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Lithiation of Pivaloylamino Derivatives of Dibenzofuran and 9-Methylcarbazole

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2-, 3- and 4-Pivaloylamino derivatives of dibenzofuran [compounds (5), (4) and (6), respectively] and analogous 3-, 2- and 1-substituted derivatives of 9-methylcarbazole [compounds (8), (7) and (9), respectively] were subjected to lithiation at 0°C and subsequent reaction with dimethylformamide. Aldehyde formation took place at positions α to δ to the heteroatom as follows: α for (4) and (7); δ for (5); δ and β (3 : 1) for (8); and α′ for (6). No formylation occurred with (9).

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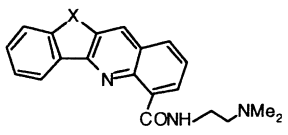
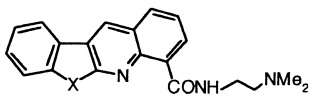
Introduction

As part of a continuing investigation of testing derivatives of polycyclic heterocycles for anticancer activity, we wished to prepare analogues of (1)[1] and (2),[2] with X = O or NR, in which the positions of the pyrido and side chain containing rings are reversed.

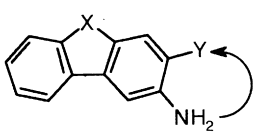


(1)

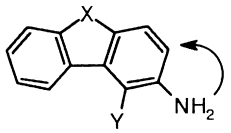


(2)

A possible approach would be to construct the pyrido ring from known amino-dibenzofurans and -carbazoles. An additional pertinent substituent *ortho* to the amino group would be useful for this annulation, e.g. (3a), or as forerunner of derivatives for biological testing (3b) (Fig. 1).



(3a)

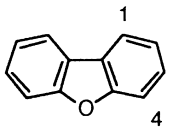


(3b)

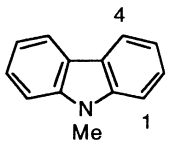
Fig. 1. Possible approach to the construction of a pyrido ring from substituted aminodibenzofurans and aminocarbazoles.

Directed *ortho*-metallation is a useful synthetic tool[3] but the products from electrophilic substitution of lithiated aminodibenzofurans and carbazoles were not known, which therefore prompted the present study.

Dibenzofuran has long been known to lithiate at the 4-position and reaction with electrophiles is a useful route to various 4-substituted products.[4] A recent example is formation of the 4-carbaldehyde derivative by reaction with *N*,*N*-dimethylformamide and subsequent hydrolysis.[5] Since the aldehyde function could be useful in further synthesis, this reaction was chosen for the present study. While free amino groups are inappropriate for lithiation, the pivaloylamino group was shown to be a good modification of anilines for *ortho*-directed lithiation and subsequent reaction with electrophiles (including the dimethylformamide (DMF) reaction).[6] We therefore wished to see how the position of substitution in dibenzofuran would be modified by the presence of a pivaloylamino group at various ring positions.



Dibenzofuran



9-Methylcarbazole

The same questions would be posed for analogous pivaloylamino derivatives of 9-methylcarbazole. Simple 9-alkyl derivatives of carbazole are less reactive to ring-carbon lithiation[7] than dibenzofuran, though useful 1-substitution was found by lithiation of 9-(dialkylamino)methyl derivatives.[8]

Results and Discussion

Dibenzofuran-2-, -3- and -4-amines and 9-methylcarbazol-1-, -2- and -3-amines were prepared by literature procedures, some with modifications (see Experimental). For comparison purposes, all compounds were lithiated under the same conditions. Tetrahydrofuran was found to be superior to diethyl ether as solvent in earlier lithiations of dibenzofuran and 9-ethylcarbazole.[9] The previous lithiation of *N*-pivaloylanilines also used n-butyllithium in tetrahydrofuran,

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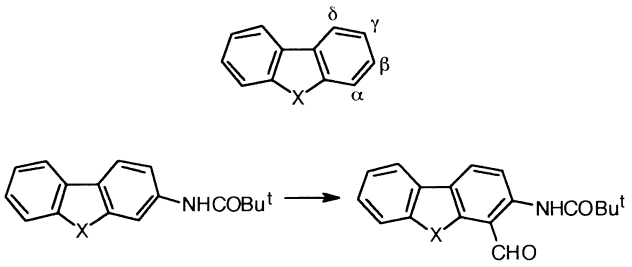
and so lithiation at 0°C and subsequent reaction with DMF was carried out by this literature procedure.[6]

As illustrated above, the systematic numbering of dibenzofuran and carbazole are different, which is confusing when comparing the same ring positions. Systematic numbering is used in the Experimental section but in this discussion the ring positions will be referred to by α, β, γ, δ as shown in Scheme 1.



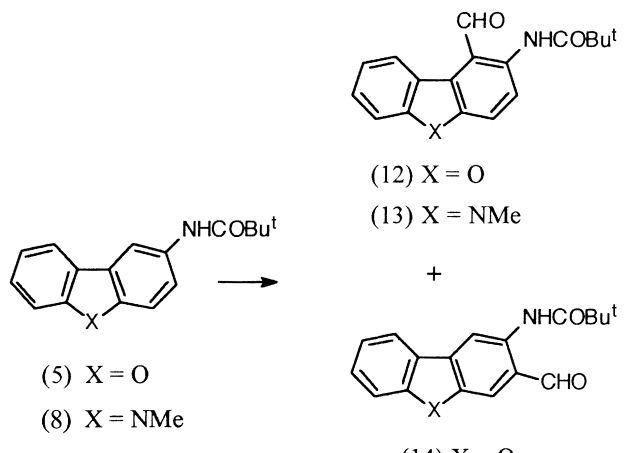
(4) X = O
(7) X = NMe

(10) X = O
(11) X = NMe

Scheme 1

Where the effect of the heteroatom and pivaloylamino group were reinforcing (Scheme 1, compounds (4) and (7)), the expected α-products (10) and (11), respectively, were the only aldehydes detected and these were isolated in ca. 65% yields. Throughout this study, ^{1}H nuclear magnetic resonance (NMR) spectra provided unequivocal evidence for the assigned structures. Thus, for (10) and (11), the singlet for H α evident in the precursors was absent.

The pivaloylamino group was activating enough to compete with the heteroatom in some situations. Thus, for compounds with a γ-pivaloylamino substituent (Scheme 2, compounds (5) and (8)), substitution *ortho* to the pivaloylamino group was seen, rather than the α-product. Here though, an appreciable difference was noted between the analogous N and O substrates. For the former, a 3 : 1 mixture of the isomers (13) and (15) was found. These had a substantial difference in chemical shift for the CHO signal in the ^{1}H NMR spectrum (11.3 and 10.0 ppm, respectively). Partial separation was achieved by chromatography and the



(5) X = O
(8) X = NMe

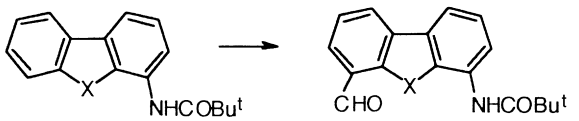
(12) X = O
(13) X = NMe

(14) X = O
(15) X = NMe

Scheme 2

singlets for H α and H δ in (15) were characteristic. In the dibenzofuran analogue, only the product of δ-substitution (12) was evident in the crude mixture.

It is interesting that the β-aldehyde should be formed to this extent in the carbazole example since, in the other case where this position was supposedly activated, i.e. compound (9) (Scheme 3), no aldehyde was found and (9) showed the lack of reactivity previously noted for simple 9-substituted carbazoles.[7] This low reactivity of the β-position was also noted in the O analogue (6) but here, because of the greater heteroatom activation, a ready reaction occurred in the α-position of the other ring to give (16) which was isolated in 67% yield. A correlation spectroscopy (COSY) ^{1}H NMR experiment showed that each of the two aromatic triplet signals was coupled to a different pair of the four doublet signals, a result consistent only with this substitution pattern. A small amount of a second aldehyde was present in the crude product but too few ^{1}H NMR signals were distinguishable for it to be identified.



(6) X = O
(9) X = NMe

(16) X = O
No product for X = NMe

Scheme 3

This study has showed an interesting interplay of effects from the heteroatom and pivaloylamino substituent in directing electrophilic substitution in these dibenzofuran and carbazole derivatives. Viable syntheses of precursors to *ortho*-amino aldehydes for further construction of tetracyclic systems have been established from (4), (5) and (7) (separation of isomeric products from (8) is problematic on a preparative scale), while the dissimilar α,α′-substitution in (6) may also have future synthetic utility.

Experimental

NMR spectra were recorded in $CDCl_3$ unless stated otherwise, on a Bruker AM-300 spectrometer operating at 300.13 (^{1}H) and 75.47 MHz (^{13}C). ^{1}H NMR signals are for single protons unless otherwise indicated. Standard PENDANT (polarization enhancement during attached nucleus testing) experiments were used to identify proton-bound carbons in ^{13}C NMR spectra. Microanalyses were carried out at the Campbell Microanalytical Laboratory, University of Otago, New Zealand.

Dibenzofuran-2-amine [10]

The title compound was prepared as reported[10] from 2-bromodibenzofuran.[11] ^{1}H NMR δ 3.75, br s, NH_2; 6.81, dd, *J* 8.6, 2.3 Hz; 7.22, d, *J* 2.3 Hz; 7.27, t, *J* 7.3 Hz; 7.35, d, *J* 8.6 Hz; 7.39, t, *J* 7.3 Hz; 7.50, d, *J* 8.1 Hz; 7.85, d, *J* 7.6 Hz. ^{13}C NMR δ 105.9, CH; 111.6, CH; 111.9, CH; 115.7, CH; 120.5, CH; 122.2, CH; 124.3, C; 124.8, C; 126.9, CH; 142.0, C; 150.3, C; 156.7, C.

Dibenzofuran-4-amine

The title compound was prepared as reported[12] (^{1}H NMR δ 4.0, br s, NH_2; 6.81, d, *J* 7.7 Hz; 7.14, t, *J* 7.7 Hz; 7.32, t, *J* 7.3 Hz; 7.36, d, *J* 7.9 Hz; 7.43, t, *J* 7.4 Hz; 7.55, d, *J* 8.1 Hz; 7.91, d, *J* 7.6 Hz. ^{13}C NMR δ 110.4, CH; 111.6, CH; 112.9, CH; 120.9, CH; 122.6, CH; 123.4, CH; 124.5, C; 124.7, C; 126.8, CH; 131.9, C; 144.8, C; 155.9, C).

3-Nitrodibenzofuran

A literature method was modified.[13] A mixture of fuming nitric acid (8 mL, 190 mmol) in glacial acetic acid (12 mL) was added dropwise over 5 min to a solution of dibenzofuran (20 g, 119 mmol) in glacial acetic acid (40 mL) at 90°C. The solution was heated for 10 min, during which time a heavy yellow precipitate separated. This mixture of nitro products (23.9 g) was filtered off, washed thoroughly with water and extracted with hot ethanol (2×150 mL). The insoluble off-white powder was recrystallized from acetic acid to give the product (17.1 g, 67%), melting point (m.p.) 180–181°C (lit.[14] 181–182°C). ^{1}H NMR δ 7.42, t, *J* 6.9 Hz; 7.58, t, *J* 7.5 Hz; 7.63, d, *J* 8.0 Hz; 8.00, d, *J* 7.6 Hz; 8.02, d, *J* 8.5 Hz; 8.26, dd, *J* 8.5, 1.8 Hz; 8.42, d, *J* 1.8 Hz, H 4. ^{13}C NMR δ 107.9, CH; 112.2, CH; 118.4, CH; 120.5, CH; 121.7, CH; 122.4, C; 123.7, CH; 129.5, CH; 130.1, C; 146.7, C; 155.0, C; 158.2, C.

Dibenzofuran-3-amine

The following represents a convenient alternative to previous reduction conditions. A mixture of 3-nitrodibenzofuran (10 g), hydrazine monohydrate (30 mL), 10% Pd–C (0.4 g) in ethanol (200 mL) was refluxed for 2 h, then filtered through a bed of Celite and the ethanol was removed under reduced pressure. The residual solid was taken up in ether (40 mL), washed with water (2 × 20 mL), dried ($MgSO_4$) and the ether was removed under reduced pressure to leave the amine (7.5 g, 87%) as a pale pink solid, m.p. 93°C (from ethanol/water; lit.[15] 94°C). ^{1}H NMR δ 3.68, br s, NH_2; 6.67, dd, *J* 8.2, 2.0 Hz; 6.83, d, *J* 2.0 Hz; 7.24–7.33, m, 2H; 7.46, d, *J* 7.2 Hz; 7.67, d, *J* 8.2 Hz; 7.74, dd, *J* 7.4, 1.5 Hz. ^{13}C NMR δ 97.4, CH; 111.1, CH; 111.2, CH; 115.6, C; 119.3, CH; 121.2, CH; 122.5, CH; 124.8, C; 125.1, CH; 146.7, C; 155.9, C; 157.9, C.

9-Methylcarbazol-2-amine

9-Acetylcarbazole was nitrated,[16] deacetylated[16] and *N*-methylated[17] to give 9-methyl-2-nitrocarbazole. This was reduced as for the synthesis of dibenzofuran-3-amine above. Minor impurities from the nitration reaction were carried through to this stage and the amine was obtained as a red oil sufficiently pure for use in the amidation reaction. ^{1}H NMR δ 3.73, s, CH_3; 6.59, dd, *J* 6.1, 1.5 Hz; 6.63, d, *J* 1.5 Hz; 7.16, t; 7.28–7.36, m, 2H; 7.83, d, *J* 8.0 Hz; 7.92, d, *J* 7.7 Hz.

1-Nitrocarbazole and 3-Nitrocarbazole

This preparation resulted in major modifications to a reported procedure.[18] Concentrated nitric acid (0.40 mL, 6.3 mmol) was added, dropwise over 2 min, to a suspension of carbazole (1 g, 6.0 mmol) in glacial acetic acid (8 mL) at 60°C. The mixture was heated for a further 10 min (during which time all the solid disappeared), and then allowed to cool for 1.5 h. The solid which separated was then filtered off to give 3,6-dinitrocarbazole (0.30 g, 19%) as a light brown solid, m.p. >310°C (from dimethyl sulfoxide; lit.[15] 383–385°C). ^{1}H NMR δ [$(CD_3)_2SO$] 7.73, d, *J* 9.0 Hz; 8.36, dd, *J* 8.9, 2.3 Hz; 9.44, d, *J* 2.3 Hz; 12.65, br s, NH.

The filtrate from the above reaction mixture was poured onto ice/water and a mixture of 1- and 3-nitrocarbazoles separated as a yellow solid, which was filtered off (0.90 g, 71%). Soxhlet extraction with carbon tetrachloride (150 mL) was carried out for 16 h, and the cooled solution gave 3-nitrocarbazole (0.40 g, 31%) as a yellow solid, m.p. 208–210°C (lit.[19] 215–216°C). ^{1}H NMR δ 7.30–7.36, m; 7.49, d, *J* 7.9 Hz; 7.49–7.52, m, 2H; 8.13, d, *J* 7.9 Hz; 8.34, dd, *J* 8.9, 1.9 Hz; 8.50, br s, NH; 9.00, d, *J* 1.9 Hz. The filtrate was concentrated to ca. 50 mL, filtered and the filtrate was evaporated to dryness under reduced pressure to give 1-nitrocarbazole (0.20 g, 16%) as a yellow solid, ca. 90% pure, m.p. 170–174°C (lit.[19] 188–189°C). ^{1}H NMR δ 7.26–7.58, m, 4H; 8.10, d, *J* 8.0 Hz; 8.27–8.36, m, 2H; 10.00, br s, NH.

9-Methyl-3-nitrocarbazole

3-Nitrocarbazole was *N*-methylated[17] to give the product (97%) as a yellow solid, m.p. 168°C (lit.[19] 173–174°C). ^{1}H NMR δ 3.90, s, CH_3; 7.31–7.41, m, 2H; 7.46, d, *J* 8.2 Hz; 7.57, dt, *J* 8.2, 1.1 Hz; 8.14, d, *J* 7.8 Hz; 8.38, dd, *J* 9.1, 2.2 Hz; 8.99, d, *J* 2.2 Hz. ^{13}C NMR δ 29.5, CH_3; 108.0, CH; 109.4, CH; 117.2, CH; 120.8, C; 120.9, CH; 121.6, CH; 122.5, C; 122.7, C; 127.4, CH; 140.6, C; 142.1, C; 143.9, C.

9-Methylcarbazol-3-amine

9-Methyl-3-nitrocarbazole was reduced as for the synthesis of dibenzofuran-3-amine above to give the title amine as a white solid (93%), m.p. 164–167°C (lit.[20] 173–174°C) ^{1}H NMR δ 3.78, s, CH_3; 6.91, dd, *J* 8.5, 2.0 Hz; 7.15, t, *J* 7.6 Hz; 7.20, d, *J* 8.9 Hz; 7.32, d, *J* 8.1 Hz; 7.39–7.45, m, 2H; 7.98, d, *J* 7.8 Hz. ^{13}C NMR δ 29.0, CH_3; 106.2, CH; 108.3, CH; 108.9, CH; 115.5, CH; 118.0, CH; 120.2, CH; 122.3, C; 123.4, C; 125.5, CH; 135.6, C; 138.9, C; 141.4, C.

9-Methylcarbazol-1-amine

1-Nitrocarbazole was *N*-methylated[17] in 98% yield (^{1}H NMR δ 3.84, s, CH_3; 7.24, t; 7.32, dt, *J* 7.9, 1.0 Hz; 7.49, d, *J* 8.2 Hz; 7.57, dt, *J* 7.1, 1.1 Hz; 7.99, dd, *J* 8.0, 0.8 Hz; 8.09, d, *J* 7.7 Hz; 8.29, dd, *J* 7.8, 1.1 Hz) and this intermediate was reduced as for the synthesis of dibenzofuran-3-amine above to give the title amine (85%) as a red oil. ^{1}H NMR δ 4.17, s, CH_3; 6.76, dd, *J* 7.5, 0.7 Hz; 7.01, t, *J* 7.6 Hz; 7.18, t, *J* 7.7 Hz; 7.34, d, 8.3 Hz; 7.44, t, 7.1 Hz; 7.61, dd, *J* 7.9, 0.75 Hz; 8.02, d, *J* 7.8 Hz. ^{13}C NMR δ 32.0, NCH_3; 108.6, CH; 112.5, CH; 114.9, CH; 118.8, CH; 119.8, CH; 120.1, CH; 123.1, C; 124.7, C; 125. 6, CH; 131.3, C; 131.9, C; 141.8, C.

General Procedure for the Preparation of Pivaloylamino Derivatives

Freshly distilled pivaloyl chloride (0.85 g, 7.1 mmol) was added dropwise, with stirring, to a solution of the amino compound (5.5 mmol) and triethylamine (1.05 g, 10.4 mmol) in dry dichloromethane (60 mL), and the solution was stirred for a further 16 h. Ether (150 mL) was added and the solution was washed with 10% sodium bicarbonate (2 × 20 mL), water (2 × 20 mL), 10% hydrochloric acid (2 × 20 mL), and water (2 × 20 mL), then dried ($MgSO_4$) and the solvent was removed. The residual solid was recrystallized from light petroleum (b.p. 100–130°C).

In this way, the following compounds were prepared.

N-*(Dibenzofuran-3-yl)-2,2-dimethylpropionamide (4)*

This was obtained as a white *solid* (89%), m.p. 161°C (Found: C, 76.4; H, 6.7; N, 5.4. $C_{17}H_{17}NO_2$ requires C, 76.4; H, 6.4; N, 5.2%). ^{1}H NMR δ 1.35, s, $C(CH_3)_3$; 7.25–7.33, m, 2H; 7.40, dt, *J* 7.2, 1.3 Hz; 7.50, br s, NH; 7.53, d, *J* 8.1 Hz; 7.81–7.87, m, 2H; 8.08, d, *J* 1.5 Hz. ^{13}C NMR δ 27.6, $(CH_3)_3$; 39.7, C; 103.6, CH; 111.6, CH; 114.9, CH; 120.1, CH; 120.3, C; 120.5, CH; 122.7, CH; 124.0, C; 126.5, CH; 137.4, C; 156.6, C; 156.7, C; 176.5, C.

N-*(Dibenzofuran-2-yl)-2,2-dimethylpropionamide (5)*

This was obtained as a cream *solid* (99%), m.p. 185–186°C (Found: C, 76.1; H, 6.5; N, 5.6. $C_{17}H_{17}NO_2$ requires C, 76.4; H, 6.4; N, 5.2%). ^{1}H NMR δ 1.31, s, $C(CH_3)_3$; 7.31, t, *J* 7.5 Hz; 7.35, dd, *J* 8.6, 2.2 Hz; 7.41–7.46, m, 3H; 7.52, t, *J* 8.1 Hz; 7.91, d, *J* 7.5 Hz; 8.37, d, *J* 2.2 Hz. ^{13}C NMR δ 27.6, $(CH_3)_3$; 39.5, C; 111.5, CH; 111.6, CH; 112.8, CH; 120.0, CH; 120.8, CH; 122.7, CH; 124.2, C; 124.6, C; 127.3, CH; 133.2, C; 152.9, C; 156.7, C; 176.7, C.

N-*(Dibenzofuran-4-yl)-2,2-dimethylpropionamide (6)*

This was obtained as a white *solid* (94%), m.p. 109°C (Found: C, 76.3; H, 6.5; N, 5.5. $C_{17}H_{17}NO_2$ requires C, 76.4; H, 6.4; N, 5.2%). ^{1}H NMR δ 1.42, s, $C(CH_3)_3$; 7.31, t, *J* 7.9 Hz; 7.36, t, *J* 7.5 Hz; 7.46, t, *J* 7.3 Hz; 7.58, d, *J* 8.2 Hz; 7.65, d, *J* 7.7 Hz; 7.93, d, *J* 7.5 Hz; 8.01, br s, NH; 8.40, d, *J* 8.0 Hz. ^{13}C NMR δ 27.6, $(CH_3)_3$; 39.9, C; 111.6, CH; 115.4, CH; 117.8, CH; 120.9, CH; 123.1, CH; 123.4, CH; 123.9, C; 124.1, C; 124.5, C; 127.1, CH; 145.6, C; 155.6, C; 176.7, C.

N-*(9-Methylcarbazol-2-yl)-2,2-dimethylpropionamide (7)*

This was obtained as a white *solid* (63%), m.p. 205°C (formed needles >170°C) (Found: C, 77.3; H, 7.4; N, 10.0. $C_{18}H_{20}N_2O$ requires C, 77.1; H, 7.2; N, 10.0%). ^{1}H NMR δ 1.36, s, $C(CH_3)_3$; 3.82, s, NCH_3; 6.91, dd, *J* 8.3, 1.8 Hz; 7.20, t, *J* 6.8 Hz; 7.35–7.45, m, 2H; 7.55, br s, NH; 7.96, d, *J* 8.3 Hz; 8.00, d, *J* 7.7 Hz; 8.21, d, *J* 1.8 Hz. ^{13}C NMR δ 27.6, $(CH_3)_3$; 29.1, NCH_3; 39.7, C; 100.1, CH; 108.3, CH; 111.2, CH; 118.9, CH;

119.1, C; 119.7, CH; 120.3, CH; 122.6, C; 125.1, CH; 136.2, C; 141.4, C; 141.6, C; 176.7, C.

N-*(9-Methylcarbazol-3-yl)-2,2-dimethylpropionamide (8)*

This was obtained as a grey/brown *solid* (84%), m.p. 189°C (Found: C, 77.0; H, 7.4; N, 9.9. $C_{18}H_{20}N_2O$ requires C, 77.1; H, 7.2; N, 10.0%). ^{1}H NMR δ 1.36, s, $C(CH_3)_3$; 3.81, s, NCH_3; 7.19, t, *J* 7.2 Hz; 7.30, d, *J* 8.7 Hz; 7.35, d, *J* 8.1 Hz; 7.42–7.49, m, 2H; 8.04, d, *J* 7.8 Hz; 8.35, d, *J* 1.9 Hz. ^{13}C NMR δ 27.7, $(CH_3)_3$; 29.1, NCH_3; 39.4, C; 108.3, CH; 108.4, CH; 112.7, CH; 118.7, CH; 119.4, CH; 120.5, CH; 122.6, C; 122.8, C; 125.8, CH; 129.9, C; 138.2, C; 141.4, C; 176.5, C.

N-*(9-Methylcarbazol-1-yl)-2,2-dimethylpropionamide (9)*

This was obtained as a grey *solid* (70%), m.p. 183°C (formed needles >165°C) (Found: C, 77.1; H, 7.3; N, 9.9. $C_{18}H_{20}N_2O$ requires C, 77.1; H, 7.2; N, 10.0%). ^{1}H NMR δ 1.39, s, $C(CH_3)_3$; 3.93, s, NCH_3; 7.12–7.23, m, 2H; 7.32, d, *J* 8.2 Hz; 7.42–7.48, t and br s, 2H; 7.98, dd, *J* 7.5, 0.8 Hz; 8.04, d, *J* 7.7 Hz. ^{13}C NMR δ 27.7, $(CH_3)_3$; 31.0, CH_3; 39.2, C; 108.6, CH; 119.0, CH; 119.3, CH; 120.1, CH; 120.5, C; 122.6, C; 125.4, C; 125.7, CH; 126.0, CH; 136.5, C; 141.7, C; 178.3, C.

General Procedure for the Lithiation of Pivalamides

n-Butyllithium in hexanes (2.5 M, 5 mL, 8.2 mmol) was added, with stirring, to a solution of the amide (0.6 mmol) in dry tetrahydrofuran (12 mL) at 0°C under an atmosphere of nitrogen (an immediate colour change occurred). Stirring was continued at 0°C for 1 h, then *N*,*N*-dimethylformamide (6 mL, 81.6 mmol) was added and the solution was stirred for a further 2 h (during which time it returned to its original colour). Diethyl ether (50 mL) was added and the organic layer was washed with water (2×50 mL) and brine (1×50 mL), then dried ($MgSO_4$) and the solvent was removed to leave a semi-solid.

The following compounds were obtained in this way.

N-(*4-Formyldibenzofuran-3-yl*)-*2,2-dimethylpropionamide (10)*

Column chromatography (silica; dichloromethane) gave the title aldehyde (67%; R_F 0.7) as a yellow *solid*, m.p. 157–158°C [from light petroleum (b.p. 100–130°C)] (Found: C, 73.4; H, 5.8; N, 4.9. $C_{18}H_{17}NO_3$ requires C, 73.2; H, 5.8; N, 4.7%). ^{1}H NMR δ 1.35, s, $C(CH_3)_3$; 7.38, t, *J* 7.4 Hz; 7.46, t, *J* 7.3 Hz; 7.59, d, *J* 7.3 Hz; 7.90, d, *J* 7.6 Hz; 8.10, d, *J* 8.8 Hz; 8.80, d, *J* 8.8 Hz; 10.80, s, CHO; 11.66, br s, NH. ^{13}C NMR δ 27.5, $(CH_3)_3$; 40.5, C; 107.7, C; 111.6, CH; 114.6, CH; 119.2, C; 120.3, CH; 123.1, C; 123.7, CH; 127.0, CH; 128.6, CH; 140.7, C; 156.2, C; 158.6, C; 178.6, C; 190.7, C.

N-(*1-Formyl-9-methylcarbazol-2-yl*)-*2,2-dimethylpropionamide (11)*

Column chromatography (silica; dichloromethane) gave the title aldehyde (65%) as a cream *solid*, m.p. 230°C (formed needles >200°C) (Found: C, 74.0; H, 6.7; N, 9.2. $C_{19}H_{20}N_2O_2$ requires C, 74.0; H, 6.5; N, 9.1%). ^{1}H NMR δ 1.40, s, $C(CH_3)_3$; 4.07, s, NCH_3; 7.30, t, *J* 7.4 Hz; 7.40, d, *J* 8.1 Hz; 7.47, t, *J* 7.4 Hz; 8.00, d, *J* 7.7 Hz; 8.21, d, *J* 8.7 Hz; 8.69, d, *J* 8.1 Hz; 10.85, s, CHO; 12.06, br s, NH. ^{13}C NMR δ 27.6, $(CH_3)_3$; 30.8, NCH_3; 40.6, C; 108.5, C; 109.2, CH; 111.4, CH; 119.6, CH; 120.2, C; 120.8, CH; 122.7, C; 125.9, CH; 128.5, CH; 141.3, C; 142.2, C; 143.1, C; 178.6, C; 190.7, C.

N-(*1-Formyldibenzofuran-2-yl*)-*2,2-dimethylpropionamide (12)*

Column chromatography (silica; dichloromethane) gave the aldehyde (54%; R_F 0.6) as a yellow *solid*, m.p. 152°C [from light petroleum (b.p. 100–130°C)] (Found: C, 73.4; H, 5.9; N, 4.8. $C_{18}H_{17}NO_3$ requires C, 73.2; H, 5.8; N, 4.7%). ^{1}H NMR δ 1.39, s, $C(CH_3)_3$; 7.38, t, *J* 7.5 Hz; 7.55, t, *J* 7.2 Hz; 7.63, d, *J* 8.3 Hz; 7.79, d, *J* 9.2 Hz; 8.04, d, *J* 7.9 Hz; 8.97, d, *J* 9.2 Hz; 11.09, s, CHO; 11.71, br s, NH. ^{13}C NMR δ 27.6, $(CH_3)_3$; 40.0, C; 115.6, CH; 118.9, CH; 121.3, C; 122.7, C; 123.4, CH; 124.1, C; 124.3, CH; 126.3, C; 126.9, CH; 127.8, CH; 146.2, C; 155.1, C; 176.9, C; 187.9, C.

N-(*4-Formyl-9-methylcarbazol-3-yl*)-*2,2-dimethylpropionamide (13) and* N-(*2-Formyl-9-methylcarbazol-3-yl*)-*2,2-dimethylpropionamide (15)*

The crude product contained a 3 : 1 isomeric mixture of (13) and (15) respectively. Column chromatography (silica gel; dichloromethane) gave partial separation of the isomers. Most product was obtained as a clean mixture of the two (52%), as a bright yellow *solid*, m.p. 156–158°C [from light petroleum (b.p. 100–130°C)] (Found: C, 73.8; H, 6.6; N, 9.2. $C_{19}H_{20}N_2O_2$ requires C, 74.0; H, 6.5; N, 9.1%), along with small samples of the individual compounds (both of which have an intense yellow fluorescence in solution).

Isomer (13) was obtained as a yellow solid (R_F 0.46), m.p. 190°C. ^{1}H NMR δ 1.40, s, $C(CH_3)_3$; 3.88, s, NCH_3; 7.25, t; 7.46, d, *J* 8.1 Hz; 7.53, t, *J* 7.4 Hz; 7.66, d, *J* 9.2 Hz; 8.15, d, *J* 8.1 Hz; 8.97, d, *J* 9.2 Hz; 11.29, s, CHO; 11.77, br s, NH. ^{13}C NMR δ 27.7, $(CH_3)_3$; 29.1, NCH_3; 40.4, C; 109.5, CH; 116.2, CH; 117.1, C; 118.1, CH; 119.6, CH; 120.7, C; 123.2, C; 124.4, CH; 126.8, CH; 135.6, C; 136.9, C; 141.9, C; 178.4, C; 193.0, C.

Isomer (15) was obtained as a yellow solid (R_F 0.54), m.p. 185–186°C. ^{1}H NMR δ 1.41, s, $C(CH_3)_3$; 3.79, s, NCH_3; 7.22, t, *J* 7.5 Hz; 7.33, d, *J* 8.2 Hz; 7.50–7.53, s and t, 2H; 8.12, d, *J* 7.9 Hz; 9.51, s; 9.98, s; 11.43, br s, NH. ^{13}C NMR δ 27.7, $(CH_3)_3$; 29.1, NCH_3; 40.3, C; 108.8, CH; 111.3, CH; 116.3, CH; 119.6, CH; 120.5, C; 122.0, CH; 128.2, CH; 128.5, C; 133.5, C; 136.0, C; 143.4, C; 178.3, C; 195.0, C.

N-(*6-Formyldibenzofuran-4-yl*)-*2,2-dimethylpropionamide (16)*

Column chromatography (silica; dichloromethane) gave the title aldehyde (67%; R_F 0.3) as a white *solid*, m.p. 137–139°C [from light petroleum (b.p. 100–130°C)] (Found: C, 73.3; H, 5.9; N, 4.7. $C_{18}H_{17}NO_3$ requires C, 73.2; H, 5.8; N, 4.7%). ^{1}H NMR δ 1.42, s, $C(CH_3)_3$; 7.37, t, *J* 7.9 Hz; 7.49, t, *J* 7.5 Hz; 7.67, d, *J* 7.8 Hz; 7.94, d, *J* 7.7 Hz; 8.09, br s, NH; 8.17, d, *J* 7.3 Hz; 8.42, d, *J* 8.0 Hz; 10.56, s, CHO. ^{13}C NMR δ 27.6, $(CH_3)_3$; 40.0, C; 115.6, CH; 118.9, CH; 121.3, C; 122.7, C; 123.4, CH; 124.1, C; 124.3, CH; 126.3, C; 126.9, CH; 127.8, CH; 146.2, C; 155.1, C; 176.9, C; 187.9, C.

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