Polycyclic Heteroaromatics from Reactions of Acylbenzotriazoles with Aryl Isocyanates

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N-Acylbenzotriazoles react with aryl isocyanates to form, depending on the type of acyl group, compounds based on five different classes of polycyclic heteroaromatics. Higher alkanoyl-, acetyl-, acetoacetyl-, aroyl-, and cinnamoylbenzotriazoles yield, respectively, derivatives of quinoline, pyrimidino[5,4-*c*]quinoline, benzo[*b*]-1,8-naphthyridine, phenanthridine, and indolo[2,3-*b*]quinoline by incorporating 3, 3, 4, 2, and 2 molecules, respectively, of the isocyanate per acylbenzotriazole molecule.

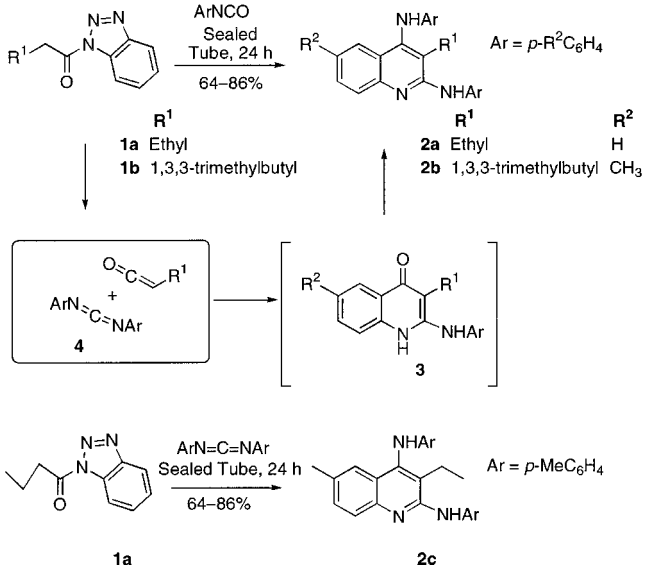
Introduction

Aryl isocyanates have been widely used for preparation of various heterocyclic compounds.[1a−g] Condensation of aryl isocyanates with aldehydes has provided short and efficient entries to diverse heterocycles.[2a,b] Previously reported condensations of isocyanates with carboxylic acid derivatives have afforded triazines,[3] triazoles,[4] pyrimidones,[5a,b] pyridones,[6] and some other heterocycles.[6,7a,b] We now report condensations of aryl isocyanates with five distinct types of *N*-acylbenzotriazoles to provide synthetic approaches to quinolines, pyrimidino[5,4-*c*]-quinolines, benz[*b*]-1,8-naphthyridine, phenanthridines, and indolo[2,3-*b*]quinolines and compare our results with those previously reported.

Results and Discussion

Quinoline Synthesis. 1-Alkanoylbenzotriazoles **1a**,**b** (1 equiv) heated neat in the presence of an aryl isocyanate (3 equiv) in a sealed tube for 24 h gave quinolines **2a** and **2b** in 86 and 83% yields, respectively (Scheme 1). The structure of **2a** was confirmed by X-ray crystallography (Figure S1), and that of **2b**[1b] was assigned by analogy and by spectroscopic data comparisons. In the X-ray structure of **2a**, the ring of the C2-anilino substituent is approximately coplanar with the quinoline ring, whereas the C4 substituent is approximately orthogonal to it. The nature of substituents R^1 and R^2 did not significantly influence the yields of such quinolines, except 1-benzotriazolyl-1-carbonyl-3-chloropropane (**1c**, $R^1 = CH_2CH_2Cl$) on heating with tolyl isocyanate gave *N*-phenyl-2-pyrrolidone and no quinoline product.[8] Quinolines of type **2** were previously prepared by heating aniline and diethyl malonate[9a] or *N*-acetylanthranilates[9b] in hexamethylphosphoric triamide (HMPT) but only in

Scheme 1



(1) (a) Sheehan, J. C.; Daves, G. D., Jr. *J. Org. Chem.* **1965**, *30*, 3247. (b) Merault, G.; Bourgeois, P.; Duffaut, N. *Bull. Soc. Chim. Fr.* **1974**, 1949. (c) Ohtsuka, Y. *J. Org. Chem.* **1978**, *43*, 3231. (d) Shindo, H.; Fujishita, T.; Sasatani, T.; Chomei, N.; Takada, S. *Heterocycles* **1989**, *29*, 899. (e) Palacios, F.; Aparicio, D.; Garcia, J. *Tetrahedron* **1997**, *53*, 2931. (f) Molina, P.; Alcantara, J.; Lopez-Leonardo, C. *Tetrahedron* **1997**, *53*, 3281. (g) Shi, C.; Zhang, Q.; Wang, K. K. *J. Org. Chem.* **1999**, *64*, 925.

(2) (a) Minami, T.; Ohshiro, Y.; Agawa, T. *J. Org. Chem.* **1974**, *39*, 3516. (b) Yamamoto, I.; Furukawa, T.; Nakajima, H.; Gotoh, H. *J. Chem. Soc., Perkin Trans. 1* **1976**, 1597.

(3) Argabright, P. A.; Phillips, B. L. *J. Heterocycl. Chem.* **1970**, *7*, 725.

(4) Bruche, L.; Garanti, L.; Zecchi, G. *J. Chem. Soc., Perkin Trans. 1* **1986**, 2177.

(5) (a) Behrend, R.; Meyer, F. C.; Buchholz, Y. *Liebigs Ann. Chem.* **1901**, *314*, 200. (b) Capuano, L.; Boschat, P.; Heyer, H. W.; Wachter, G. *Chem. Ber.* **1973**, *106*, 312.

(6) Ozaki, S.; Nagase, T.; Kato, T. *Heterocycles* **1988**, *27*, 2063.

(7) (a) Huisgen, R.; Grashey, R.; Knupfer, H.; Kunz, R.; Seidel, M. *Chem. Ber.* **1964**, *97*, 1085. (b) Capuano, L.; Bronder, M.; Djokar, K.; Muller, I. *Chem. Ber.* **1980**, *113*, 395.

(8) Toth, G.; Kovacs, A.; Bitter, I.; Duddeck, H. *Liebigs Ann. Chem* **1991**, 1215.

(9) (a) Pedersen, E. B. *Acta Chem. Scand.* **1976**, *B30*, 133. (b) Pedersen, E. B. *Tetrahedron* **1977**, *33*, 217.

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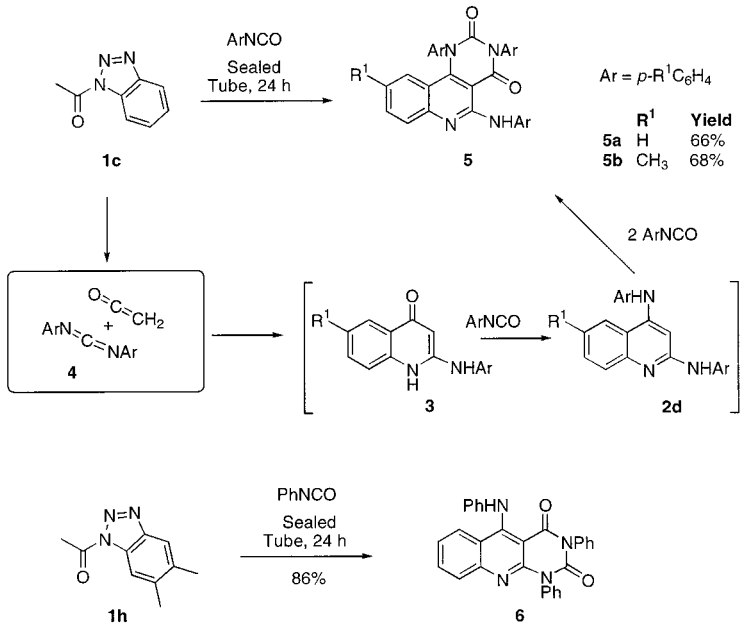
Scheme 2



5% yield for R^1 = alkyl. For R^1 = H the yield of **2** was 17−70% depending on the nature of R^2.

Although it is known that some benzotriazole derivatives extrude nitrogen to form quinolines,[10a−e] structures **2a** and **2b** clearly excluded the possibility of the quinoline ring arising from the benzotriazole moiety. The mechanism of the conversion **1** → **2** likely involves the ketene derived from the 1-acylbenzotriazole[11] reacting with the carbodiimide[12] **4** formed from two molecules of the isocyanate. The resulting 4-quinolone **3** apparently reacts further with another molecule of isocyanate to yield the observed product **2**.[13] These intermediates are different to the imine or enamine species which were suggested earlier as intermediates in condensations of aldehydes with isocyanates.[2a,b] Our mechanistic speculations are supported by the facts that (1) the corresponding 1-benzotriazolyl imines[14a,b] failed to produce quinolines under these reaction conditions and (2) the reaction of *N*,*N*′-bis(4-methylphenyl)carbodiimide with 1-butyrylbenzotriazole (**1a**) afforded 3-ethyl-7-methyl-N^2-(4-methyl-1,4-cyclohexadien-1-yl)-N^4-(4-methylphenyl)-2,4-quinolinediamine (**2c**) in 76% yield (Scheme 1).

Reactions **1** → **2** are somewhat similar to the direct syntheses of quinoline systems from aryl isocyanates by reacting them with carbonyl compounds,[2a,b] enamines,[1e] imines,[15] and other compounds.[1b,16] However, reactions **1** → **2** offer a higher degree of functionalization as well as mechanistic diversity.

Pyrimidino[4,5-*b*]quinolines. We found that 1-acetylbenzotriazole **1c**, when heated with an excess of C_6H_5-NCO or *p*-MeC_6H_4NCO in a sealed tube at 210 °C for 24 h, gave pyrimidino[5,4-*c*]quinolines **5a** and **5b** in 66% and 86% yields, respectively (Scheme 2). The structures of compounds **5a** and **5b** were determined by X-ray crystallography (Figure S2). The structures and conformations of these two molecules are very similar, and in each case, the NH hydrogen of the anilino substituent is involved in an intramolecular hydrogen bond to the nearby carbonyl oxygen. We believe that mechanistically the first steps in this reaction are very similar to the transformation **1** → **2** discussed above and probably give **3**. The reaction then proceeds via the formation of **2d** followed by reaction with two more moles of ArNCO. The 3-position in **2d** is somewhat nucleophilic and forms another pyrimidine ring under the reaction conditions. The GC/MS of the reaction mixture indicates the presence of molecular ions for **5a** and **5b**.

Previously, compounds of type **5** were available via Wittig reaction of isocyanates with phosphorus ylides derived from bromoacetic esters.[7b] This earlier method gave **5** mixed with other products: our direct condensation of isocyanates with 1-acetylbenzotriazole **1c** affords the pyrimidino[5,4-*c*]quinolines **5a** as a 6:1 mixture with **6** and **5b** as the only product in 66% and 68% yields. Curiously enough under identical conditions **1h** displayed just the opposite selectivity yielding **6** as the only product. This quite remarkable difference between chemical behavior of benzotriazolyl and 5,6-dimethylbenzotriazolyl moieties suggests more complex mechanism and their intimate involvement in it.

The structure of **6** was confirmed by X-ray crystallography (Figure S3). Once again the NH group is

(10) (a) Kulagowski, J. J.; Moody, C. J.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1985**, 2725. (b) Barker, S. J.; Jones, G. B.; Randles, K. R.; Storr, R. C. *Tetrahedron Lett.* **1988**, *29*, 953. (c) Katritzky, A. R.; Lan, X.; Lam, J. N. *Chem. Ber.* **1991**, *124*, 1431. (d) Katritzky, A. R.; Yang, B. *J. Heterocycl. Chem.* **1996**, *33*, 607. (e) Katritzky, A. R.; Du, W.; Matsukawa, Y.; Ghiviriga, I.; Denisenko, S. N. *J. Heterocycl. Chem.* **1999**, *36*, 927.

(11) Katritzky, A. R.; Soleiman M.; Yang, B. *Heteroatom Chem.* **1996**, *7*, 367.

(12) The formation of carbodiimide was suggested by the side products isolated—the corresponding amides and a carbodiimide dimer. Previous publications report reaction of carbodiimide with aryl isocyanate to form 2-imino-1,3-diazetan-4-ones: (a) Ulrich, H.; Richter, R.; Tucker, B. *J. Heterocyclic Chem.* **1987**, *24*, 1121. (b) Farrissey, W. J., Jr.; Ricciardi, R. J.; Sayigh, A. A. R. *J. Org. Chem.* **1968,** *33*, 1913. (c) Neidlein, R. *Archiv. Pharm.* **1964**, *297*, 623.

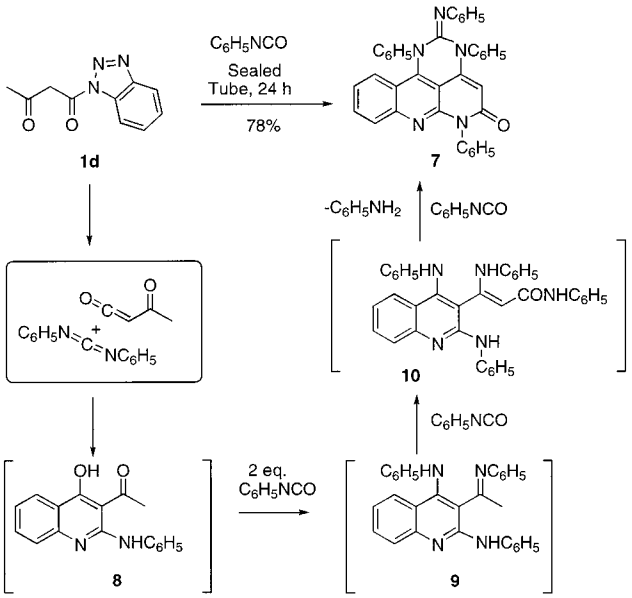
(13) In unpublished work, treatment of 4-quinolone with *p*-tolyl isocyanate under similar conditions gave 4-p-tolylaminoquinoline in 71% yield.

(14) (a) Katritzky, A. R.; Rachwal, S.; Offerman, R. J.; Najzarek, Z.; Yagoub, A. K.; Zhang, Y. *Chem. Ber.* **1990**, *123*, 1545. (b) Katritzky, A. R.; Stevens, C. V.; Zhang, G.-F.; Jiang, J.; Kimpe, N. *Heterocycles* **1995**, *40*, 231.

(15) Saito, T.; Nakane, M.; Miyazaki, T.; Motoki, S. *J. Chem. Soc., Perkin Trans. 1* **1989**, 2140.

(16) Molina, P.; Alcantara, J.; Lopez-Leonardo, C. *Tetrahedron* **1997**, *53*, 3281.

Scheme 3



involved in an intramolecular hydrogen bond to the adjacent carbonyl oxygen.

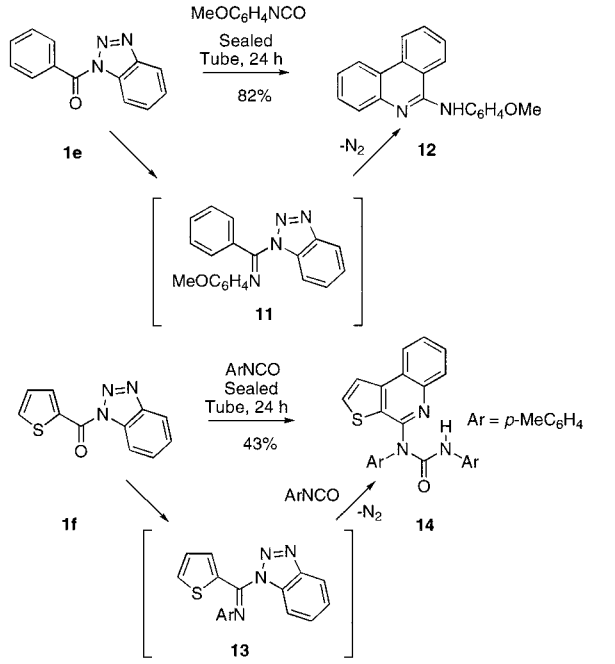
Benz[*b*]-1,8-naphthyridine. Acetoacetylbenzotriazole **1d** when heated with an excess of phenyl isocyanate gave benz[*b*]-1,8-naphthyridine **7** in 83% yield (Scheme 3). The mechanism of formation of benz[*b*]-1,8-naphthyridine **7** is more complex and appears to involve more steps than the formation of quinolines **2** and **5**. A plausible mechanism depicted in Scheme 3 involves the formation of intermediate **8**, which is then transformed into imine species **9**. The intermediate **9** reacts further with isocyanate to form the intermediate **10**, which upon annulation with formal loss of aniline (isolated from the reaction mixture in the form of the *N*,*N*′-diphenylurea) followed by further reaction with another molecule of isocyanate affords benz[*b*]-1,8-naphthyridine **7**.

This method is advantageous in comparison with the earlier reported synthesis of benz[*b*]-1,8-naphthyridines from 2-chloroquinoline-3-aldehyde in 22−59% yields.[17]

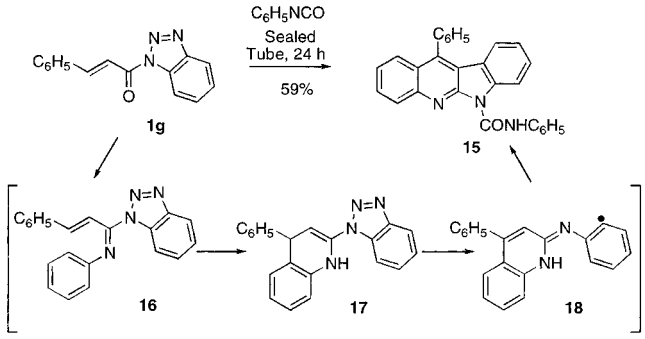
Phenanthridine. 1-Benzoylbenzotriazole **1e** readily reacts with 2 equiv of *p*-methoxyphenyl isocyanate to afford phenanthridine **12** in 82% yield (Scheme 4).[1g,18a,b] Compound **14** was similarly obtained in 43% yield from 1-(2-thiophenoyl)benzotriazole derivative **1f**. In contrast, 1-(2-furanoyl)benzotriazole afforded the corresponding 1-imidoylbenzotriazole derivative. The structure of **12** was established by X-ray analysis (Figure S4), while that of **14** was assigned from spectroscopic data. Compound **12** crystallizes in the monoclinic space group $P2_1/c$, with two independent molecules in the asymmetric unit, which differ only in the conformations of the anisyl rings.

Since 1-acylbenzotriazoles **1e**,**f** lack α-protons, the formation of ketenes or their amino analogues is excluded. Thus, the formation of quinoline rings in **12** and **14** proceeds via a different mechanism. It most likely involves formation of the corresponding imidoylbenzotriazole species **11** and **13** followed by a thermal fragmentation of the benzotriazole moiety[10d,e] and formation of the pyridine ring within **12** and **14**.

Scheme 4



Scheme 5



This approach potentially provides access to a wider range of substitution along with good yields and is an advantageous alternative to previously reported condensations of aryl isocyanates with anthranilic acid.[1a]

Indolo[2,3-*b*]quinoline. When 1-cinnamoylbenzotriazole **1g** was heated with 2 equiv of phenyl isocyanate, indolo[2,3-b]quinoline **15**[1g] was isolated in 59% yield (Scheme 5). The structure of **15** was established by X-ray analysis (Figure S5). In this case, the NH hydrogen is involved in an intramolecular hydrogen bond to the quinoline nitrogen. This rearrangement most likely proceeds via the initial formation of the corresponding imidoyl benzotriazole derivative **16** followed by electrocyclic cyclization to yield **17**. Finally, thermal decomposition of the benzotriazolyl moiety in **17** and cyclization of the resulting radical **18** affords product **15**. There are mechanistic similarities between this reaction and some of those earlier reported.[1g] However, in contrast to Wang's synthesis of indolo[2,3-*b*]quinoline, our approach is based on a more readily accessible starting material and is also two steps shorter.

In conclusion, we have demonstrated that five distinct types of *N*-acylbenzotriazoles can react with isocyanates to provide synthetic approaches to quinolines, pyrimi-

(17) Meth-Cohn, O.; Tarnowski, B. *Tetrahedron Lett.* **1980**, *21*, 3721.
(18) (a) Saito, T.; Ohmori, H.; Ohkubo, T.; Motoki, S. *J. Chem. Soc., Chem. Commun.* **1993**, *24*, 1802. (b) Schmittel, M.; Steffen, J.-P.; Engels, B.; Lennartz, C.; Hanrath, M. *Angew. Chem., Int. Ed. Engl.* **1998**, *37*, 2371.

dino[5,4-*c*]quinolines, benz[*b*]-1,8-naphthyridine, phenanthridines, and indolo[2,3-*b*]quinolines, respectively.

Experimental Section

General Methods. Melting points were determined on a capillary melting point apparatus equipped with a digital thermometer. NMR spectra were taken in $CDCl_3$ with tetramethylsilane as the internal standard for ^1H (300 MHz) or solvent as the internal standard for ^{13}C (75 MHz). THF was distilled from sodium/benzophenone under nitrogen immediately prior to use. All reactions with air-sensitive compounds were carried out under an argon atmosphere. Column chromatography was conducted with silica gel 230−400 mesh.

General Procedure for the Preparation of Compounds 1a−d,f. To a solution of 0.1 mol of acyl chloride and 11.9 g of benzotriazole in 300 mL of methylene chloride was added a mixture of 11.0 g of triethylamine and 50 mL of methylene chloride at 0−20 °C dropwise over 30 min. The mixture was refluxed for 4 h, cooled to room temperature, and washed with 100 mL of water, 50 mL of saturated NH_4Cl, 50 mL of 10% $NaHCO_3$, and 100 mL of water. The organic layer was dried over anhydrous $MgSO_4$, and the filtrate was diluted with hexane (about 60 mL) and was kept at 0 °C overnight. The desired product was isolated as colorless crystals. The analytically pure acyl-1-benzotriazoles were obtained by re-crystallization from 2-propanol.

Compounds **1e**,**g** were prepared according to published procedures.[19a,b,20]

General Procedure for the Preparation of Compounds 2a,b, 5a,b, 6, 7, 12, 14, and 15. The mixture of 3 mmol of 1-acyl-benzotriazole and 5−10 mmol of aryl isocyanate was heated at 210 °C for 24 h (unless mentioned otherwise) in a 50 mL sealed tube and then cooled to room temperature. The reaction mixture was subjected to column chromatography with hexane/ethyl acetate (6/1∼10/1) to give the corresponding product. Analytically pure product was obtained as yellow crystals by re-crystallization from methylene chloride−ethanol mixture.

Butyryl-1-benzotriazole (1a): 92% white needles; mp 62−63 °C; ^1H NMR δ 1.08 (t, 3H, J = 7.5 Hz), 1.82−1.90 (m, 2H), 3.40 (t, 2H, J = 7.2 Hz), 7.60 (t, 1H, J = 7.2 Hz), 7.75 (t, 1H, J = 7.2 Hz), 8.18 (d, 1H, J = 8.4 Hz), 8.20 (d, 1H, J = 8.4 Hz); ^{13}C NMR δ 13.3, 17.0, 36.6, 113.7, 119.7, 126.0, 130.3, 145.3, 172.0. Anal. Calcd for $C_{10}H_{11}N_3O$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.78; H, 6.07; N, 22.42.

1-(1*H*-1,2,3-Benzotriazol-1-yl)-1,3-butanedione (1d): 91% white prisms; mp 69−70 °C (lit.[21] mp 69 °C), as 2:1 mixture of tautomers; ^1H NMR (C_6D_6) δ 1.53 (d, 1.8H, J = 4.1 Hz), 1.67 (d, 1.2 H, J = 7.3 Hz), 3.81 (d, 0.6H, J = 9.2 Hz), 6.44 (s, 0.6H), 6.87−7.11 (m, 1.2H), 7.72 (dd, 0.4H, J = 7.6, 0.6 Hz), 7.80 (d, 0.6H, J = 8.2 Hz), 8.11−8.12 (m, 1H), 13.29 (br s, 0.6H); ^{13}C NMR (C_6D_6) δ 21.6, 29.7, 50.6, 90.6, 114.4, 114.8, 120.3, 125.8, 126.2, 127.7, 128.0, 128.3, 129.9, 130.3, 131.1, 131.4, 146.7, 146.9, 166.1, 169.6, 182.0, 182.1, 199.0.

1-(2-Thiophenoyl)benzotriazole (1f): 89% colorless needles; mp 175−176 °C; ^1H NMR δ 7.27 (t, 1H, J = 3.9 Hz), 7.53 (t, 1H, J = 8.4 Hz), 7.68 (t, 1H, J = 6.9 Hz), 7.88 (dd, 1H, J = 4.8, 1.2 Hz), 8.15 (d, 1H, J = 8.4 Hz), 8.39 (d, 1H, J = 8.4 Hz), 8.57 (dd, 1H, J = 3.9, 1.2 Hz); ^{13}C NMR δ 114.8, 120.2, 126.3, 128.1, 130.5, 132.1, 133.4, 137.3, 138.5, 145.8, 159.2. Anal. Calcd for $C_{11}H_7N_3OS$: C, 57.63; H, 3.08; N, 18.33. Found: C, 57.78; H, 3.13; N, 18.39.

1-Acetyl-5,6-dimethylbenzotriazole (1h): 61% white prisms; mp 97−98 °C; ^1H NMR δ 2.41 (s, 3H), 2.43 (s, 3H), 2.97 (s, 3H), 7.80 (s, 1H), 8.00 (s, 1H); ^{13}C NMR δ 20.4, 20.9, 23.2, 113.9, 119.2, 129.8, 135.8, 140.9, 145.29, 169.6. Anal. Calcd for $C_{10}H_{11}N_3O$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.26; H, 5.92; N, 22.33.

2,4-Dianilino-3-ethylquinoline (2a): 86% yellow hexagonal crystals; mp 171−172 °C; ^1H NMR δ 1.21 (t, 3H, J = 7.5 Hz), 2.72 (q, 2H, J = 7.5 Hz), 5.60 (s, 1H, D_2O exchangeable), 6.62 (s, 1H, D_2O exchangeable), 6.62 (d, 2H, J = 7.5 Hz), 6.82 (t, 1H, J = 7.2 Hz), 7.05 (t, 1H, J = 7.2 Hz), 7.13−7.20 (m, 3H), 7.38 (t, 2H, J = 8.4 Hz), 7.51 (t, 1H, J = 8.1 Hz), 7.67 (d, 1H, J = 8.1 Hz), 7.84 (d, 1H, J = 8.4 Hz), 7.85 (d, 2H, J = 8.1 Hz); ^{13}C NMR δ 13.0, 19.6, 115.1, 119.6, 119.7, 121.1, 122.0, 122.2, 123.0, 123.4, 127.4, 128.9, 129.0, 129.3, 140.6, 142.9, 146.0, 146.9, 152.8. Anal. Calcd for $C_{23}H_{21}N_3$: C, 81.38; H, 6.24; N, 12.38. Found: C, 81.19; H, 6.38; N, 12.40.

6-Methyl-N^2,N^4-bis(4-methyphenyl)-3-(1,3,3-trimethylbutyl)quinoline-2,4-diamine (2b): 83%, glassy solid; ^1H NMR δ 0.84 (s, 9H), 1.34 (d, 3H, J = 7.3 Hz), 1.60 (dd, 1H, J = 5.7, 13.2 Hz), 1.85 (dd, 1H, J = 5.7, 13.2 Hz), 2.27 (s, 3H), 2.36 (br s, 6H), 3.74 (br s, 1H), 5.48 (br s, 1H), 6.59 (d, 2H, J = 8.2 Hz), 6.62 (br s, 1H), 6.99 (d, 2H, J = 8.2 Hz), 7.18 (d, 2H, J = 8.2 Hz), 7.34 (d, 1H, J = 8.1 Hz), 7.47 (br s, 1H), 7.71 (d, 2H, J = 8.2 Hz), 7.75 (br s, 1H); ^{13}C NMR δ 20.5, 20.8, 21.6, 27.2, 29.5, 31.9, 50.4, 115.4, 119.5, 122.1, 126.1, 126.9, 128.8, 129.3, 129.8, 130.8, 131.3, 132.5, 138.2, 141.7, 144.1, 145.2, 150.0, 152.8. Anal. Calcd for $C_{31}H_{37}N_3$: N, 9.30; Found: N, 9.22

2,4-Di(4-methylphenylamino)-3-ethyl-6-methylquinoline (2c): 76% yellow needles; mp 165−166 °C; ^1H NMR δ 1.19 (t, 3H, J = 7.8 Hz), 2.26 (s, 3H), 2.34 (s, 3H), 2.36 (s, 3H), 2.72 (q, 2H, J = 7.5 Hz), 5.56 (br s, 1H), 6.58 (d, 2H, J = 8.1 Hz), 6.98 (d, 2H, J = 8.1 Hz), 7.16 (d, 2H, J = 8.1 Hz), 7.25 (s, 1H), 7.33 (dd, 1H, J = 1.7, 7.6 Hz), 7.45 (br s, 1H), 7.70 (t, 3H, J = 8.4 Hz); ^{13}C NMR δ 13.2, 19.9, 20.7, 21.0, 21.8, 115.5, 120.0, 120.8, 122.1, 122.4, 127.4, 129.3, 129.6, 130.0, 131.1, 131.8, 132.7, 138.5, 143.1, 143.9, 145.5, 152.8; HRMS calcd for $C_{26}H_{28}N_3$ 382.2283, found 382.2244.

5-Anilino-1,3-diphenylpyrimido[5,4-*c*]quinoline-2,4-(1*H*,3*H*)-dione (5a): 66% yellow needles; mp 272−273 °C; ^1H NMR δ 6.92−6.98 (m, 1H), 7.14 (d, 2H, J = 7.8 Hz), 7.21 (t, 1H, J = 7.2 Hz), 7.30−7.58 (m, 15H), 11.92 (br s, 1H); ^{13}C NMR δ 94.1, 115.9, 122.7, 123.5, 125.8, 126.6, 128.2, 128.6, 128.8, 129.1, 129.2, 129.3, 129.4, 132.3, 134.7, 136.5, 141.4, 149.9, 150.4, 150.6, 155.2, 165.3. Anal. Calcd for $C_{29}H_{20}N_4O_2$: N, 12.27. Found: N, 11.93.

3-(4-Methylphenyl)-9-methyl-1-(4-methylphenyl)-5-(4-toluidino)[5,4-*c*]quinoline-2,4(1*H*,3*H*)-dione (5b): 68% yellow prisms; mp 229−230 °C; ^1H NMR δ 1.98 (s, 3H), 2.33 (s, 3H), 2.42 (s, 3H), 2.44 (s, 3H), 6.54−6.55 (br, 1H), 7.14 (d, 2H, J = 8.4 Hz), 7.22−7.27 (m, 6H), 7.33 (t, 3H, J = 8.1 Hz), 7.58 (d, 1H, J = 8.1 Hz), 7.80 (d, 2H, J = 8.1 Hz), 11.11 (s, 1H); ^{13}C NMR δ 20.9, 21.2, 21.3, 21.4, 97.7, 112.6, 120.6, 125.7, 127.7, 127.9, 128.6, 129.2, 130.1, 130.3, 130.9, 131.9, 132.0, 134.1, 137.5, 137.7, 139.2, 148.6, 150.0, 151.1, 151.6, 163.9. Anal. Calcd for $C_{33}H_{28}N_4O_2$: C, 77.32; H, 5.51; N, 10.93. Found: C, 77.46; H, 5.86; N, 10.91.

5-Anilino-1,3-diphenylpyrimido[4,5-b]quinoline-2,6-(1*H*,3*H*)-dione (6): 86% yellow cubic crystals; mp 272−273 °C; ^1H NMR δ 6.75 (t, 1H, J = 7.8 Hz), 6.86 (d, 1H, J = 8.1 Hz), 7.06−7.12 (m, 1H), 7.30−7.61 (m, 13 H), 7.73 (d, 1H, J = 8.4 Hz), 7.96 (d, 2H, J = 7.8 Hz), 11.24 (br s, 1H); ^{13}C NMR δ 98.2, 113.1, 120.8, 120.9, 122.1, 123.1, 126.4, 128.3, 128.4, 128.9, 129.0, 129.2, 129.4, 129.5, 129.9, 132.5, 134.7, 140.1, 140.4, 149.3, 151.8, 152.1, 163.9. Anal. Calcd for $C_{29}H_{20}N_4O_2$: C, 76.30; H, 4.42; N, 12.27. Found: C, 74.67; H, 4.31; N, 11.94.

1,3,6-Triphenyl-2-(phenylimino)-2,3-dihydro-1*H*-benzo[*b*]pyrimido[4,5,6-*de*][1,8] naphthyridin-5(6*H*)-one (7): 78% yellow block crystals; mp 290−291 °C; ^1H NMR δ 5.29 (s, 1H), 7.03−7.67 (m, 21H), 7.79 (ss, 1H, J = 8.7, 0.9 Hz), 7.90 (dd, 1H, J = 8.9 Hz, J = 1.2 Hz), 12.67 (s, 1H); ^{13}C NMR δ 100.5, 117.7, 121.8, 122.5, 123.3, 123.7, 125.4, 126.8, 127.2, 128.2, 128.3, 129.1, 129.5, 129.6, 130.8, 132.2, 138.5, 142.5, 144.0, 148.1, 148.5,152.5, 153.0,154.6, 166.3; HRMS calcd for $C_{37}H_{25}N_5O_2$ 556.2153, found 556.2137. Anal. Calcd for $C_{37}H_{25}N_5O_2$: N, 12.60. Found: N, 12.36.

***N*-(4-Methoxyphenyl)-6-phenanthridinamine (12):** 82% yellow needles; mp 165−166 °C; ^1H NMR δ 3.81 (s, 3H), 6.93

(19) (a) Kreutzberger, A.; Dietz, E.; *Tetrahedron Lett.* **1970**, 1457. (b) Katritzky, A. R.; Pastor, A.; Voronkov, M. *J. Heterocycl. Chem.* **1999**, *36*, 777.

(20) Katritzky, A. R.; Shobana, N.; Pernak, J.; Afridi, A. S.; Fan, W.-Q. *Tetrahedron* **1992**, *48*, 7817.

(21) Katritzky, A. R.; Rachwal, S.; Rachwal, B. *J. Chem. Soc., Perkin Trans. 1* **1990**, 1717.

(t, 2H, J = 8.4 Hz), 7.14 (s, 1H), 7.36 (t, 1H, J = 7.2 Hz), 7.53−7.52 (m, 2H), 7.73−7.83 (m, 4H), 7.94 (d, 1H, J = 7.8 Hz), 8.34 (d, 1H, J = 8.1 Hz), 8.53 (d, 1H, J = 8.1 Hz); ^{13}C NMR δ 55.5, 114.1, 119.5, 121.7, 122.2, 122.9, 123.3, 127.1, 127.6, 128.8, 130.2, 133.4, 134.2, 151.3, 155.4. Anal. Calcd for $C_{20}H_{16}N_2O$: C, 79.98; H, 5.37; N, 9.33. Found: C, 79.74; H, 5.58; N, 9.36.

***N*,*N*′-Bis(4-methylphenyl)-*N*-thieno[2,3-*c*]quinolin-4-ylurea (14):** 43% yellow needles; mp 172−173 °C; ^{1}H NMR δ 2.61 (s, 3H), 2.68 (s, 3H), 7.31 (dd, 1H, J = 3.6, 4.8 Hz), 7.46 (d, 2H, J = 8.1 Hz), 7.54 (d, 2H, J = 7.8 Hz), 7.61 (dd, 2H, J = 5.1, 1.6 Hz), 7.71 (t, 1H, J = 8.4 Hz), 7.96−8.04 (m, 5H), 8.14 (dd, 1H, J = 1.2, 2.4 Hz); ^{13}C NMR δ 20.9, 21.3, 113.9, 119.1, 121.0, 125.2, 127.8, 128.4, 129.4, 130.9, 133.2, 133.5, 133.7, 135.4, 136.1, 137.1, 139.8, 148.3, 157.3. Anal. Calcd for $C_{26}H_{21}N_3OS$: N, 9.92. Found: N, 10.22.

***N*-1,1-Diphenyl-6*H*-indolo[2,3-*b*]quinoline-6-carboxamide (15):** 59% yellow needles; mp 189−190 °C; ^{1}H NMR δ 6.87 (d, 1H, J = 7.2 Hz), 7.05 (t, 1H, J = 7.8 Hz), 7.16 (t, 1H, J = 7.2 Hz), 7.40−7.47 (m, 6H), 7.60−7.63 (m, 3H), 7.66−7.75 (m, 2H), 7.82 (d, 2H, J = 7.82 Hz), 8.12 (d, 1H, J = 8.1 Hz), 8.79 (d, 1H, J = 8.1 Hz), 13.1 (br s, 1H); ^{13}C NMR δ 116.9, 117.6, 120.2, 121.7, 122.3, 123.0, 123.8, 125.0, 125.1, 126.3, 127.5, 128.9, 129.0, 129.1, 129.2, 129.6, 135.3, 138.4, 140.5, 143.3, 144.0, 150.5, 150.8. Anal. Calcd for $C_{28}H_{19}N_3O$: N, 10.16. Found: N, 10.10.

X-ray Crystallography. The crystal data, data collection, and refinement parameters for the six structures are listed in Table S1. Data were collected with a Siemens SMART CCD area detector, using graphite-monochromatized Mo Kα radiation (λ = 0.710 73 Å). The structures were solved by direct methods using SHELXS[22] and refined on F^2, using all data, by full-matrix least-squares procedures with SHELXTL.[23] CH hydrogen atoms were included in calculated positions with isotropic displacement parameters 1.2 times the isotropic equivalent of their carrier atoms, while the NH hydrogens were located from difference Fourier syntheses and their positions refined. The functions minimized were $\sum w(F_o^2 - F_c^2)^2$, with $w = [\sigma^2(F_o^2) + (aP)^2 + bP]^{-1}$, where $P = [\max(F_o)^2 + 2F_c^2]/3$.

Supporting Information Available: Perspective views (Figures S1−S5), crystal data, data collection and refinement parameters, full tables of atom coordinates, bond lengths and angles, and thermal displacement parameters (Tables S1−S25) for X-ray crystal structures of **2a**, **5a**,**b**, **6**, **12**, and **15**. This material is available free of charge via the Internet at http://pubs.acs.org.

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(22) Sheldrick, G. M. *Acta Crystallogr., Sect. A* **1990**, *46*, 467.
(23) Sheldrick, G. M. *SHELXTL*, Bruker Analytical X-ray Systems, 1997.