12] liquid, ν_{max}(neat)/cm^{-1} 2240 (CN) and 1610; *m*/*z* 200 (M^+, 35%) and 171 (100); δ_H($CDCl_3$) 1.00 (3 H, t, *J* 6.1), 1.53 (2 H, m), 2.40 (2 H, dt, *J* 8.4, 8.0), 3.12 (3 H, s), 5.91 (1 H, t, *J* 8.4), 6.90–7.05 (3 H, m) and 7.20–7.40 (2 H, m).

5-*Bromo*-2-(N-*methylanilino*)*pent*-2-*enenitrile* **2d**.—The reaction of **1** and 1-bromo-3-iodopropane, by a procedure similar to that for **2a** except that heating (60 °C, 24 h) was applied, gave **2d** (*E*-configuration) in 62% yield; liquid, TLC (EtOAc–hexane, 3:97), R_f 0.3; ν_{max}(neat)/cm^{-1} 2238 (CN) and 1600; δ_H($CDCl_3$) 2.95 (2 H, dt, *J* 8.1, 7.9), 3.16 (3 H, s), 3.47 (2 H, t, *J* 7.9), 5.65 (1 H, t, *J* 8.1), 7.02–7.15 (2 H, m) and 7.20–7.40 (3 H, m); *m*/*z* 266 (20%), 264 (M^+, 20) and 171 (100) (Found: M^+, 264.0258. Calc. for *M*, 264.0262).

7-*Iodo*-2-(N-*methylanilino*)*hept*-2-*enenitrile* **2e**.—The reaction of **1** and 1,5-diiodopentane, by a procedure similar that for **2a**, gave **2e** (*E*-configuration) in 50% yield; liquid, TLC (EtOAc–hexane, 2:98), R_f 0.3; ν_{max}(neat)/cm^{-1} 2221 (CN) and 1593; δ_H($CDCl_3$) 1.62 (2 H, m), 1.90 (2 H, m), 2.45 (2 H, dt, *J* 7.1, 6.8), 3.12 (3 H, s), 3.2 (2 H, t, *J* 7.0), 5.77 (1 H, t, *J* 7.1), 6.8–7.12 (2 H, m) and 7.20–7.40 (3 H, m); *m*/*z* 340 (M^+, 20%), 171 (100); (Found: M^+, 340.0426. Calc. for *M*, 340.0438).

Ethyl 3-(N-*Methylanilino*)-3-*cyanoprop*-2-*enoate* **2f**.—The reaction of **1** and ethyl iodoacetate, by a procedure similar to that for **2a** except that heating (60 °C, 24 h) was applied, gave **2f** (*E*-configuration) in 72% yield; liquid, TLC (EtOAc–hexane, 15:85), R_f 0.2; ν_{max}(neat)/cm^{-1} 2223 (CN) and 1700; δ_H($CDCl_3$) 1.30 (3 H, t, *J* 8.1), 3.35 (3 H, s), 4.21 (2 H, q, *J* 8.1), 5.28 (1 H, s), 7.12–7.25 (2 H, m) and 7.30–7.50 (3 H, m); *m*/*z* 230 (M^+, 100%) and 157 (96) (Found: M^+, 230.1053. Calc. for *M*, 230.1054).

2-(N-*Methylanilino*)-3-*phenylprop*-2-*enenitrile* **2g**.[12]—The reaction of **1** and benzyl bromide, by a procedure similar to that for **2a**, gave **2g** (*E*-configuration) as a liquid in 64% yield. The spectral data have been described earlier.[12]

2-(N-*Methylanilino*)*penta*-2,4-*dienenitrile* **2h**.[13]—The reaction of **1** and allyl bromide, by a procedure similar to that for **2a**, gave **2h** (2*E*-configuration) in 61% yield; liquid, HPLC (EtOAc–hexane, 2:98) t_R 4.8 min; ν_{max}(neat)/cm^{-1} 2223; δ_H($CDCl_3$) 3.21 (3 H, s), 5.21 (1 H, br d, *J* 10.2), 5.31 (1 H, br d, *J* 16.8), 6.13 (1 H, d, *J* 11.1), 6.58–6.77 (1 H, m), 7.04–7.15 (3 H, m) and 7.26–7.37 (2 H, m); δ_C($CDCl_3$) 40.3 (NCH_3), 114.3 (CN), 118.4 (C-5), 122.8 (C-4), 123.1 (C-3), 124.5 (d), 129.3 (d), 132.3 (d), 138.7 (C-2) and 145.7 (s); *m*/*z* 183 (100%, $M^+ - 1$) and 168 (25) (Found: C, 77.9; H, 6.6; N, 15.2. $C_{12}H_{12}N_2$ requires C, 78.23; H, 6.57; N, 15.20%).

2-(N-*Methylanilino*)-5-*phenylpenta*-2,4-*dienenitrile* **2i**.[14]—The reaction of **1** and cinnamyl chloride, by a procedure similar to that for **2a** except that heating (60 °C, 48 h) was applied, gave **2i** (2*E*,4*E*-configuration) as a liquid in 63% yield. The spectral data have been described earlier.[14]

2-(N-*Methylanilino*)*hexa*-2,4-*dienenitrile* **2j**.[14]—The reaction of **1** and crotyl chloride, by a procedure similar to that for **2a** except that heating (60 °C, 24 h) was applied, gave **2j** (2*E*,4*E*- and 2*Z*,4*E*-isomers, 2:1) as a liquid in 61% yield. The spectral data have been described earlier.[14]

2-(N-*Methylanilino*)-5-*bromopenta*-2,4-*dienenitrile* **2k**.—The reaction of **1** and 1,3-dibromopropene, by a procedure similar to that for **2a**, gave **2k** in 72% yield; liquid, TLC (EtOAc–hexane, 5:95), R_f 0.3; ν_{max}(neat)/cm^{-1} 2227 (CN) and 1587; δ_H($CDCl_3$) 3.22 (3 H, s), 5.93 (1 H, d, *J* 11.1), 6.36 (1 H, d, *J* 13.4), 7.02–7.25 (4 H, m) and 7.30–7.45 (2 H, m); *m*/*z* 264 (20%), 262 (M^+, 20) and 183 (100) (Found: M^+, 262.0100. Calc. for *M*, 262.0106).

2-(N-*Methylanilino*)-6-*phenylsulfanylhexa*-2,4-*dienenitrile* **2l**.—The reaction of **1** and 1,4-dibromobut-2-ene, by a procedure similar to that for **2a**, gave **2l** in 69% yield. The reaction involved a counterattack of benzenethiolate ion. 2*E*,4*E*-Isomer, liquid; ν_{max}(neat)/cm^{-1} 2225 (CN) and 1578; δ_H($CDCl_3$) 3.16 (3 H, s), 3.65 (2 H, dd, *J* 7.0, 6.1), 5.80 (1 H, dt, *J* 14.6, 7.6), 6.05 (1 H, d, *J* 11.2), 6.48 (1 H, dd, *J* 14.6, 11.2) and 7.02–7.40 (10 H, m); *m*/*z* 306 (M^+, 44%) and 197 (100) (Found: M^+, 306.1199. Calc. for *M*, 306.1191. Found: C, 74.3; H, 5.9; N, 9.2. $C_{19}H_{18}N_2S$ requires C, 74.47; H, 5.92; N, 9.14%).

2-(N-*Methylanilino*)-5-*phenylsulfanylpenta*-2,4-*dienenitrile* **2m**.—The reaction of **1** and 3-bromo-1-(trimethylsilyl)prop-1-yne, by a procedure similar to that for **2a**, gave **2m** in 55% yield. The reaction involved a counterattack by benzenethiolate ion. The 2*E*,4*E*- and 2*Z*,4*E*-isomers (3:2) were separated by HPLC (EtOAc–hexane, 1:9) appearing at t_R 10.0 and 8.5 min, respectively. 2*E*,4*E*-Isomer: ν_{max}(neat)/cm^{-1} 2219, 1583 and 1543; δ_H($CDCl_3$) 3.22 (3 H, s), 6.21 (1 H, d, *J* 10.3), 6.52 (1 H, d, *J* 17.0), 6.73 (1 H, dd, *J* 10.3, 17.0), 7.02–7.2 (3 H, m) and 7.3–7.45 (7 H, m); *m*/*z* (Found: M^+, 292.1032. Calc. for *M*, 292.1034). 2*E*,4*Z*-Isomer: δ_H($CDCl_3$) 3.28 (3 H, s), 6.32 (1 H, d, *J* 10.0), 6.47 (1 H, d, *J* 12.5), 6.74 (1 H, dd, *J* 10.0, 12.5), 7.10–7.22 (3 H, m) and 7.25–7.45 (7 H, m); *m*/*z* 292 (M^+, 100%) and 183 (92) (Found: M^+, 292.1024. Calc. for *M*, 292.1034).

Methyl N-*Methyl*-N-*phenylcarbamate* **3a**.[15]—To a THF solution (5 cm^3) of **1** (254 mg, 1 mmol) was added CuI (20 mg) and MeONa (65 mg, 1.2 mmol). After 10 min, a stream of oxygen was bubbled into the solution. The mixture was stirred at room temperature for 12 h and quenched by addition to it of aqueous KI. The mixture was filtered, concentrated and extracted with EtOAc. The combined extracts were dried (Na_2SO_4), concentrated and separated on a silica gel column (EtOAc–hexane, 1:19) to give **3a** (180 mg, 71%); liquid, TLC (EtOAc–hexane, 1:19), R_f 0.2. The spectral data have been described earlier.[15]

Ethyl N-*Methyl*-N-*phenylcarbamate* **3b**.[16]—The autoxidation of **1** in the presence of EtONa, by a procedure similar to that for **3a**, gave **3b** as liquid in 64% yield, the spectral data have been described earlier.[16]

Isopropyl N-*Methyl*-N-*phenylcarbamate* **3c**.[17]—The autoxidation of **1** in the presence of Pr^{i}OLi (prepared from Pr^{i}OH and BuLi), by a procedure similar to that for **3a**, gave **3c** as liquid in 74% yield. The spectral data have been described earlier.[17]

Allyl N-*Methyl*-N-*phenylcarbamate* **3d**.—The autoxidation of **1** in the presence of lithium allyl oxide (prepared from allyl alcohol and BuLi), by a procedure similar to that for **3a**, gave **3d** in 65% yield; liquid, TLC (EtOAc–hexane, 1:19), R_f 0.3; ν_{max}(neat)/cm^{-1} 1710 (C=O) and 1598; *m*/*z* 191 (M^+, 37%) and 105 (100); δ_H($CDCl_3$) 3.31 (3 H, s), 4.60 (2 H, m), 5.18 (2 H, m), 5.88 (1 H, m) and 7.16–7.39 (5 H, m); δ_C($CDCl_3$) 37.6 (NCH_3), 66.1 (C-1), 117.1 (C-3), 125.7 (C-2′), 126.0 (C-4′), 128.7 (C-3′), 132.7 (C-2), 143.1 (C-1′) and 155.3 (C=O) (Found: M^+, 191.0952. Calc. for *M*, 191.0946).

N-Methyl-N-phenylcyanamide **4** *and S-Phenyl N-Methyl-N-phenylthiocarbamate* **5**.—To a cold (−78 °C) THF solution (2 cm^3) of **1** (254 mg, 1 mmol) was added Bu^{t}OK (60 mg) in THF (5 cm^3). The solution was saturated with oxygen, warmed to room temperature, and stirred for 18 h. Aqueous KI was added to the mixture to quench the reaction. The mixture was concentrated and extracted with EtOAc. The combined extracts were washed with aqueous $Na_2S_2O_3$ and brine, dried (Na_2SO_4), filtered and concentrated. The residue was separated by silica-gel chromatography (EtOAc–hexane, 1:19) to give **4** (86 mg, 54%) and **5** (58 mg, 24%). Compound **4**: ν_{max}(KBr)/cm^{-1} 2230 (CN) and 1698 (C=O); *m/z* 160 (M^+, 100%) and 132 (24); δ_H($CDCl_3$) 3.37 (3 H, s) and 7.20–7.45 (5 H, m) (Found: M^+, 160.0642. Calc. for *M*, 160.0637). Compound **5**: ν_{max}(KBr)/cm^{-1} 1668; *m/z* 243 (M^+, 22%) and 134 (100); δ_H($CDCl_3$) 3.35 (3 H, s) and 7.25–7.50 (5 H, m); δ_C($CDCl_3$) 38.5 (s), 128.3 (d), 128.6 (d), 128.8 (d), 129.0 (d), 129.4 (s), 129.5 (d), 135.4 (d), 141.8 (s) and 167.4 (s, C=O) (Found: M^+, 243.0713. Calc. for *M*, 243.0718).

2-(*N-Methylanilino*)*propanenitrile* **6a**.[18]—To a cold (−40 °C) THF solution (5 cm^3) of **1** (178 mg, 0.7 mmol) and CuI (10 mg) was added dropwise MeMgCl (3.0 mol dm^{-3} THF solution; 1.4 mmol, 0.47 cm^3). The mixture was warmed to room temperature and stirred for 2 h. After addition of ice–water to the mixture it was extracted with EtOAc. The combined extracts were washed with water and brine, dried (Na_2SO_4), filtered and concentrated. The residue was purified by silica-gel chromatography (EtOAc–hexane, 1:9) to give **6a** (111 mg, 99%); liquid, TLC (EtOAc–hexane, 1:9), R_f 0.2. The spectral data have been reported earlier.[18]

2-(*N-Methylanilino*)*butanenitrile* **6b**.—Compound **6b** was prepared in 81% yield from **1** and EtMgBr by a procedure similar to that for **6a**; liquid, TLC (EtOAc–hexane, 1:19), R_f 0.2; ν_{max}(neat)/cm^{-1} 2227 (CN); *m/z* 174 (M^+, 60%) and 146 (100); δ_H($CDCl_3$) 1.90 (3 H, t, *J* 7), 1.95 (2 H, m), 2.88 (3 H, s), 4.36 (1 H, t, *J* 7) and 6.88–7.33 (5 H, m) (Found: M^+, 174.1156. Calc. for *M*, 174.1157).

2-(*N-Methylanilino*)*hexanenitrile* **6c**.—Compound **6c** was prepared in 84% yield from **1** and BuLi by a procedure similar to that for **6a**; liquid, TLC (EtOAc–hexane, 1:19), R_f 0.3; ν_{max}(neat)/cm^{-1} 2220 (CN); *m/z* 202 (M^+, 56%) and 145 (100); δ_H($CDCl_3$) 0.93 (3 H, t, *J* 7), 1.45 (4 H, m), 1.95 (2 H, q, *J* 7), 2.90 (3 H, s), 4.45 (1 H, t, *J* 7) and 6.85–7.35 (5 H, m); δ_C($CDCl_3$) 13.8 (C-6), 22.0 (C-4), 27.8 (C-5), 31.4 (C-3), 34.2 (NCH_3), 54.0 (C-2), 116.8 (C-2′), 118.0 (CN), 120.7 (C-4′), 129.3 (C-3′) and 149.3 (C-1′) (Found: M^+, 202.1474. Calc. for *M*, 202.1470).

2-(*N-Methylanilino*)*pent-4-enenitrile* **7**.—To a cold (−78 °C) CH_2Cl_2 solution (4 cm^3) of **1** (254 mg, 1 mmol) was added sequentially $TiCl_4$ (0.15 cm^3, 1.5 mmol) and allylsilane (0.2 cm^3, 1.27 mmol). The mixture was stirred at −78 °C for 40 min, quenched by addition of aqueous NaOH (5%, 0.5 cm^3) to it and extracted with $CHCl_3$. The extract was washed with brine, dried (Na_2SO_4), concentrated and purified by silica-gel chromatography (EtOAc–hexane, 1:19) to give **7** (143 mg, 77%); liquid, TLC (EtOAc–hexane, 1:19), R_f 0.19; ν_{max}(neat)/cm^{-1} 2231 (CN) and 1641; *m/z* 186 (M^+, 12%) and 145 (100); δ_H($CDCl_3$) 2.62 (2 H, t, *J* 7.5), 2.89 (3 H, s), 4.49 (1 H, t, *J* 7.5), 5.17–5.30 (2 H, m), 5.70–5.91 (1 H, m) and 6.82–7.33 (5 H, m); δ_C($CDCl_3$) 34.3 (NCH_3), 35.8 (C-3), 54.0 (C-2), 116.6 (C-2′), 117.2 (CN), 119.5 (C-5), 120.8 (C-4′), 129.2 (C-3′), 131.5 (C-4) and 148.9 (C-1′) (Found: M^+, 186.1151. Calc. for *M*, 186.1157).

Methyl 3-*Cyano*-2,2-*dimethyl*-3-(*N-methylanilino*)*propanoate* **8**.—To a cold (−78 °C) THF solution (10 cm^3) of LDA (10 mmol), prepared from BuLi (1.6 mol dm^{-3} hexane solution; 7.7 cm^3) and diisopropylamine (1.5 cm^3), was added dropwise methyl isobutyrate (1.15 cm^3, 10 mmol). After 30 min, chlorotrimethylsilane (1.4 cm^3, 11 mmol) was added to the mixture which was then stirred at −78 °C for 5 min, and warmed to room temperature over 1 h. Saturated aqueous NH_4Cl (0.5 cm^3) was added to the mixture which was then concentrated and extracted with Et_2O. The combined extracts were washed with brine, dried (Na_2SO_4), concentrated and distilled under reduced pressure to give the corresponding silyl ketene acetal, b.p. 46 °C/30 Torr.

To a cold (−78 °C) CH_2Cl_2 solution (2 cm^3) of **1** (254 mg, 1 mmol) was added $TiCl_4$ (0.15 cm^3, 1.5 mmol) and the freshly prepared silyl ketene acetal (191 mg, 1.1 mmol). After the addition, the mixture was warmed to room temperature and stirred for 1 h. The solution was poured into cold (0 °C) aqueous NaOH (5%), and extracted with EtOAc. The combined extracts were washed with brine, dried (Na_2SO_4) and concentrated, and the residue separated by silica-gel chromatography (EtOAc–hexane, 1:9) to give **8** (71 mg, 30%), accompanied by recovery of **1** (25%). Compound **8**: liquid, TLC (EtOAc–hexane, 1:9) R_f 0.23; ν_{max}(neat)/cm^{-1} 2250 (CN) and 1735 (CO_2Me); δ_H($CDCl_3$) 1.40 (3 H, s), 1.47 (3 H, s), 2.97 (3 H, s), 3.65 (3 H, s), 4.95 (3 H, s), 6.88–7.02 (3 H, m) and 7.18–7.42 (2 H, m); *m/z* 246 (M^+, 20%) and 1.45 (100) (Found: M^+, 246.1375. Calc. for *M*, 246.1368) (Found C, 68.1; H, 7.35; N, 11.3. $C_{14}H_{18}N_2O_2$ requires C, 68.27; H, 7.37; N, 11.37%).

3-*Benzoyl*-2-(*N-methylanilino*)*butanenitrile* **9a**.—To a cold (−78 °C) CH_2Cl_2 solution (15 cm^3) of propiophenone (402 mg, 3 mmol) was added $TiCl_4$ (0.31 cm^3, 3.1 mmol) under N_2. The yellow slurry was stirred for 2 min after which *N,N*-diisopropylethylamine (0.56 cm^3, 3.2 mmol) was added dropwise to it; the resulting deep red solution was stirred at −78 °C for 1.5 h. A CH_2Cl_2 solution (2 cm^3) of **1** (254 mg, 1 mmol) was added dropwise to the mixture which was then warmed to room temperature and stirred for 1.5 h. The mixture was worked up by a procedure similar to that for **8** to give **9a** (659 mg, 80%) as a mxiture of two diastereoisomers (62:38). Liquid, TLC (EtOAc–hexane 12:88), R_f 0.19; ν_{max}(neat)/cm^{-1} 2228 and 1678; δ_H($CDCl_3$) 1.37/1.45 (3 H, d, *J* 6), 2.97/2.81 (3 H, s), 4.13–4.29 (1 H, m), 4.96/5.05 (1 H, d, *J* 6), 6.92–7.06 (3 H, m), 7.23–7.28 (2 H, m), 7.44–7.57 (3 H, m) and 7.90–7.94 (2 H, m); *m/z* 278 (M^+, 15%) and 145 (100) (Found: C, 77.3; H, 6.5; N, 9.85. $C_{18}H_{18}N_2O$ requires C, 77.67; H, 6.52; N, 10.06%).

3-*Methyl*-2-(*N-methylanilino*)-4-*oxohexanenitrile* **9b**.—Compound **9b** was prepared by condensation of pentan-3-one and **1** in 65% yield by a procedure similar to that for **9a**. Compound **9b**: a mixture of two diastereoisomers (60:40), liquid, TLC (EtOAc–hexane, 12:88), R_f 0.2; ν_{max}(neat)/cm^{-1} 2229 and 1710; δ_H($CDCl_3$) 1.05 (3 H, t, *J* 6), 1.28/1.19 (3 H, d, *J* 6), 2.31–2.76 (2 H, m), 2.86/2.85 (3 H, s), 3.23–3.34 (1 H, m), 4.78/4.86 (1 H, d, *J* 12), 6.89–7.02 (3 H, m) and 7.24–7.33 (2 H, m); *m/z* 230 (M^+, 10%) and 145 (100) (Found: C, 72.9; H, 7.7; N, 11.8. $C_{14}H_{18}N_2O$ requires C, 73.01; H, 7.88; N, 12.16%).

2,3-*Bis*(*N-methylanilino*)*butane*-1,4-*dinitrile* **10**.—To a mild refluxing (80 °C) solution of **1** (127 mg, 0.5 mmol) in benzene (3 cm^3) was added dropwise a benzene solution (7 cm^3) of Bu_3SnH (0.28 cm^3, 1 mmol), methyl acrylate (0.09 cm^3, 1 mmol) and azoisobutyronitrile (16.4 mg) over a period of 2 h. The mixture was heated for 6 h at reflux, cooled and concentrated by rotary evaporation. The residue was passed through a silica gel column by elution with hexane to remove benzenethiol, and by elution with EtOAc–hexane (5:95) to give methyl 3-(tributylstannyl)propanoate (67.7 mg, 37%), 2-(*N*-methylanilino)-acetonitrile (8.8 mg, 12%) and **10** (63 mg, 44%, containing two isomers in equal amounts). Compound **10**: oil, TLC (EtOAc–

hexane, 10:90), R_f 0.19; *m/z* 290 (M^+, 17%), 263 (11) and 145 (100); $\delta_H(CDCl_3)$ 7.34–6.84 (10 H, m), 4.97 (2 H, s) 4.85 (2 H, s) and 2.89 (6 H, s)/3.03 (6 H, s); $\delta_C(CDCl_3)$ 148.1/148.7 (s), 129.6/129.7 (d), 122.0/123.3 (d), 117.0/118.9 (d), 114.7/114.2 (s, CN), 56.0/58.1 (d, C-2) and 35.5/36.7 (q) (Found: M^+, 290.1510. Calc. for *M*, 290.1531).

2-[N-*Methyl*-(o-*propenylphenyl*)*amino*]-2-*phenylsulfanyl*-*acetonitrile* **11**.—Treatment of 2-[*N*-methyl-(*o*-propenylphenyl)amino]acetonitrile with LDA and diphenyl disulfide, by a procedure similar to that for **1**, gave **11** in 74% yield; oil, TLC (EtOAc–hexane, 5:95), R_f 0.22; ν_{max}(neat)/cm^{-1} 2211; $\delta_H(CDCl_3)$ 1.82 (3 H, dd, *J* 6.6, 1.0), 3.02 (3 H, s), 5.42 (1 H, s), 6.06 (1 H, dq, *J* 16.0, 6.6), 6.44 (1 H, dd, *J* 16.0, 1.0) and 7.12–7.54 (9 H, m); $\delta_C(CDCl_3)$ 18.8 (q), 36.2 (q), 64.1 (d), 115.5 (s), 121.7 (d), 125.2 (d), 127.2 (d), 127.5 (d), 127.8 (d), 128.1 (d), 129.1 (d), 129.2 (d, 2 C), 131.2 (s), 132.8 (s), 134.6 (d, 2 C) and 145.1 (s); *m/z* 294 (1%, M^+) and 185 (100) (Found: M^+, 294.1176. Calc. for *M*, 294.1191).

3-*Ethyl*-1-*methyl*-2,3-*dihydroindole*-2-*carbonitrile* **12**.—To a mild refluxing (80 °C) solution of **11** (150 mg, 0.51 mmol) in benzene (15 cm^3) was added dropwise a benzene solution (15 cm^3) of Bu_3SnH (0.17 cm^3, 0.61 mmol) and azoisobutyronitrile (17 mg) over a period of 2.5 h. The mixture was heated for 6 h and concentrated. The residue was chromatographed on a silica gel column by elution with hexane to remove tin compounds and followed by elution with EtOAc. The EtOAc phase was treated with Et_3N (0.5 cm^3) and the white precipitate was filtered off. The filtrate was concentrated and separated by HPLC (EtOAc–hexane, 5:95) to give *cis*-**12** (53 mg) and *trans*-**12** (28 mg) in 91% total yield. Compound *trans*-**12**: oil, TLC (EtOAc–hexane, 5:95), R_f 0.20; ν_{max}(neat)/cm^{-1} 2248; $\delta_H(CDCl_3)$ 1.08 (3 H, t, *J* 7.4), 1.61–1.76 (1 H, m), 1.81–1.96 (1 H, m), 2.88 (3 H, s), 3.40–3.50 (1 H, m), 3.93 (1 H, d, *J* 6), 6.54 (1 H, d, *J* 8), 6.80 (1 H, ddd, *J* 8, 8, 1), 7.09 (1 H, dd, *J* 8, 1) and 7.16 (1 H, dd, *J* 8, 8); $\delta_C(CDCl_3)$ 11.4 (q), 26.2 (t), 34.2 (q), 48.5 (d, C-3), 61.4 (d, C-2), 108.2 (d), 118.6 (s, CN), 119.5 (d), 123.8 (d), 128.5 (d), 130.3 (s) and 150.1 (s); *m/z* 186 (33%, M^+) and 157 (100). Compound *cis*-**12**: oil, TLC (EtOAc–hexane, 5:95), R_f 0.17; ν_{max}(neat)/cm^{-1} 2219 (CN); $\delta_H(CDCl_3)$ 1.11 (3 H, t, *J* 7.4), 1.80–1.96 (1 H, m), 2.00–2.18 (1 H, m), 2.87 (3 H, s), 3.28–3.41 (1 H, m), 4.42 (1 H, d, *J* 8), 6.56 (1 H, d, *J* 8), 6.81 (1 H, ddd, *J* 8, 8, 1), 7.09 (1 H, dd, *J* 8, 1) and 7.16 (1 H, ddd, *J* 8, 8, 1); $\delta_C(CDCl_3)$ 11.9 (t), 22.6 (t), 34.1 (q), 45.4 (d), 62.4 (d), 108.3 (d), 116.1 (s), 119.7 (d), 123.5 (d), 128.4 (d), 130.6 (s) and 150.3 (s); *m/z* 186 (34%, M^+) and 157 (100) (Found: M^+, 186.1145. Calc. for *M*, 186.1157).

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