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Metallation of pyridines and quinolines in the presence of a remote carboxylate group. New syntheses of heterocyclic quinones

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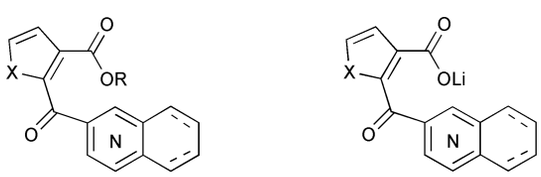
2-(3- and 2-Pyridylcarbonyl)benzoic acids (**2**, **3**), 2-(2-pyridylcarbonyl)thiophene-3-carboxylic acid (**6**), 2-(3-quinolylcarbonyl)benzoic acid (**10**), and most of the corresponding esters (compounds **1**, **7** and **9**) are readily synthesized and involved in a deprotonation–condensation sequence. Biologically active aza-anthraquinones such as benzo[*g*]isoquinoline-5,10-dione (2-azaanthraquinone, **4**) and benzo[*g*]quinoline-5,10-dione (1-azaanthraquinone, **5**) are prepared using the strategy. Extension to other heterocyclic quinones such as thieno[3,2-*g*]quinoline-4,9-dione (**8**) and benzo[*j*]phenanthridine-7,12-dione (**11**) is also investigated.

Introduction

Directed *ortho*-metallation (DoM) plays an important role in the modern organic synthesis.[1] The heteroatom-containing unit (known as the directed metallation group, DMG) acts in several ways: while an electron-donating substituent only facilitates the deprotonation at nearby sites (not necessarily at the *ortho* position) through coordination to the Lewis acidic metal, an electron-withdrawing substituent also acidifies the ring hydrogens in its environment (mostly at the *ortho* position).[2–5]

The carboxylic acid and derived functions stand out as particularly useful for subsequent elaborations. In the π-deficient aza-aromatic series, lithium pyridinecarboxylates, pyridine-oxazolines and pyridinecarboxamides have been deprotonated at ring positions adjacent to the DMG.[6,7] Moreover, studies concern the deprotonation of pyridine rings followed by *in situ* condensation with remote *N,N*-dialkylcarboxamide,[5] alkyl carboxylate[8,9] or lithium carboxylate groups.[9]

In order to obtain more complex structures, we decided to synthesize various (het)arylpyridylketones bearing an alkyl carboxylate or a lithium carboxylate group remote from the pyridine ring, and study their metallation (Scheme 1).



X = CH=CH, S

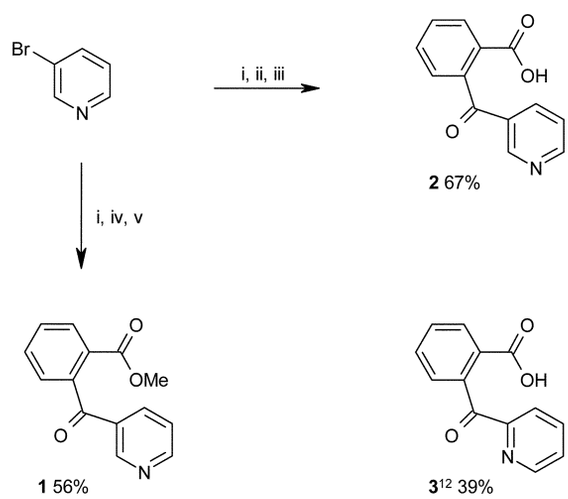
Scheme 1

Results and discussion

Methyl 2-(3-pyridylcarbonyl)benzoate and the 2-(pyridylcarbonyl)benzoic acids

Epsztajn and co-workers performed syntheses of methoxy-aza-anthraquinones through deprotonation of methyl 2-(2 and 4-pyridylcarbonyl)benzoates substituted on the phenyl ring, and subsequent intramolecular condensation in modest to medium yields (26–55%).[8] We decided to spread the method and first examined the behaviour of methyl 2-(3-pyridyl-carbonyl)benzoate (**1**), which was not studied before. Then, we considered the use of the 2-(pyridylcarbonyl)benzoic acids **2**,**3**.

Methyl 2-(3-pyridylcarbonyl)benzoate (**1**) and 2-(3-pyridyl-carbonyl)benzoic acid (**2**) were easily prepared from 3-bromo-pyridine *via* a bromine–lithium exchange reaction.[10] To reach the acid **2**, the trapping[11] of 3-lithiopyridine with phthalic anhydride reported by Yamaguchi and co-workers was improved, keeping the reaction mixture at −75 °C. 2-(3-Pyridyl-carbonyl)benzoic acid (**3**) was prepared using a published protocol.[12] Esterification of the acid **2** was not necessary to get the ester **1**; this latter was obtained in 56% yield quenching 3-lithiopyridine with dimethyl phthalate. (Scheme 2).



Scheme 2 *Synthesis of methyl 2-(3-pyridylcarbonyl)benzoate and the 2-(pyridylcarbonyl)benzoic acids*: (i) 1 equiv. BuLi, Et_2O, −75 °C, 1 h; (ii) 1 equiv. phthalic anhydride, −75 °C, 2 h; (iii) acidic hydrolysis; (iv) 1 equiv. dimethyl phthalate, −75 °C, 2 h; (v) hydrolysis.

The aforementioned metallation–cyclization sequence described by Epsztajn and co-workers used lithium diisopropyl-amide (LDA, pK_a 35.7, 3 equiv.).[8] Nevertheless, a survey of the literature revealed that lithium 2,2,6,6-tetramethylpiperidide (LTMP, pK_a 37.3) was capable of deprotonating ethyl benzoate at the *ortho* position while LDA was found to react with the function.[13] We therefore embarked on reactions using LTMP (3 equiv.). Interestingly, when exposed to this base in tetra-hydrofuran (THF) at 0 °C, the ester **1** was deprotonated and the lithio derivative at C4′ was converted *in situ* to biologically active[14] 2-azaanthraquinone (**4**) in 44% yield. The product **4** was also formed from the related acid **2**, albeit in lower yield (35%) (Scheme 3).

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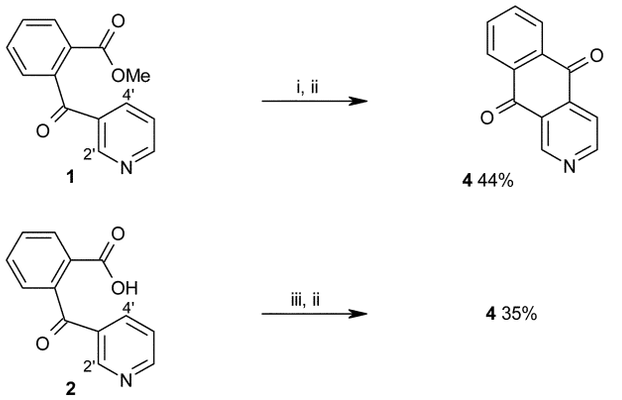
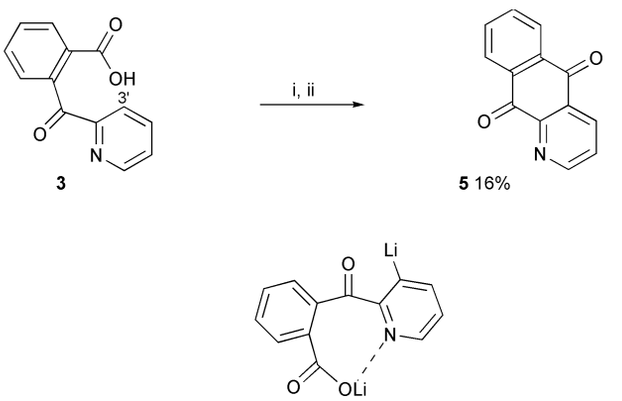


Scheme 3 *Synthesis of benzo[g]isoquinoline-5,10-dione (2-azaanthraquinone)*: (i) 3 equiv. LTMP, THF, 0 °C, 2 h; (ii) hydrolysis; (iii) 3 equiv. LTMP, THF, rt, 2 h.

Since aza-fluorenones were prepared[9] in rather good yields starting from 2-(pyridyl)benzoic acids or ethyl 2-(pyridyl)-benzoates, the modest yields here noted could be due to the presence of the reactive ketone function. It should be pointed out that the reaction was completely regioselective in both cases, as already noticed when deprotonating lithium pyridine-3-carboxylates, pyridine-3-oxazolines and pyridine-3-carboxamides.[6,7]

The protocol was extended to the acid **3**, giving biologically active[15] 1-azaanthraquinone (**5**) in a poor yield of 16%. Intramolecular complexation of the Lewis acidic lithium atom of the COOLi group by the pyridine nitrogen could favour intermolecular addition of the lithiopyridine formed to a ketone C=O group present (Scheme 4).



Scheme 4 *Synthesis of benzo[g]quinoline-5,10-dione (1-azaanthraquinone)*: (i) 3 equiv. LTMP, THF, 0 °C, 2 h; (ii) hydrolysis.

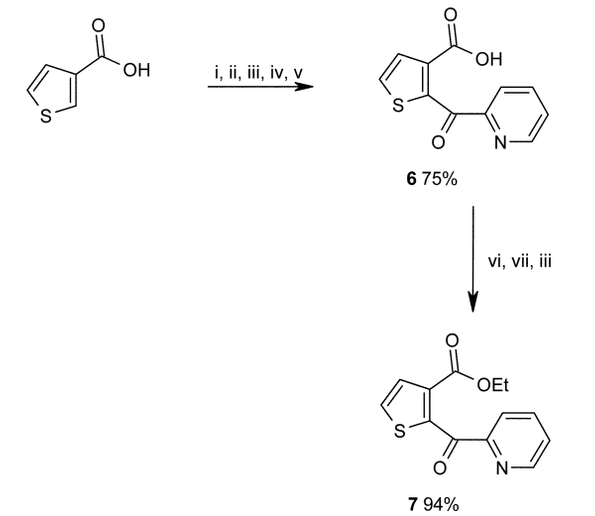
2-(2-Pyridylcarbonyl)thiophene-3-carboxylic acid and ethyl 2-(2-pyridylcarbonyl)thiophene-3-carboxylate

In order to reach other heterocyclic quinones, 2-(2-pyridylcarbonyl)thiophene-3-carboxylic acid (**6**) was synthesized, adapting a procedure[16] performed by Yamaguchi and co-workers (Scheme 5).

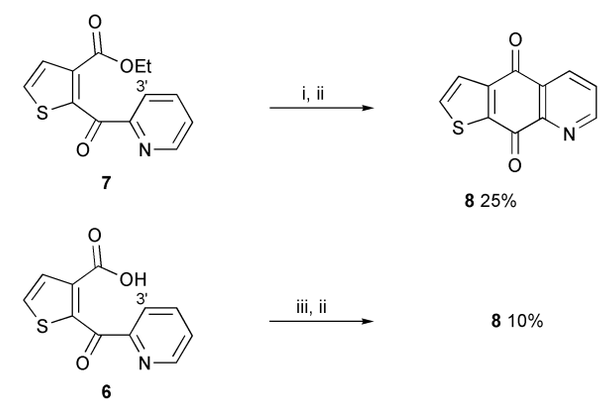
Active thieno[3,2-*g*]quinoline-4,9-dione (**8**)[17] was obtained in 10% and 25% yields, respectively, when the acid **6** and its ethyl ester **7** were exposed to LTMP. The aforementioned less acidic[6] hydrogen at C3′ and, more importantly, the facile deprotonation[18] of the thiophene ring under the conditions used could alter the course of the reaction (Scheme 6).

Methyl 2-(3-quinolylcarbonyl)benzoate and 2-(3-quinolylcarbonyl)benzoic acid

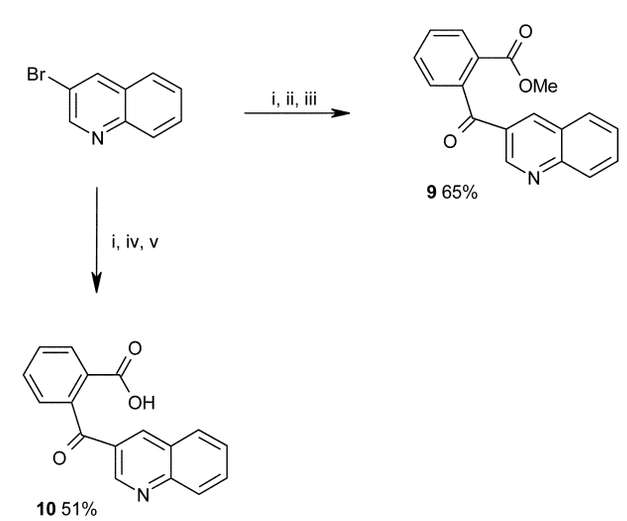
Methyl 2-(3-quinolylcarbonyl)benzoate (**9**) and 2-(3-quinolylcarbonyl)benzoic acid (**10**) were prepared through a bromine–lithium exchange reaction[19] of 3-bromoquinoline. Trapping 3-lithioquinoline with dimethyl phthalate and phthalic



Scheme 5 *Synthesis of 2-(2-pyridylcarbonyl)thiophene-3-carboxylic acid and ethyl 2-(2-pyridylcarbonyl)thiophene-3-carboxylate*: (i) 2 equiv. LDA, THF, 0 °C; (ii) pyridine-2-carboxaldehyde, rt, 3 h; (iii) hydrolysis; (iv) $KMnO_4$, H_2O, 60 °C, 3 h; (v) 3 mol dm^{-3} aq. HCl; (vi) $SOCl_2$, reflux, 2 h; (vii) EtOH, rt, 12 h.



Scheme 6 *Synthesis of thieno[3,2-g]quinoline-4,9-dione*: (i) 3 equiv. LTMP, THF, −75 °C, 2 h; (ii) hydrolysis; (iii) 3 equiv. LTMP, THF, 0 °C, 2 h.

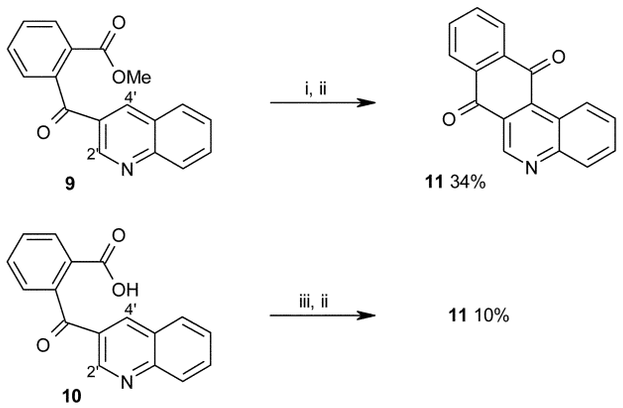


Scheme 7 *Synthesis of methyl 2-(3-quinolylcarbonyl)benzoate and 2-(3-quinolylcarbonyl)benzoic acid*: (i) 1 equiv. *tert*-BuLi, Et_2O, −100 °C, 1 h; (ii) 1 equiv. dimethyl phthalate, −75 °C, 2 h; (iii) hydrolysis; (iv) 1 equiv. phthalic anhydride, −75 °C, 2 h; (v) acidic hydrolysis.

anhydride, respectively, provided the ester **9** and the acid **10** in medium to good yields (Scheme 7).

As previously, the deprotonation–cyclization technique proved 100% regioselective, and gave benzo[*j*]phenanthridine-7,12-dione (**11**) in yields depending on the reactivity of the

remote function: 34% and 10%, with the methyl carboxylate and lithium carboxylate, respectively. It should be noted that leading the reaction with the more reactive ester **9** at −75 °C could reduce the degradation reactions (Scheme 8).



Scheme 8 *Synthesis of benzo[j]phenanthridine-7,12-dione*: (i) 3 equiv. LTMP, THF, −75 °C, 2 h; (ii) hydrolysis; (iii) 3 equiv. LTMP, THF, rt, 2 h.

Conclusion

We have described syntheses of various heterocyclic quinones, using as the key step the tandem metallation–*in situ* cyclization of (het)arylpyridylketones bearing an alkyl carboxylate or a lithium carboxylate group at a remote position from the pyridine ring. In particular, biologically active 2-azaanthraquinone (**4**) was prepared in two steps from commercial 3-bromopyridine, in a 25% overall yield.

Both alkyl carboxylate and lithium carboxylate were compared: best results were obtained with the former since it interceps the lithio intermediate at a lower temperature.

Experimental

General

Melting points were measured on a Kofler apparatus. NMR spectra were recorded on a Bruker AM 300 spectrometer (^{1}H at 300 MHz and ^{13}C decoupled spectra at 75 MHz) with residual protic solvent as the internal reference. Chemical shifts are quoted in ppm and coupling constants in Hz. IR spectra were taken on a Perkin-Elmer FT IR 205 spectrometer. Elemental analyses were performed on a Carlo Erba 1106 apparatus. THF and Et_2O were distilled from benzophenone–Na. Reactions were carried out under dry N_2. Silica gel (Geduran Si 60, 0.063–0.200 mm) was purchased from Merck. BuLi (2.5 mol dm^{-3} in hexane) and *tert*-BuLi (1.7 mol dm^{-3} in pentane) were supplied by Aldrich. *Note:* unless otherwise specified 'work-up' refers to extraction with diethyl ether (20 cm^3) and DCM (2 × 20 cm^3), followed by drying ($MgSO_4$) and removal of the solvent *in vacuo*.

Methyl 2-(3-pyridylcarbonyl)benzoate 1

BuLi (1.0 mmol) and, 1 h later, dimethyl phthalate (0.17 cm^3, 1.0 mmol), were added to a solution of 3-bromopyridine (96 mm^3, 1.0 mmol) in Et_2O (10 cm^3) at −75 °C. The mixture was stirred at −75 °C for 2 h before hydrolysis with water (5 cm^3). Column chromatography on silica gel (9 : 1 DCM–Et_2O) afforded **1** (0.14 g, 56%) as a white powder; mp 72 °C (Found: C, 69.7; H, 4.7; N, 5.8. $C_{14}H_{11}NO_3$ requires: C, 69.7; H, 4.6; N, 5.8%); ν_{max}(KBr)/cm^{-1} 3416, 2952, 1779, 1715, 1674, 1585, 1285, 931, 733 and 708; δ_H($CDCl_3$) 3.60 (3 H, s, Me), 7.32 (2 H, m, 4′ and 5′-H), 7.54 (1 H, t, *J* 7.5, 4-H), 7.60 (1 H, t, *J* 7.2, 5-H), 7.96 (1 H, d, *J* 8.3, 6-H), 8.00 (1 H, d, *J* 8.3, 3-H), 8.67 (1 H, d, *J* 4.1, 6′-H), 8.76 (1 H, s, 2′-H); δ_C($CDCl_3$) 52.8 (Me), 123.9 (5′-C), 127.9 (3-C), 129.3 (1-C), 130.5 (4-C), 130.7 (4′-C), 133.0 (2-C), 133.2 (6-C), 136.4 (5-C), 141.2 (3′-C), 151.1 (2′-C), 153.8 (6′-C), 166.4 (ester CO), 196.3 (ketone CO).

2-(3-Pyridylcarbonyl)benzoic acid 2

BuLi (1.0 mmol) and, 1 h later, phthalic anhydride (0.15 g, 1.0 mmol), were added to a solution of 3-bromopyridine (96 mm^3, 1.0 mmol) in Et_2O (10 cm^3) at −75 °C. The mixture was stirred at −75 °C for 2 h before hydrolysis with water (1 cm^3). After removal of the solvent, the residue was dissolved in water (10 cm^3), the aqueous phase was washed with Et_2O and then acidified to pH 3–4 using a 3 M aqueous solution of hydrochloric acid. The precipitate was recovered by filtration and dried under vacuum to give **2** (0.15 g, 67%) as a white powder; which was identified by comparison of physical and spectral data with those described[11] (Found: C, 68.6; H, 3.7; N, 6.0. $C_{13}H_9NO_3$ requires: C, 68.7; H, 4.0; N, 6.2%); ν_{max}(KBr)/cm^{-1} 3057, 2802, 2451, 1673, 1597 and 1576.

2-(2-Pyridylcarbonyl)benzoic acid 3

A procedure described[12] was used to prepare **3** (39%) as a white powder; mp 228 °C (lit.,[20] 228–229 °C) (Found: C, 68.4; H, 3.8; N, 5.9. $C_{13}H_9NO_3$ requires: C, 68.7; H, 4.0; N, 6.2%); ν_{max}(KBr)/cm^{-1} 2799, 2484, 1908, 1681, 1592, 1310, 1280, 1014, 760 and 715; δ_H(DMSO-d_6) 7.52 (1 H, d, *J* 7.5, 3-H), 7.68 (2 H, m, Ph and 5′-H), 7.78 (1 H, t, *J* 7.5, Ph), 7.99 (1 H, d, *J* 7.5, 6-H), 8.13 (2 H, m, 3′ and 4′-H), 8.59 (1 H, s, 6′-H), 13.2 (1 H, s, OH); δ_C(DMSO-d_6) 122.3 (3′-C), 127.3 (5-C), 128.1 (6-C), 129.2 (4-C), 130.0 (5′-C), 131.2 (1-C), 132.6 (3-C), 137.7 (4′-C), 141.7 (2-C), 149.1 (6′-C), 153.9 (2′-C), 167.5 (acid CO), 197.1 (ketone CO).

Benzo[*g*]isoquinoline-5,10-dione-(2-azaanthraquinone) 4

To a solution of **1** (0.11 g, 0.44 mmol) in THF (3 cm^3) at 0 °C was added a solution of LTMP [obtained by adding BuLi (1.3 mmol) to a solution of 2,2,6,6-tetramethylpiperidine (0.24 cm^3, 1.4 mmol) in THF (2 cm^3) at 0 °C]. The mixture was stirred at 0 °C for 2 h before hydrolysis with water (5 cm^3). Column chromatography on silica gel (95 : 5 DCM–Et_2O) gave **4** (41 mg, 44%); which was identified by comparison of physical and spectral data with those described.[14,21]

Benzo[*g*]quinoline-5,10-dione-(1-azaanthraquinone) 5

To a suspension of **3** (0.10 g, 0.44 mmol) in THF (3 cm^3) at 0 °C was added a solution of LTMP [obtained by adding BuLi (1.3 mmol) to a solution of 2,2,6,6-tetramethylpiperidine (0.24 cm^3, 1.4 mmol) in THF (5 cm^3) at 0 °C]. The mixture was stirred at 0 °C for 2 h before hydrolysis with water (2 cm^3). Column chromatography on silica gel (95 : 5 DCM–Et_2O) gave **5** (15 mg, 16%); which was identified by comparison of physical and spectral data with those described;[22] ν_{max}(KBr)/cm^{-1} 3076, 1687, 1671, 1578, 1300, 1270 and 700; δ_C($CDCl_3$) 127.7 (3-C), 128.3 (6-C), 128.4 (9-C), 131.0 (b-C), 133.1 (c-C), 133.8 (d-C), 135.0 (4-C), 135.2 (8-C), 135.9 (7-C), 149.3 (a-C), 155.5 (2-C), 182.0 (10-CO), 183.0 (5-CO).

2-(2-Pyridylcarbonyl)thiophene-3-carboxylic acid 6

To a solution of thiophene-3-carboxylic acid (5.0 g, 39 mmol) in THF (200 cm^3) at 0 °C was rapidly added dropwise a solution of LDA [obtained by adding BuLi (86 mmol) to a solution of diisopropylamine (12 cm^3, 86 mmol) in THF (50 cm^3) at 0 °C]. Pyridine-2-carboxaldehyde (4.1 cm^3, 43 mmol) was added to the mixture at 0 °C, and the mixture was stirred for 3 h at rt. The reaction was quenched by the addition of ice-water (100 cm^3), and the mixture was concentrated under reduced pressure and washed with AcOEt (2 × 30 cm^3). To the residual aqueous layer, $KMnO_4$ (12 g, 78 mmol) was added in portions, and the mixture

was stirred for 3 h at 60 °C. It was then filtrated and washed with hot water, and the resulting filtrate was acidified to pH 4 using a 3 M aqueous solution of hydrochloric acid. The precipitate was recovered by filtration and dried under vacuum to give **6** (6.8 g, 75%) as a beige powder; mp 158 °C (Found: C, 56.6; H, 2.7; N, 6.3; S, 13.7. $C_{11}H_7NO_3S$ requires: C, 56.6; H, 3.0; N, 6.0; S, 13.7%); ν_{max}(KBr)/cm^{-1} 3118, 3088, 2482, 1726, 1558, 1467, 1370, 1286, 1250, 746, 737 and 699; δ_H(DMSO-d_6) 7.30 (1 H, d, *J* 5.1, 5-H), 7.57 (1 H, dd, *J* 7.9 and 4.7, 5′-H), 7.87 (1 H, d, *J* 5.1, 4-H), 7.97 (2 H, m, 3′-H and 4′-H), 8.57 (1 H, d, *J* 4.7, 6′-H), 12.8 (1 H, s, OH); δ_C(DMSO-d_6) 123.3 (4-C), 127.9 (3′-C), 128.5 (5′-C), 132.8 (4′-C), 138.1 (3-C), 139.2 (2-C), 140.6 (5-C), 149.0 (2′-C), 153.4 (6′-C), 165.2 (acid CO), 187.4 (ketone CO).

Ethyl 2-(2-pyridylcarbonyl)thiophene-3-carboxylate 7

A mixture of **6** (2.8 g, 12 mmol) and $SOCl_2$ (30 cm^3) was heated under reflux for 2 h. After removal of the excess of $SOCl_2$, EtOH (40 cm^3) was introduced dropwise at 0 °C. After 12 h at rt, EtOH was evaporated and water (10 cm^3) was added. Column chromatography on silica gel (1 : 1 DCM–Et_2O) afforded **7** (2.9 g, 94%) as a yellow oil (Found: C, 59.5; H, 3.9; N, 5.1. $C_{13}H_{11}NO_3S$ requires: C, 59.8; H, 4.2; N, 5.4; S, 12.3%); ν_{max}(KBr)/cm^{-1} 3420, 2982, 1722, 1652, 1284, 1266, 1025 and 745; δ_H($CDCl_3$) 0.96 (3 H, t, *J* 7.2, Me), 3.93 (2 H, q, *J* 7.2, CH_2), 7.35 (1 H, d, *J* 5.3, 5-H), 7.41 (1 H, dd, *J* 7.0 and 4.4, 5′-H), 7.51 (1 H, d, *J* 5.3, 4-H), 7.83 (1 H, t, *J* 7.0, 4′-H), 8.08 (1 H, d, *J* 7.0, 3′-H), 8.57 (1 H, d, *J* 4.4, 6′-H); δ_C($CDCl_3$) 14.1 (Me), 61.6 (CH_2), 123.9 (4-C), 127.4 (3′-C), 129.1 (5′-C), 131.6 (4′-C), 137.7 (5-C), 138.0 (3-C), 141.7 (2-C), 148.9 (6′-C), 154.0 (2′-C), 164.4 (ester CO), 187.1 (ketone CO).

Thieno[3,2-*g*]quinoline-4,9-dione 8

To a solution of **7** (0.11 g, 0.44 mmol) in THF (3 cm^3) at −75 °C was added a solution of LTMP [obtained by adding BuLi (1.3 mmol) to a solution of 2,2,6,6-tetramethylpiperidine (0.24 cm^3, 1.4 mmol) in THF (2 cm^3) at 0 °C]. The mixture was stirred at −75 °C for 2 h before hydrolysis with water (5 cm^3). Column chromatography on silica gel (95 : 5 DCM–Et_2O) afforded **8** (24 mg, 25%); which was identified by comparison of physical and spectral data with those described;[22] δ_C($CDCl_3$) 126.9 (3-C), 127.7 (6-C), 130.5 (a-C), 135.4 (5-C), 135.6 (2-C), 142.4 (b-C), 145.8 (d-C), 149.6 (a-C), 154.4 (7-C), 176.5 (4-CO), 178.6 (9-CO).

Methyl 2-(3-quinolylcarbonyl)benzoate 9

tert-BuLi (7.4 mmol) and, 2 h later, dimethyl phthalate (1.2 cm^3, 7.4 mmol), were added dropwise to a solution of 3-bromoquinoline (1.0 cm^3, 7.4 mmol) in Et_2O (20 cm^3) at −100 °C. After warming to −75 °C over 2 h, hydrolysis was performed with water (10 cm^3). Column chromatography on silica gel (9 : 1 DCM–Et_2O) afforded **9** (1.4 g, 65%) as a white powder; mp 102 °C (Found: C, 74.1; H, 4.4; N, 4.8. $C_{18}H_{13}NO_3$ requires: C, 74.2; H, 4.5; N, 4.8%); ν_{max}(KBr)/cm^{-1} 3337, 3065, 2952, 1720, 1673, 1287 and 760; δ_H($CDCl_3$) 3.57 (3 H, s, Me), 7.38 (1 H, d, *J* 7.2, 6-H), 7.51 (1 H, t, *J* 7.5, 4-H), 7.57 (1 H, d, *J* 7.5, 5′-H), 7.63 (1 H, t, *J* 7.1, 5-H), 7.75 (2 H, m, 6′-H and 7′-H), 8.06 (2 H, m, 3-H and 8′-H), 8.30 (1 H, d, *J* 1.5, 4′-H), 9.26 (1 H, d, *J* 1.5, 2′-H); δ_C($CDCl_3$) 52.8 (Me), 127.1 (1-C), 127.9 (6′-C), 128.0 (8′-C), 129.4 (4′-C), 129.8 (b-C), 129.9 (3-C), 130.0 (3′-C), 130.5 (4-C), 130.8 (6-C), 132.5 (5′-C), 133.2 (7′-C), 138.6 (5-C), 141.4 (2-C), 150.1 (2′-C), 150.1 (a-C), 166.5 (ester CO), 196.3 (ketone CO).

2-(3-Quinolylcarbonyl)benzoic acid 10

tert-BuLi (7.4 mmol) was added dropwise to a solution of 3-bromoquinoline (1.0 cm^3, 7.4 mmol) in Et_2O (20 cm^3) at −100 °C. After 2 h, a solution of phthalic anhydride (1.1 g, 7.4 mmol) in Et_2O (20 cm^3) was added dropwise. After warming to −75 °C over 2 h, hydrolysis was performed with water (1 cm^3). After removal of the solvent, the residue was dissolved in water (10 cm^3), the aqueous phase was washed with Et_2O and then acidified to pH 3–4 using a 3 M aqueous solution of hydrochloric acid. The precipitate was recovered by filtration and dried under vacuum to give **10** (1.0 g, 51%) as a white powder; mp 200 °C (Found: C, 73.3; H, 4.2; N, 4.7. $C_{17}H_{11}NO_3$ requires: C, 73.6; H, 4.0; N, 5.0%); ν_{max}(KBr)/cm^{-1} 3436, 3062, 2469, 1678, 1621, 1579, 1280, 1266, 926 and 709; δ_H(DMSO-d_6) 7.62 (1 H, d, *J* 7.5, 6-H), 7.75 (2 H, m, 4-H and 5′-H), 7.84 (1 H, t, *J* 7.1, 5-H), 7.97 (1 H, dd, *J* 8.3 and 6.8, 7′-H), 8.09 (1 H, d, *J* 7.5, 3-H), 8.17 (2 H, m, 6′-H and 8′-H), 8.51 (1 H, s, 4′-H), 9.24 (1 H, s, 2′-H), 12.8 (1 H, s, OH); δ_C(DMSO-d_6) 126.7 (6′-C), 127.7 (1-C), 128.1 (8′-C), 128.9 (4′-C), 130.1 (5-C), 130.1 (3′-C), 130.5 (b-C), 130.7 (6-C), 131.0 (2-C), 132.6 (4-C), 133.1 (3-C), 138.0 (5′-C), 141.2 (a-C), 149.0 (7′-C), 149.2 (2′-C), 168.8 (acid CO), 198.9 (ketone CO).

Benzo[*j*]phenanthridine-7,12-dione 11

To a solution of **9** (0.13 g, 0.44 mmol) in THF (3 cm^3) at −75 °C was added a solution of LTMP [obtained by adding BuLi (1.3 mmol) to a solution of 2,2,6,6-tetramethylpiperidine (0.24 cm^3, 1.4 mmol) in THF (2 cm^3) at 0 °C]. The mixture was stirred at −75 °C for 2 h before hydrolysis with water (5 cm^3). Column chromatography on silica gel (DCM) afforded **11** (39 mg, 34%) which was identified by comparison of physical and spectral data with those described;[23] ν_{max}(KBr)/cm^{-1} 2963, 1732, 1677, 1666, 1568, 1293, 1262, 1096, 1026, 800, 762 and 714; δ_C($CDCl_3$) 122.8 (a-C), 124.7 (f-C), 126.7 (8-C), 127.5 (5-C), 128.4 (11-C), 130.5 (3-C), 130.6 (4-C), 132.0 (b-C), 132.2 (9-C), 133.9 (d-C), 134.4 (c-C), 135.6 (10-C), 134.8 (6-C), 148.6 (1-C), 152.0 (e-C), 183.4 (12-CO), 186.3 (7-CO).

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