A convenient access to 1-substituted-2-azinyl-1-ethanones via acylation of alkylated azines with N-acylbenzotriazoles

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Abstract
Reactions of alkylazines 9a–f (2-methylpyridine, 2-benzylpyridine, 4-benzylpyridine, 2-methylquinoline, 4-methylquinoline or 4-methylpyrimidine) with readily available N-acylbenzotriazoles 8a–j produced 1-substituted-2-azinyl-1-ethanones 10a–p in 50–95% yields.

Keywords: N-Acylbenzotriazoles, alkylated azines, 1-substituted-2-azinyl-1-ethanones

Introduction
1,2-Disubstituted-1-ethanones (X-CH$_2$CO-Y) play an important role in organic synthesis.$^1$ Among such derivatives, 1-substituted-2-azin-2-yl-1-ethanones (Het-CH$_2$COY) find important and widespread uses as ligands to chelate transition metals$^2$ and medically important gallium$^6$Ga,$^6$Ga, and 68Ga radioisotopes.$^3$ Compounds of this class are also useful as synthetic templates in the preparation of chiral building blocks$^4$ for a wide variety of alkaloids, e.g., hydrangea$^1_5$, lamellarins$^2_6$, sedamines$^3_7$ and lobelinas$^4_4$ and$^5_5$ as well as steroid-like compounds such as azasteroids$^6_6$. These systems have long been recognized as bioactive natural products.$^{10}$ For example, early findings on the biological properties of lobelinas (also known as Indian tobacco) support their potential ability to exhibit agonist activity$^8$ and enhance latent inhibition$^{11}$ at nicotinic receptors, stimulate autonomic ganglia,$^{12}$ and improve memory.$^{10a}$

Moreover, certain 1-substituted-2-azinyl-1-ethanone derivatives exhibit biological activities as potential hypocholesteremic agents having minimal estrogenic activity$^{13}$ and others are valuable synths in the development of various pharmaceutically important molecules$^{1a,14}$ and in the preparation of chiral nematic materials.$^{15}$

Previous protocols for syntheses of 1-substituted-2-azinyl-1-ethanones (Scheme 1) include: (i) from 1-substituted-2-azinylethynes by hydration in 2N H$_2$SO$_4$ in the presence of HgCl$_2$;$^{16}$ (ii) reactions of organometallic reagents with aldehyde followed by Swern oxidation;$^{17}$ (iii) radical...
nucleophilic substitution reactions (S_{RN1}) of haloazines with ketone enolates;\(^\text{18}\) (iv) reactions of \(\alpha\)-haloazinium salts (pseudo-Vilsmeier reagents) with \(N,N\)-disubstituted enamines followed by acidic hydrolysis and dequaternization;\(^\text{19}\) and (v) acylation of methylated azines. Approaches of type (v) are the most commonly used and include treatment of methylyazines with carbonitriles\(^\text{20}\) or with activated derivatives of carboxylic acids, especially acid chlorides,\(^\text{21}\) esters,\(^\text{13,22}\) and amides.\(^\text{23}\)

![Figure 1](image-url)

Claisen-type condensation methods in refs\(^\text{22a-c}\) require either a 2:1 molar ratio of metallated alkylazine:acylating ester or 2 molar equivalents of base that might cause ester self-condensation prior to the lateral acylation. Among the conventional methods available for the synthesis of 1-substituted-2-azinyl-1-ethanones, approaches based on the use of amides as acylating reagents are scarce.

We have reported earlier the use of \(N\)-acylbenzotriazoles in the syntheses of amides,\(^\text{24}\) esters,\(^\text{25}\) \(\beta\)-keto sulfones\(^\text{26}\) and \(\beta\)-keto nitriles.\(^\text{27}\) In view of our previous results, we now describe a further application of \(N\)-acylbenzotriazoles in a general and convenient access to a variety of 1-substituted-2-azinyl-1-ethanones in satisfactory to excellent yields by the acylation of alkylated azines.

**Results and Discussion**

The starting \(N\)-acylbenzotriazoles \(8a–f\) with alkyl, alkenyl or aryl substituents (\(R = \text{isobutyl, } n\)-butyl, cinnamyl, phenyl, 4-chlorophenyl or 4-nitrophenyl) were prepared by stirring acid chlorides in \(\text{CH}_2\text{Cl}_2\) with benzotriazole in the presence of \(\text{Et}_3\text{N}\) at room temperature\(^\text{28}\) while \(8g–j\) (\(R = 4\)-diethylaminophenyl, 3-pyridyl, 2-thienyl or 2-furyl) were readily prepared by refluxing
the corresponding carboxylic acids in THF with 1-(methansulfonyl)-1H-benzotriazole in the presence of Et₃N.²⁴a

Scheme 1

The acylation reactions were accomplished by treatment of alkylazines 9a–f (1.0 equivalent) in THF at -78 °C with LDA (2.0 equivalents), itself prepared in situ from n-butyllithium and diisopropylamine), followed by the addition, at -78 °C, of a THF solution of the appropriate N-acylbenzotriazole 8a–j (1.0 equivalent). The solution was allowed to warm up to room temperature overnight. After aqueous workup, 1-substituted-2-azinyl-1-ethanones 10a–p were isolated as the only products in good to excellent yields (Scheme 2, Table 1). This approach provided known compounds 10a,d,i²²a and 10b²⁹ in yields comparable with those reported in the literature and dramatically improved the previous yields of 10f, 10g, 10h, and 10j from 12,¹³ 41%,²²d 58%²²a and 50.3%²²b to 91%, 95%, 84% and 72% yield, respectively.

Scheme 2

For designation of R, R¹ and Het in 10 see Table 1
Table 1. Preparation of 1-Substituted–2-azinyl-1-ethanones 10a–p

| Entry | Het          | R of RCOBt 8 | R$^1$ of HetCH$_2$R$^1$ 9 | Yield (%)$^a$ (keto + enol) | Keto/enol (%)$^b$ |
|-------|--------------|--------------|-----------------------------|-----------------------------|-------------------|
| 10a   | Pyrid-2-yl   | (CH$_3$)$_2$CHCH$_2$ | H                          | 65 (60$^{22a}$)$^c$          | 95/5              |
| 10b   | Pyrid-2-yl   | CH$_3$(CH$_3$)$_2$CH$_2$ | H                          | 60 (52$^{20a}$)$^c$          | 100/0             |
| 10c   | Pyrid-2-yl   | PhCH=CH      | H                          | 65                           | 27/73             |
| 10d   | Pyrid-2-yl   | Ph           | H                          | 78 (82$^{22a}$)$^c$          | 59/41             |
| 10e   | Pyrid-2-yl   | 4-ClC$_6$H$_4$ | H                          | 83                           | 38/62             |
| 10f   | Pyrid-2-yl   | 4-ClC$_6$H$_4$ | Ph                         | 95 (12$^{13}$)$^c$          | 58/42             |
| 10g   | Quinolin-2-yl | Ph           | H                          | 91 (41$^{22d}$)$^c$          | 8/92              |
| 10h   | Pyrid-2-yl   | Fur-2-yl     | H                          | 84 (58$^{22a}$)$^c$          | 68/32             |
| 10i   | Pyrid-2-yl   | Thien-2-yl   | H                          | 68 (73$^{22a}$)$^c$          | 85/15             |
| 10j   | Pyrid-2-yl   | Pyrid-3-yl   | H                          | 72 (50$^{22b}$)$^c$          | 16/84             |
| 10k   | Pyrimidin-4-yl | Fur-2-yl     | H                          | 50                           | 50/50             |
| 10l   | Quinolin-4-yl | Thien-2-yl   | H                          | 66                           | 100/0             |
| 10m   | Pyrid-4-yl   | 4-ClC$_6$H$_4$ | Ph                         | 63                           | 100/0             |
| 10n   | Pyrid-4-yl   | 4-[(C$_2$H$_3$)$_2$NC$_6$H$_4$] | Ph                     | 67                           | 100/0             |
| 10o   | Quinolin-4-yl | 4-ClC$_6$H$_4$ | H                          | 87                           | 100/0             |
| 10p   | Quinolin-4-yl | 4-NO$_2$C$_6$H$_4$ | H                          | 72                           | 100/0             |

$^a$ Products were recovered as mixture of keto/enol tautomers as evidenced by $^1$H NMR in CDCl$_3$ with the exceptions of 10b,l–p, where the percentage of the keto form was 100%. $^b$ Determined by $^1$H NMR of products 10. $^c$ Literature yield.

The structures of the novel condensation products 10c,e,k–p are supported by their spectroscopic data together with microanalyses and known compounds 10a,b,d,f–j by comparison of their melting points and spectroscopic data with the literature reports together with microanalyses in some cases. In nearly all cases, the acylated products derived from 2-alkylazines exist in CDCl$_3$ solution as tautomeric mixtures. Their $^1$H NMR spectra display two closely overlapping sets of signals and their proton-decoupled $^{13}$C NMR spectra generally show two sets of lines. By comparison of the magnitudes of the enolic and ketonic shifts to values from the literature, they were identified as the ketone and enol forms K and O; enaminone tautomers E were not observed (Scheme 3). The integrated intensities of the side-chain methylene and vinyl protons in the $^1$H NMR spectra of CDCl$_3$ solutions of 10a–k indicated a predominance of the O forms in 10c,e,g,j 62–92% while K forms predominated in 10a,d,f,h,i 58–95%. Although $^1$H NMR spectra showed a tautomeric mixture of about 1:1 for 10k, 10b was observed exclusively in the K form. This finding is in accord with the facts that hydrogen-bonding reinforces tautomeric effects$^{31}$ and tautomer ratio is crucially dependent on both steric and polar effects of the substituents attached to the carbonyl group$^{30}$ (Scheme 3). However, the
condensation products 10l–p derived from 4-benzylpyridine and 4-methylquinoline exist predominantly in the ketonic form.

![Diagram](image)

**Scheme 3**

This new synthetic procedure for the preparation of 1-substituted-2-azinyl-1-ethanones offers several advantages. Good generality has been demonstrated since a variety of alkyated azines can be acylated with aliphatic (to give 10a,b), alkenyl (to give 10c), benzenoid (to give 10d–g,m–p) and heterocyclic acylation reagents (to give 10h–l). The high average yield for the 8 previously known examples (78%) compared to the reported (47%) and the overall average yield for 16 examples (73%), confirm once again the superiority of N-acylbenzotriazoles as an alternative class of acylating reagents, which extend and complement the arsenal of reagents for acylations of alkylated heterocycles. Compared with acid chlorides, the advantage of N-acylbenzotriazoles resides in their neutral character and high stability. While N,N-dimethylamides\(^23\) have been used successfully for the synthesis of 1-alkyl-2-pyridin-2-yl-1-ethanones, they are not as easily accessible as the corresponding N-acylbenzotriazoles.

In summary, we have developed a convenient and quite general method for the synthesis of 1,2-disubstituted-1-ethanones having a pyridyl, quinolyl or pyrimidyl moiety that describes the potentiality of N-acylbenzotriazoles as valuable acylating agents of alkyated azines.

**Experimental Section**

**General Procedures.** All reactions were carried out under an atmosphere of nitrogen, unless otherwise specified. Glassware was routinely oven-dried at 160 °C for a minimum of 4 h and then connected to a vacuum line before assembling under a dry argon stream. Anhydrous solvents were obtained by distillation immediately prior to use, from sodium benzophenone ketyl (tetrahydrofuran). Melting points were uncorrected. \(^1\)H NMR (300 MHz) and \(^13\)C NMR (75 MHz) spectra were recorded using deuteriochloroform (CDCl\(_3\)) as solvent. Column chromatography was carried out on silica gel (230–400 mesh).
General procedure for the preparation of 1-substituted-2-azinyl-1-ethanones 10a–p

To a solution of LDA (4.0 mmol) (prepared \textit{in situ} from diisopropylamine and \textit{n}-butyllithium in THF at $-78\,^\circ\text{C}$), a solution of the alkylated heterocycle 9 (2.0 mmol) in dry THF (15 mL) was added dropwise under argon. After stirring the resulting mixture for 1 h at this temperature to ensure complete carbanion formation, a solution of \textit{N}-acylbenzotriazole 8 (2.0 mmol) in dry THF (10 mL) was added dropwise at $-78\,^\circ\text{C}$. The reaction mixture was allowed to warm to rt overnight before quenching with water (50 mL) and extraction with EtOAc (3 x 30 mL). The combined organic layers were washed with water (50 mL), dried over MgSO$_4$. The solvent was removed under vacuum and the residue was placed in a silica-gel column and eluted with hexanes/EtOAc 10:1 followed by recrystallization from CH$_2$Cl$_2$/ hexanes for solid products to give the pure 1-substituted-2-azinyl-1-ethanones 10. All $^1$H and $^{13}$C NMR signals for tautomeric compounds are for [keto + enol] unless otherwise specified.

3-Methyl-1-(pyrid-2-yl)-2-pentanone (10a). Colorless oil (65%). $^1$H NMR [keto + enol] $\delta$ 8.54 (dd, $J = 4.8$, 1.0 Hz, 1H), 8.20 (br d, 5.0 Hz, 1H), 7.64 (dt, $J = 7.6$, 1.8 Hz, 1H), 7.52 (td, $J = 7.5$, 1.5 Hz, 1H), 7.23–7.15 (m, 2H), 6.92–6.86 (m, 2H), 5.30 (enol s, 0.05H), 3.92 (keto s, 1.9H), 2.47 (d, $J = 6.7$ Hz, 2H), 2.16 (septet, $J = 6.6$ Hz, 1H), 0.89 (d, $J = 6.6$ Hz, 6H). $^{13}$C NMR [keto + enol] $\delta$ 200.9, 169.2, 158.5, 154.7, 149.3, 144.2, 136.7, 136.4, 124.0, 121.7, 120.2, 117.8, 95.9, 52.6, 51.4, 45.4, 26.2, 24.2, 22.3 (2C). Anal. Calcd. For C$_{11}$H$_{15}$NO: N, 8.48. Found: N, 8.22.

1-(Pyrid-2-yl)-2-heptanone (10b). Colorless oil (60%). $^1$H NMR $\delta$ 8.57 (d, $J = 4.8$ Hz, 1H), 7.66 (td, $J = 7.7$, 7.7 Hz, 1H), 7.25–7.18 (m, 2H), 3.94 (s, 2H), 2.53 (t, $J = 7.4$ Hz, 2H), 1.34–1.19 (m, 6H), 0.86 (t, $J = 7.1$ Hz, 3H). $^{13}$C NMR $\delta$ 207.6, 154.7, 149.2, 136.7, 124.2, 121.9, 52.0, 42.7, 31.1, 23.3, 22.3, 13.8.

(E)-4-Phenyl-1-pyrid-2-yl-but-3-en-2-one (10c). Yellow prisms (65%), mp 90–92 °C. $^1$H NMR [keto + enol] $\delta$ 14.6 (enol br s, 0.73H), 8.58 (d, $J = 8.1$ Hz, 1H), 8.43 (d, $J = 8.1$ Hz, 1H), 8.35 (d, $J = 5.0$ Hz, 1H), 8.16 (d, $J = 7.2$ Hz, 1H), 8.15 (s, 1H), 7.78–7.47 (m, 8H), 7.40–7.26 (m, 5H), 7.05–6.97 (m, 2H), 6.84 (d, $J = 16.2$ Hz, 1H), 6.59 (d, $J = 15.9$ Hz, 1H), 5.60 (enol s, 0.73H), 4.18 (keto s, 0.54H). $^{13}$C NMR [keto + enol] $\delta$ 190.1, 158.7, 148.8, 145.5, 137.0, 136.6, 132.0, 131.5, 130.3, 129.0, 128.9, 128.7, 128.4, 128.2, 127.1, 126.2, 124.5, 121.6, 120.2, 119.0, 116.1, 114.8, 100.6, 100.3, 50.7. HRMS For C$_{15}$H$_{13}$NO: 223.2743. Found: 223.1006.

1-Phenyl-2-(pyrid-2-yl)-1-ethanone (10d). Yellow needles (78%), mp 67–69 °C (lit.$^{22a}$ 52.5–54.0 °C). $^1$H NMR [keto + enol] $\delta$ 8.56 (d, $J = 4.3$ Hz, 1H), 8.28 (d, $J = 4.9$ Hz, 1H), 8.07 (d, $J = 7.1$ Hz, 2H), 7.85 (dd, $J = 8.0$, 2.1 Hz, 2H), 7.66–7.52 (m, 3H), 7.47–7.38 (m, 4H), 7.30 (d, $J = 7.8$ Hz, 2H), 7.18–7.14 (m, 1H), 7.06 (d, $J = 8.1$ Hz, 3H), 6.99–6.95 (m, 1H), 6.8 (enol s, 0.41 H), 4.50 (keto s, 1.18 H). $^{13}$C NMR [keto + enol] $\delta$ 196.8, 164.3, 158.5, 155.2, 149.5, 144.2, 138.8, 137.1, 136.5, 136.4, 133.2, 129.3, 128.7, 128.6, 128.3, 125.4, 124.2, 121.9, 121.5, 118.4, 94.1, 48.4. Anal. Calcd. For C$_{13}$H$_{13}$NO: C, 79.16; H, 5.62; N, 7.10. Found: C, 79.15; H, 5.63; N, 7.08.

1-(4-Chlorophenyl)-2-(pyrid-2-yl)-1-ethanone (10e). Yellow needles (83%), mp 96–97 °C. $^1$H NMR [keto + enol] $\delta$ 8.45 (d, $J = 4.4$ Hz, 1H), 8.27 (d, $J = 4.8$ Hz, 1H), 8.01 (d, $J = 8.4$ Hz, 2H),...
7.77 (d, J = 8.5 Hz, 2H), 7.66–7.58 (m, 2H), 7.42 (d, J = 8.6 Hz, 2H), 7.36 (d, J = 8.4 Hz, 2H), 7.29 (d, J = 7.8 Hz, 1H), 7.19–7.15 (m, 1H), 7.05 (d, J = 8.1 Hz, 1H), 7.00–6.98 (m, 1H), 6.03 (enol s, 0.62H), 4.45 (keto s, 0.76H). 13C NMR [keto + enol] δ 195.7, 163.5, 158.2, 154.9, 149.6, 144.0, 139.7, 137.2, 136.6, 135.1, 135.0, 130.2, 128.9, 128.5, 126.8, 124.1, 122.0, 121.6, 11.6, 100.2, 94.1, 48.5. Anal. Calcd. For C13H10ClNO: C, 67.40; H, 4.35; N, 6.05. Found: C, 67.38; H, 4.30; N, 5.93.

1-(4-Chlorophenyl)-2-phenyl-2-(pyrid-2-yl)-1-ethanone (10f). Yellow prisms (95%), mp 90–92 °C (lit. 22d 95–98 °C). 1H NMR [keto + enol] δ 8.54 (d, J = 4.8 Hz, 1H), 8.34 (d, J = 5.1 Hz, 1H), 7.95 (d, J = 8.5 Hz, 2H), 7.64–7.50 (m, 2H), 7.37–6.99 (m, 19 H), 6.84 (d, J = 8.4 Hz, 1H), 6.21 (keto s, 0.58H). 13C NMR [keto + enol] δ 196.3, 163.3, 159.8, 159.0, 149.3, 143.0, 139.5, 137.7, 137.3, 137.2, 136.7, 136.5, 134.9, 133.7, 132.5, 130.4, 130.3, 129.1, 129.0, 128.9, 128.7, 127.6, 127.5, 127.0, 123.8, 122.1, 120.8, 118.7, 109.0, 62.1. Anal. Calcd. For C19H14ClNO: C, 74.15; H, 4.58; N, 4.55. Found: C, 74.23; H, 4.56; N, 4.59.

(Z)-1-Phenyl-2-quinolin-2-y lethanol (10g). Yellow needles (91%), mp 114–116 °C (lit. 22d 115.5–117.0 °C). 1H NMR δ 15.78 (enol br s, 0.92H), 8.02 (dd, J = 5.9, 2.2 Hz, 2H), 7.69 (d, J = 9.0 Hz, 1H), 7.61–7.49 (m, 6H), 7.30 (dd, J = 6.8, 2.0 Hz, 1H), 6.91 (d, J = 9.0 Hz, 1H), 6.1 (enol s, 0.92H). 13C NMR δ 184.0, 154.0, 139.7, 137.7, 136.1, 130.9, 130.3, 128.2, 127.5, 126.6, 123.6, 123.2, 122.2, 118.1, 89.8.

1-Fur-2-yl-2-(pyrid-2-yl)-1-ethanone (10h). Yellow needles (84%), mp 54–55 °C (lit. 22a 49.5–51.0 0 °C). 1H NMR [keto + enol] δ 8.55 (d, J = 4.4 Hz, 1H), 8.18 (d, J = 5.1 Hz, 1H), 7.67–7.55 (m, 3H), 7.46 (s, 1H), 7.35–7.31 (m, 2H), 7.19–7.15 (m, 1H), 7.03 (d, J = 8.2 Hz, 1H), 6.92 (t, J = 6.0 Hz, 1H), 6.84 (d, J = 3.3 Hz, 1H), 6.54 (br s, 1H), 6.49 (br s, 1H), 6.03 (enol s, 0.32H), 4.34 (keto s, 1.36H). 13C NMR [keto + enol] δ 185.4, 169.9, 152.3, 151.3, 149.5 (2C), 146.8 (2C), 143.0, 137.2, 136.5, 132.3, 124.1, 122.0, 121.6, 118.5, 117.7, 112.4, 111.7, 109.4, 92.4, 48.0. Anal. Calcd. For C11H9NO2: C, 70.58; H, 4.85; N, 7.48. Found: C, 70.51; H, 4.91; N, 7.36.

2-(Pyrid-2-yl)-1-(thien-2-yl)-1-ethanone (10i). Pale yellow oil (68%). 1H NMR [keto + enol] δ 8.58 (ddd, J = 4.9, 1.8, 0.8 Hz, 1H), 8.06 (ddd, J = 4.9, 1.7, 0.9 Hz, 1H), 7.87 (dd, J = 3.9, 1.3 Hz, 1H), 7.66 (td, J = 7.6, 1.8 Hz, 1H), 7.63 (dd, J = 4.9, 1.2 Hz, 1H), 7.57 (d, J = 1.8 Hz, 1H), 7.55 (dd, J = 2.9, 1.1 Hz, 1H), 7.52 (dd, J = 3.9, 1.3 Hz, 1H), 7.34–7.43 (m, 1H), 7.19 (ddd, J = 8.9, 5.1, 1.2 Hz, 1H), 7.11 (dd, J = 5.1, 3.9 Hz, 1H), 7.05 (dd, J = 5.1, 3.6 Hz, 1H), 6.98 (dt, J = 8.4, 0.9 Hz, 1H), 6.84 (ddd, J = 7.2, 5.4, 1.2 Hz, 1H), 5.95 (enol s, 0.15H), 4.45 (keto s, 1.7H). 13C NMR [keto + enol] δ 189.6, 157.5, 154.7, 149.4, 143.7, 141.3, 137.4, 136.7, 134.3, 133.4, 128.2, 127.6, 127.1, 125.4, 125.3, 124.2, 122.1, 121.4, 116.7, 115.0, 91.5, 48.9.

2-(Pyrid-2-yl)-1-(pyrid-3-yl)-1-ethanone (10j). Yellow prisms (72%), mp 70–71 °C (lit. 22b 69–70 °C). 1H NMR [keto + enol] δ 15.80 (s, 1H), 9.27 (dd, J = 2.4, 0.9 Hz, 1H), 9.07 (dd, J = 2.4, 0.9 Hz, 1H), 8.76 (dd, J = 4.8, 1.5 Hz, 1H), 8.60 (dd, J = 4.8, 1.5 Hz, 1H), 8.34 (dt, J = 9.9, 2.4 Hz, 1H), 8.29 (d, J = 5.1 Hz, 1H), 8.11 (dt, J = 8.4, 1.8 Hz, 1H), 7.67 (d, J = 1.8 Hz, 1H), 7.64 (ddd, J = 1.8, 0.9 Hz, 1H), 7.62 (d, J = 1.5 Hz, 1H), 7.40 (ddd, J = 7.8, 4.8, 0.9 Hz, 1H), 7.34 (ddd, J = 7.8, 4.8, 0.9 Hz, 1H), 7.30 (br s, 1H), 7.19 (ddd, J = 7.5, 5.4, 1.2 Hz, 1H), 7.10 (dd, J =
8.1, 0.9 Hz, 1H), 7.02 (ddd, J = 7.5, 5.4, 1.2 Hz, 1H), 6.09 (enol s, 0.84H), 4.50 (keto s, 0.32H). 13C NMR [keto + enol] δ 195.6, 162.3, 158.0, 154.4, 153.5, 150.0, 150.0, 149.7, 147.1, 143.9, 137.4, 136.6, 136.0, 132.8, 131.8, 124.1, 123.5, 123.1, 122.1, 121.7, 118.9, 94.8, 48.6.

1-(Fur-2-yl)-2-(pyrimidin-4-yl)-1-ethanone (10k).

Yellow prisms (50%), mp 128–130 °C. 1H NMR [keto + enol] δ 9.16 (d, J = 1.2 Hz, 1H), 8.70 (s, 1H), 8.68 (s, 1H), 8.31 (d, J = 5.7 Hz, 1H), 7.63 (dd, J = 1.8, 0.7 Hz, 1H), 7.51 (br s, 1H), 7.39 (dd, J = 5.1, 1.5 Hz, 1H), 7.34 (d, J = 3.6 Hz, 1H), 6.96 (br d, J = 3.3 Hz, 1H), 6.86 (br d, J = 5.7 Hz, 1H), 6.58 (dd, J = 3.6, 1.8 Hz, 1H), 6.50–6.53 (m, 1H), 5.97 (enol s, 0.5H), 4.33 (keto s, 1H). 13C NMR [keto + enol] δ 183.7, 163.4, 163.0, 161.4, 158.8, 156.9, 154.7, 153.1, 150.6, 147.1, 144.3, 121.8, 118.7, 117.1, 112.6, 112.0 (2C), 112.0, 91.0, 47.1. Anal. Calcd. For C10H8N2O2: C, 63.82; H, 4.28; N, 14.89. Found: C, 63.81; H, 4.22; N, 14.85.

1-(4-Chlorophenyl)-2-phenyl-2-(pyrid-4-yl)-1-ethanone (10m).

Oil (63%). 1H NMR δ 8.50 (dd, J = 6.1 Hz, 2H), 7.90 (dd, J = 8.7 Hz, 2H), 7.36 (dd, J = 8.7 Hz, 2H), 7.25–7.33 (m, 5H), 7.14 (dd, J = 6.1 Hz, 2H), 5.94 (s, 1H). 13C NMR δ 195.4, 149.7, 147.7, 139.8, 136.7, 134.3, 130.2, 129.2, 128.9, 128.8, 127.8, 124.2, 58.5. Anal. Calcd. For C19H14ClNO: N, 4.55. Found: N, 5.42.

1-[(4-Diethylamino)phenyl]-2-phenyl-2-(pyrid-4-yl)-1-ethanone (10n).

Colorless prisms (67%), mp 134–136 °C. 1H NMR δ 8.50 (dd, J = 6.1 Hz, 2H), 7.89 (d, J = 9.2 Hz, 2H), 7.24–7.33 (m, 6H), 7.21 (dd, J = 6.1 Hz, 2H), 6.57 (d, J = 9.2 Hz, 2H), 3.36 (q, J = 7.1 Hz, 4H), 1.16 (t, J = 7.1 Hz, 6H). 13C NMR δ 193.9, 151.3, 149.7, 149.0, 138.2, 131.5, 128.9, 128.8, 128.7, 127.3, 124.6, 110.2, 57.5, 44.4, 12.4. Anal. Calcd For C23H24N2O: C, 80.20; H, 7.02; N, 8.13. Found: C, 80.54; H, 7.26; N, 8.25.

1-(4-Chlorophenyl)-2-(quinolin-4-yl)-1-ethanone (10o).

Colorless plates (87%), mp 138–139 °C. 1H NMR δ 8.84 (d, J = 4.3 Hz, 1H), 8.14 (d, J = 8.4 Hz, 1H), 7.97 (d, J = 8.5 Hz, 2H), 7.82 (d, J = 8.2 Hz, 1H), 7.70 (t, J = 7.1, 1H), 7.53 (t, J = 7.1 Hz, 1H), 7.45 (d, J = 8.5 Hz, 2H), 7.23 (d, J = 4.3 Hz, 1H), 4.67 (s, 2H). 13C NMR δ 194.7, 150.0, 148.3, 140.6, 140.1, 134.4, 130.3, 129.7, 129.3, 129.1, 127.5, 126.8, 123.4, 122.7, 42.0. Anal. Calcd. For C17H12N2O3: C, 77.47; H, 4.29; N, 9.47. Found: C, 72.30; H, 4.34; N, 4.87.

1-(4-Nitrophenyl)-2-(quinolin-4-yl)-1-ethanone (10p).

Pink prisms (72%), mp 127–128 °C. 1H NMR δ 8.88 (d, J = 4.3 Hz, 1H), 8.35 (d, J = 8.1 Hz, 2H), 8.22 (d, J = 8.1 Hz, 2H), 8.16 (s, 1H), 7.83 (d, J = 8.1 Hz, 1H), 7.75 (t, J = 8.1 Hz, 1H), 7.58 (t, J = 7.6 Hz, 1H), 7.28 (d, J = 4.3 Hz, 1H), 4.79 (s, 2H). 13C NMR δ 194.0, 163.0, 150.0, 140.6, 139.9, 130.5, 129.6, 129.5, 127.2, 124.1, 123.3, 122.8, 113.1, 42.7. Anal. Calcd. For C17H12N2O3: N, 9.58. Found: N, 9.43.
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References

1. (a) Revesz, L.; Padova, F. E. D.; Buhl, T.; Feifel, R.; Gram, H.; Hiestand, P.; Manning, U.; Zimmerlin, A. *Bioorganic & Med. Chem. Lett.* **2000**, *10*, 1261. (b) Olivera, R.; SanMartin, R.; Domínguez, E.; Solans, X.; Urtiaga, M. K.; Arriortua, M. I. *J. Org. Chem.* **2000**, *65*, 6398. (c) Chen, C.; Zhu, Y.-F.; Liu, X.-J.; Lu, Z.-X.; Xie, Q.; Ling, N. *J. Med. Chem.* **2001**, *44*, 4001. (d) Churuca, F.; SanMartin, R.; Tellitu, I.; Domínguez, E. *Org. Lett.* **2002**, 1591. (e) Veeramaneni, V. R.; Pal, M.; Yeleswarapu, R. *Tetrahedron* **2003**, 59, 3283. (f) Mamolo, M. G.; Zampieri, D.; Falagiani, V. *ARKIVOC* **2004**, (xi), 231.

2. (a) El-Dissouky, A.; Masoud, M. S. *Transition Metal. Chemistry* **1984**, *9*, 327. (b) Adu Zuhri, A. Z.; El-Dissouky, A. *Mikrochim. Acta* **1991**, 111.

3. Chesunt, R. W.; Cesati III, R. R.; Cutler, C. S.; Pluth, S. L.; Katzenellenbogen, J. A. *Organometallics* **1998**, *17*, 4889.

4. Ohtsuka, Y.; Ikeno, T.; Yamada, T. *Tetrahedron: Asymmetry* **2000**, *11*, 3671.

5. Baker, B. R.; McEvoy, F. J. *J. Org. Chem.* **1955**, *20*, 118.

6. Ishibashi, F.; Tanabe, S.; Oda, T.; Iwao, M. *J. Nat. Chem.* **2002**, *65*, 500.

7. Yu, C.-Y.; Meth-Cohn, O. *Tetrahedron Lett.* **1999**, *40*, 6665.

8. Terry Jr., A. V.; Williamson, R.; Gattu, M.; Beach, J. W.; McCurdy, C. R.; Sparks, J. A.; Pauly, J. R. *Neuropharmacology* **1998**, *37*, 93.

9. Cèlanire, S.; Salliot-Maire, I.; Ribèreau, P.; Godard, A.; Quèguiner, G. *Tetrahedron* **1999**, *55*, 9269.

10. (a) Reddy, M. V. R.; Faulkner, D. J.; Venkateswarlu, Y.; Rao, M. R. *Tetrahedron* **1997**, *53*, 3457. (b) Strunz, G. M.; Findlay, J. A. *Pyridine and Piperidine Alkaloids. In The Alkaloids; Brossi, A., Ed.* Academic Press: New York, 1985; Vol. 26, pp 89-174. (c) Guarna, A.; Belle, C.; Machetti, F.; Occhiato, E. G.; Cassiani, C.; Comerci, A.; Danza, G.; De Bellis, A.; Dini, S.; Marrucci, A.; Serio, M. *J. Med. Chem.* **1997**, *40*, 1112.

11. Rochford, J.; Sen, A. P.; Quirion, R. *J. Pharmc. Exp. Ther.* **1996**, *277*, 1267.

12. Goodman, Gilman, A.; Rall, T. W.; Nies, A. S.; Taylor, P. The Pharmacological Basis of Therapeutics, 8th Ed.; Pergamon: New York, 1990; pp 166.

13. Hewitt, L. E.; Wade, D. R.; Sinsheimer, J. E.; Wang, J. H.; Drach, J. C.; Burckhalter, J. H. *J. Med. Chem.* **1978**, *21*, 1339.

14. (a) Heiner, G. H.; Alfons, E. B.; Werner, K.; Karl-Heinz, B. W. EP869121, 1998; *Chem. Abstr.* **1998**, *129*, 302559. (b) Kirsch, R. B.; Enhsen, A. B.; Glombik, H.; Kramer, W. M.-L.
Eugen, F. WO 0020393, 2000; Chem. Abstr. 2000, 132, 279546. (c) Renga, J. M.; McLaren, K. L.; Ricks, M. J. Organic Process Research & Development 2003, 7, 267.

15. Lesac, A.; Moslavac-Forjan, D.; Bruce, D. W.; Sunjic, V. Helv. Chim. Acta 1999, 82, 1707.
16. Nishiwaki, N.; Minakata, S.; Komatsu, M.; Ohshiro, Y. Synlett 1990, 273.
17. Nicola, T.; Vieser, R.; Eberbach, W. Eur. J. Org. Chem. 2000, 527.
18. (a) Hay, J. V.; Hudlicky, T.; Wolfe, J. F. J. Am. Chem. Soc. 1975, 97, 5374. (b) Komin, A.P.; Wolfe, J. F. J. Org. Chem. 1977, 42, 2481. (c) Nazareno, M. A.; Rossi, R. A. Tetrahedron Lett. 1994, 35, 185.
19. Yu, C.-Y.; Tayler, D. L.; Meth-Cohn, O. Tetrahedron Lett. 1999, 40, 6661.
20. Reichardt, C.; Che, D.; Heckenkemper, G.; Schafer, G. Eur. J. Org. Chem. 2001, 2343.
21. Khutova, B. M.; Klyuchko, S. V.; Prikazchikova, L. P.; Cherkasov, V. M. J. Heterocycl. Chem. 1982, 522.
22. (a) Goldberg, N. N.; Barkley, L. B.; Levine, R. J. Am. Chem. Soc. 1951, 73, 4301. (b) Goldberg, N. N.; Levine, R. J. Am. Chem. Soc. 1952, 74, 5217. (c) Levine, R.; Raynolds, S. J. Org. Chem. 1960, 25, 530. (d) Sund, E. H.; Lowe, W. D. J. Chem. Eng. Data 1983, 28, 137. (e) Sund, E. H.; Strickland, S. K. J. Chem. Eng. Data 1988, 33, 216.
23. Cassity, R. P.; Tayler, L. T.; Wolfe, J. F. J. Org. Chem. 1978, 43, 2286.
24. (a) Katritzky, A. R.; He, H.-Y.; Suzuki, K. J. Org. Chem. 2000, 65, 8210. (b) Katritzky, A. R.; Yang, H.; Zhang, S.; Wang, M. ARKIVOC 2002, (xi), 39.
25. Katritzky, A. R.; Denisko, O. V.; Fang, Y.; Zhang, L.; Wang, Z. ARKIVOC 2001, (xi), 41.
26. Katritzky, A. R.; Abdel-Fattah, A. A. A.; Wang, M. J. Org. Chem. 2003, 68, 1443.
27. Katritzky, A. R.; Abdel-Fattah, A. A. A.; Wang, M. J. Org. Chem. 2003, 68, 4932.
28. Katritzky, A. R.; Pastor, A. J. Org. Chem. 2000, 65, 3679.
29. Gore, T. L.; Rogers, H. N., Jr.; Schumacher, R. M.; Sund, E. H.; Weaver, T. J. J. Chem. Eng. Data 1971, 16, 491.
30. Kolehmainen, E.; Osmialowski, B.; Krygowski, T. M.; Kauppinen, R.; Nissinen, M.; Gawinecki, R. J. Chem. Soc. Perkin Trans. 2 2000, 1259.
31. Kolehmainen, E.; Osmialowski, B.; Nissinen, M.; Kauppinen, R.; Gawinecki, R. J. Chem. Soc. Perkin Trans. 2 2000, 2185.