

3-Acylindoles via a One-Pot, Regioselective Friedel–Crafts Reaction

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Abstract: Within we report a general one-pot high-yielding Friedel–Crafts acylation of indole using acid chlorides and diethylaluminum chloride in gram scale quantities. This general synthesis affords products that are easily isolated and require no complex purification procedures.

Key words: indole, regioselectivity, Friedel–Crafts reactions, acylations

A need for gram quantities of 3-acylindoles as artificial nutrients for spore germination promotion studies has prompted our search for an efficient direct synthetic route to this class of compound.¹ Historically, 3-acylindoles have been the subject of considerable interest due to their close relationship with many alkaloids, and also due to other numerous biological activities that they are reported to possess.^{2–4} Recently, similar compounds have been examined and found to be active against HIV-1^{5–7}, as well as diabetes.⁸ Related indole compounds have even been employed as optical switches and fulgides.⁹ Additionally, certain indolyl glyoxylamides have been reported to exhibit a broad spectrum of anticancer activity in human gastric, breast, and uterus cancer cells in addition to their multi-drug resistant sublines.¹⁰

A wide variety of 3-substituted indoles have been prepared by several well-known synthetic methods such as the Vilsmeier–Haack type reaction,¹¹ Grignard reactions,¹² and Friedel–Crafts acylations.¹³ Other more obscure methods that have been reported involve the use of nitrilium salts with dialkyl carbenium ions^{14,15} and pyridinium salts.¹⁶ We have also reported that 3-arylaminoethylindoles¹⁷ can be made in good yield but this requires the use of a protecting group, which is also a problem in some of the other reported methods.¹⁸

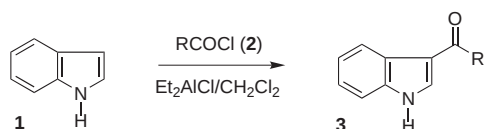
In acylations, it has been well documented that the 3-position of the indole nucleus is most susceptible to electrophilic attack; however, low yields frequently resulted due to competing reactivity at the 1-position. This competition frequently resulted in the formation of the undesirable 1-isomer in addition to 1,3-diacyl products. Also, it is well documented that under acidic conditions, indole polymerization readily occurs.² As stated previously, this can be

prevented by the use of various protecting groups in the 1-position and these have been extensively investigated utilizing many different methods and blocking agents.¹¹ In all of these cases, the use of a protecting group resulted in additional steps and in many of these, lower overall yields. Bennasar and co-workers^{19,20} have developed a unique approach to the synthesis of long-chained acyl indoles; this method proceeds through a selenium intermediate followed by a Stille coupling with a variety of olefins. Utilization of Suzuki-type coupling was also employed in an intramolecular cyclization reaction, but resulted in few pure 3-acylated indoles, and afforded mostly 2,3-diacyl indole products.²¹ Yeung et al.²² reported a novel method of acylating indoles with aluminum chloride in ionic liquids at room temperature; however, this method was limited to deactivated indole systems. The recent report by Katritzky²³ concerning the acylation of indole employing *N*-acylbenzotriazoles has prompted us to report our complementary general synthetic method for the regioselective production of gram quantities of 3-acylindoles and their facile isolation by crystallization.

When starting our study, we noted two reports in the recent literature concerning the direct acylation of indole giving 3-acylindoles without the use of protecting groups.^{2,24} The first reported the regioselective production of 3-acylindoles under Friedel–Crafts conditions using SnCl₄ as a Lewis acid and stated that for best results the use of a nitromethane co-solvent was necessary.² Despite being a unique method, when long-chained alkyl substituents, or those possessing aromatic character, were introduced in our lab, very little if any desirable product was afforded. Since the procedure involved a three organic solvent system (CH₂Cl₂–MeNO₂–EtOAc), it also proved extremely difficult to isolate gram quantities of any product. The report by Okauchi et al.²⁴ proved to be more germane to our goals of developing a single-solvent, high-yielding, large-scale synthesis of 3-acylindoles. This group reported that generally high yields of 3-acylindoles were produced when dialkylaluminum chloride was used as the Lewis acid in dichloromethane. Although we found this approach to be more successful than that of the aforementioned group,² modifications were necessary to allow us to perform larger scale reactions than those reported by Okauchi²⁴ in the 63 mg range. In particular, the isolation of product using the reported method proved impractical when scaled-up reactions were attempted; a method not

requiring TLC or column chromatography for purification was sought.

While we were developing a single-pot high-yielding approach using readily available materials, Katritzky published his unique approach that removes the possibility of decomposition and self-polymerization, which frequently results from the release of HCl during the reaction.²³ In our synthetic sequence, however, we did not find polymerization to be a problem for the substrates reported (Scheme 1). The method that we developed does not seem to be compromised by the use of acid chlorides; perhaps the reaction complex, as described,² is stable and releases no HCl until the buffer solution is added. We found, as reported by other authors,^{2,24} the utilization of acyl chlorides as electrophiles afford the desired products in good yields under appropriate work-up conditions.



Scheme 1

Many of the reported yields are from single trials without further optimization, but in those cases where multiple runs were made, consistent results were obtained. As shown in Table 1, good yields resulted when either straight chain or branched chain alkyl groups were part of the acyl chloride (entries 1–8). Alkyl groups containing halides, such as the long chained monochloro (entry 9) and the perfluoro groups (entry 10) also gave successful reaction, albeit in lower yields, probably due to solubility effects. Conjugated and isolated olefin containing substituents, like the previously described alkyl substituents provided excellent product yields (entries 11 and 12). Substituents possessing aromatic character also were examined in entries 13–21; high yields were afforded when either electron-withdrawing or electron-donating substituents were on the aromatic ring. When aromatic heterocyclic substituents were incorporated in the product acyl indoles, lower yields were found (entries 22–24). When acyl halides were employed, it was noted that all compounds isolated by work-up method A were obtained with consistently higher yields than those substrates requiring work-up method B. This observation can be explained by the differing product solubilities in dichloromethane. The aryl and fluoro containing 3-acylindoles were much more soluble in dichloromethane thus requiring method B to involve extra manipulations of the CH_2Cl_2 layers (see experimental).

Non-branched anhydrides (Scheme 2) were found to be successful acylating agents (Table 2); entries 2, 4 and 5 gave products that were also discussed in Table 1. In all cases where both anhydrides and acyl halides were employed to give the same product, a much lower yield was isolated for the anhydride reactions. This could be the result of the lower reactivity of the anhydride or because

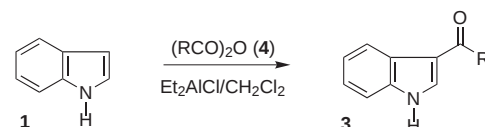
Table 1 Acyl Chloride Condensation

Entry	R	Product	Work-up	Yield (%)
1	Et	3a	A	75
2	<i>n</i> -C ₅ H ₁₁	3b	A	95
3	<i>n</i> -C ₇ H ₁₅	3c	A	92
4	<i>n</i> -C ₁₁ H ₂₃	3d	A	84
5	<i>n</i> -C ₁₅ H ₃₁	3e	A	67
6	CHMe ₂	3f	A	60
7	CMe ₃	3g	A	85
8	CH ₂ CHMe ₂	3h	A	79
9	CH ₂ (CH ₂) ₃ Cl	3i	B	53
10	<i>n</i> -C ₃ F ₇	3j	B	48
11	CH=CHCH ₃	3k	A	88
12	<i>n</i> -CH ₂ (CH ₂) ₇ CH=CH ₂	3l	A	94
13	Ph	3m	B	80
14	4-C ₆ H ₄ Cl	3n	B	71
15	2-C ₆ H ₄ OMe	3o	B	73
16	4-C ₆ H ₄ OMe	3p	B	86
17	4-C ₆ H ₄ NO ₂	3q	B	52
18	CH ₂ OPh	3r	B	85
19	3-C ₆ H ₄ CF ₃	3s	B	69
20	4-C ₆ H ₄ CF ₃	3t	B	74
21	C ₆ F ₅	3u	B	66
22	2-thienyl	3v	B	52
23	3-pyridyl ^a	3w	B	26
24	CH ₂ (CH ₂) ₃ CO-3-indole ^b	3x	B	38

^a Nicotinoyl chloride hydrochloride employed.

^b Product resulted from adipoyl chloride with 2 equiv indole.

work-up method B was necessary in these cases; it is speculated that a combination of both factors must be at work.



Scheme 2

In summary, a new synthetic procedure for the production of gram quantities of a variety of 3-acylindoles has been developed that proceeds without the necessity of using a protecting group. The reaction was found to be very sensitive to slight modifications of the procedure. We found

Table 2 Anhydride Condensation

Entry	R	Product	Yield ^a
1	Me	3y	53
2	Et	3a	47
3	CF ₃	3z	61
4	<i>n</i> -C ₅ H ₁₁	3b	35
5	<i>n</i> -C ₇ H ₁₅	3c	53

^a All employing work-up method B.

the previously reported experimental notes^{1,23} to be very incomplete in their descriptions of the problems encountered in these experiments. In many early trials, intractable red oils were afforded, so a new isolation technique was developed that required strict adherence if the pure products were to be isolated in large quantities in pure form.

Reagents were obtained from commercial suppliers and were used without further purification except as noted. Melting points are uncorrected. FTIR spectra of samples were obtained either as KBr pellets or on NaCl disks. ¹H and ¹³C NMR were determined at 300 and 75 MHz, respectively, in CDCl₃ unless otherwise noted, and chemical shifts are reported downfield from TMS. Coupling constants, *J*, are reported in Hz. THF was distilled from a sodium–benzophenone ketal pair and CH₂Cl₂ from CaH₂, all under nitrogen. All moisture-sensitive reactions and reagent transfers were carried out under either nitrogen or argon.

Preparation of **3** from **1**; General Procedure

Into a 100 mL round-bottomed flask equipped with magnetic stir bar and a pressure equalizing addition funnel was placed indole (3.55 g, 20 mmol) and CH₂Cl₂ (50 mL). Nitrogen was used to copiously flush the apparatus for a few minutes through a syringe needle piercing the septum on the addition funnel. The solution was cooled to –78 °C in a dry ice–acetone bath for 15 min before the addition of Et₂AlCl–hexanes (1 M; 20 mL) into the addition funnel via an 18 gauge cannula. Slow, dropwise addition of the Et₂AlCl was made over a 10 min period while maintaining the –78 °C reaction temperature. The solution turned yellow yet remained transparent. The bath was exchanged for a salt–ice bath and the solution warmed to –10 °C. The resulting yellow solution was allowed to stir for 15 min before the slow dropwise addition of the corresponding acyl halide (30 mmol) was made employing the same addition funnel at a rate of 1 drop every 3 seconds. The solution changed to an orange color. The solution was allowed to stir for 2 h during which time the reaction temperature gradually warmed to r.t. For some substrates, higher rates of magnetic stirring were required to ensure adequate mixing as a result of precipitate formation. CAUTION Very slow addition of an aliquot (10 mL) of pH 7 buffer solution was made at a rate of 1 drop every 10 s. Extreme caution was taken to avoid the violent bubbling or foaming that ensues from this neutralization. It is believed that the bubbling is a result of ethane evolution from the neutralization of the aluminum catalyst.

Work-up A

The whitish suspended solid produced upon neutralization was vacuum filtered, washed with CH₂Cl₂ (50 mL) and allowed to dry. The dried solid was dissolved in acetone with minimum heat; sometimes below reflux, to avoid a color change from light pink to dark red. Any residual solid not dissolved in the acetone was filtered and dis-

carded. The acetone layer was allowed to concentrate to 50% of its volume without heating and then cooled in an ice bath before isolation by filtration to afford the pure desired crystalline product.

Work-up B

The aryl- and fluoro-containing 3-acylindoles were more soluble in CH₂Cl₂ than were the 3-alkyl acylindoles. In these cases, very little of the whitish suspended solid was produced upon neutralization of the reaction mixture. That which was formed was a small amount of the aluminum salts that were filtered and discarded to avoid emulsification in later steps of isolation. The filtered liquid contained most of the product in the organic layer and likewise most of the aluminum salts in the buffered aqueous layer. The filtrate was extracted with additional CH₂Cl₂ (2 × 35 mL). The aq layer containing the majority of the aluminum salts was discarded. The CH₂Cl₂ layer was washed with H₂O (3 × 25 mL), dried (MgSO₄), and evaporated to afford the crude product. The crude product was recrystallized from acetone using minimal heat as specified in work-up A.

1-(1*H*-Indol-3-yl)propan-1-one (**3a**)

Mp 172–173 °C (lit.²⁵ 171–173 °C).

IR (neat): 3164, 2930, 1626, 1519, 1439, 1237, 1154, 1067 cm^{–1}.

¹H NMR (DMSO-*d*₆): δ = 10.17 (br s, 1 NH), 8.40 (d, *J* = 6 Hz, 1 H), 8.06–7.93 (m, 2 H), 7.55–7.41 (m, 1 H), 7.36 (d, *J* = 6 Hz, 1 H), 2.91 (q, *J* = 6 Hz, 2 H), 1.25 (t, *J* = 6 Hz, 3 H).

¹³C NMR (DMSO-*d*₆): δ = 192.3, 131.3, 125.4, 124.7 (overlapping peaks), 123.0 (overlapping peaks), 122.0, 111.4, 32.5, 8.7.

Anal. Calcd for C₁₁H₁₁NO: C, 76.28; H, 6.40; N, 8.09. Found: C, 76.21; H, 6.32; N, 8.23.

1-(1*H*-Indol-3-yl)hexan-1-one (**3b**)

Mp 155–156 °C (lit.²⁶ 153–155 °C).

IR (neat): 3152, 2934, 2862, 1614, 1523, 1435, 1233, 1150, 1096, 940, 877, 746, 635 cm^{–1}.

¹H NMR (DMSO-*d*₆): δ = 8.64 (br s, 1 H), 8.37 (d, *J* = 6 Hz, 1 H), 7.82 (d, *J* = 3 Hz, 1 H), 7.39–7.34 (m, 1 H), 7.21–7.28 (m, 2 H), 2.82 (t, *J* = 6 Hz, 2 H), 1.70–1.80 (m, 2 H), 1.26–1.37 (m, 4 H), 0.86 (t, *J* = 6 Hz, 3 H).

¹³C NMR (DMSO-*d*₆): δ = 196.7, 136.3, 130.9, 123.7, 122.5 (overlapping peaks), 118.3, 111.3, 106.7, 40.0, 31.7, 24.9, 22.6, 14.0.

Anal. Calcd for C₁₄H₁₇NO: C, 78.10; H, 7.96; N, 6.51. Found: C, 77.75; H, 7.93; N, 6.47.

1-(1*H*-Indol-3-yl)octan-1-one (**3c**)

Mp 161–165 °C (lit.²⁷ 170 °C).

IR (neat): 3152, 3041, 2926, 2851, 1614, 1578, 1519, 1431, 1233, 1130, 928, 746, 631 cm^{–1}.

¹H NMR (DMSO-*d*₆): δ = 10.16 (br s, 1 NH), 8.38 (d, *J* = 6 Hz, 1 H), 7.93 (d, *J* = 3 Hz, 1 H), 7.44–7.40 (m, 1 H), 7.23–7.29 (m, 2 H), 2.87 (t, *J* = 6 Hz, 2 H), 1.76–1.84 (m, 2 H), 1.29–1.37 (m, 8 H), 0.87 (t, *J* = 6 Hz, 3 H).

¹³C NMR (DMSO-*d*₆): δ = 197.0, 133.8, 131.4, 123.0, 122.1, 121.9 (overlapping peaks), 111.2, 103.9, 39.6, 29.6 (overlapping peaks), 25.6, 22.4, 13.8.

Anal. Calcd for C₁₆H₂₁NO: C, 78.97; H, 8.70; N, 5.76. Found: C, 78.72; H, 8.67; N, 5.76.

1-(1*H*-Indol-3-yl)dodecan-1-one (**3d**)

Mp 131–132 °C.

IR (neat): 3125, 2918, 2847, 1614, 1527, 1439, 1313, 1237, 1150, 936, 873, 746, 635 cm^{–1}.

^1H NMR (DMSO- d_6): δ = 8.63 (br s, 1 NH), 8.41 (d, J = 6 Hz, 1 H), 7.87 (d, J = 3 Hz, 1 H), 7.43–7.40 (m, 1 H), 7.31–7.26 (m, 2 H), 2.86 (t, J = 6 Hz, 2 H), 1.80–1.57 (m, 2 H), 1.34–1.23 (m, 16 H), 0.87 (t, J = 6 Hz, 3 H).

^{13}C NMR (DMSO- d_6): δ = 195.4, 136.3, 130.8, 123.7, 122.5 (overlapping peaks), 118.9, 111.2, 40.0, 31.9, 30.9 (overlapping peaks), 29.6 (overlapping peaks), 25.2, 22.7, 14.1.

Anal. Calcd for $\text{C}_{20}\text{H}_{29}\text{NO}$: C, 80.22; H, 9.76; N, 4.68. Found: C, 79.84; H, 9.48; N, 4.49.

1-(1*H*-Indol-3-yl)hexadecan-1-one (3e)

Mp 124–125 °C.

IR (neat): 3148, 2946, 2918, 2843, 1614, 1523, 1439, 1237, 1134, 1087, 932, 742 cm^{-1} .

^1H NMR (DMSO- d_6): δ = 10.58 (br s, 1 NH), 8.42 (d, J = 6 Hz, 1 H), 7.97 (d, J = 3 Hz, 1 H), 7.50 (s, 1 H), 7.43–7.40 (m, 1 H), 7.25–7.21 (m, 1 H), 2.87 (t, J = 6 Hz, 2 H), 1.78–1.75 (m, 2 H), 1.35–1.23 (m, 24 H), 0.87 (t, J = 6 Hz, 3 H).

^{13}C NMR (DMSO- d_6): δ = 195.9, 136.3, 131.4, 125.3, 122.6, 121.7 (overlapping peaks), 117.1, 111.2, 39.2, 31.4, 29.2 (overlapping peaks), 24.6, 22.2, 13.5, 9.1.

Anal. Calcd for $\text{C}_{24}\text{H}_{37}\text{NO}$: C, 81.07; H, 10.49; N, 3.94. Found: C, 80.99; H, 10.59; N, 3.97.

1-(1*H*-Indol-3-yl)-2-methylpropan-1-one (3f)

Mp 127–129 °C (lit.²⁸ 127–128 °C).

IR (neat): 3231, 2953, 2870, 1629, 1522, 1435, 1241, 1157, 932, 745 cm^{-1} .

^1H NMR: δ = 9.25 (br s, 1 NH), 8.44 (t, J = 6 Hz, 1 H), 7.86 (d, J = 6 Hz, 2 H), 2.40–2.31 (m, 1 H), 1.01 (d, J = 6 Hz, 6 H).

^{13}C NMR: δ = 204.5, 136.5, 131.6, 125.5, 123.7, 123.1, 122.6, 122.4, 111.5, 49.0, 22.9.

1-(1*H*-Indol-3-yl)-2,2-dimethylpropan-1-one (3g)

Mp 160–162 °C (lit.²⁷ 170 °C).

IR (neat): 3283, 3056, 2968, 2875, 1805, 1705, 1604, 1516, 1420, 1362, 1239, 1123, 1012, 908, 750 cm^{-1} .

^1H NMR: δ = 8.86 (br s, 1 H), 8.51 (d, J = 6 Hz, 1 H), 7.34 (s, 1 H), 7.22–7.13 (m, 1 H), 7.18 (d, J = 6 Hz, 1 H), 6.91 (t, J = 6 Hz, 1 H), 1.23 (s, 9 H).

^{13}C NMR: δ = 191.2, 136.5, 135.4, 130.2, 127.3, 126.6, 123.5, 119.1, 111.1, 44.1, 27.2.

1-(1*H*-Indol-3-yl)-3-methylbutan-1-one (3h)

Mp 125–127 °C (lit.²⁹ 123–125 °C).

IR (neat): 3231, 2953, 2870, 1629, 1522, 1435, 1241, 1157, 932, 745 cm^{-1} .

^1H NMR: δ = 9.25 (br s, 1 NH), 8.44 (t, J = 6 Hz, 1 H), 7.86 (d, J = 6 Hz, 1 H), 7.43–7.39 (m, 1 H), 7.32–7.25 (m, 2 H), 2.73 (d, J = 6 Hz, 2 H), 2.40–2.31 (m, 1 H), 1.01 (d, J = 6 Hz, 6 H).

^{13}C NMR: δ = 194.3, 136.5, 131.6, 125.5, 123.7, 123.1, 122.6, 122.4, 111.5, 49.0, 26.0, 22.9.

5-Chloro-1-(1*H*-indol-3-yl)pentan-1-one (3i)

Mp 178–181 °C.

IR (neat): 3853, 3151, 2949, 2366, 2335, 1843, 1621, 1522, 1439, 1237, 936, 753 cm^{-1} .

^1H NMR: δ = 9.23 (br s, 1 NH), 8.41 (s, 1 H), 7.80 (d, J = 3 Hz, 1 H), 7.38 (d, J = 3 Hz, 1 H), 7.27 (m, 1 H), 7.24 (m, 1 H), 3.64 (t, J = 12 Hz, 1 H), 2.88 (t, J = 12 Hz, 1 H).

^{13}C NMR: δ = 194.1, 131.3, 124.8, 122.0, 121.0, 120.8, 116.8, 114.4, 110.8, 43.7, 37.2, 31.2, 21.3. Anal. Calcd for $\text{C}_{13}\text{H}_{14}\text{ClNO}$: C, 66.24; H, 5.99; N, 5.94. Found: C, 65.87; H, 6.19; N, 6.06.

2,2,3,3,4,4,4-Heptafluoro-1-(1*H*-indol-3-yl)butan-1-one (3j)

Mp 172–175 °C.

IR (neat): 2914, 2844, 1705, 1685, 1462, 1408, 1293, 1208, 934, 742 cm^{-1} .

^1H NMR: δ = 8.37 (br s, 1 NH), 7.51 (d, J = 6 Hz, 1 H), 7.47 (s, 1 H), 7.42 (d, J = 6 Hz, 1 H), 7.17 (t, J = 9 Hz, 1 H), 7.03 (t, J = 9 Hz, 1 H).

^{13}C NMR: δ = 199.3, 131.2, 127.8, 127.2 (m), 125.7, 123.4, 121.3 (m), 121.2, 120.9, 120.1, 113.0, 109.6 (m), 103.5.

Anal. Calcd for $\text{C}_{12}\text{H}_6\text{F}_7\text{NO}$: C, 46.02; H, 1.93; N, 4.47. Found: C, 45.83; H, 1.59; N, 4.61.

1-(1*H*-Indol-3-yl)but-2-en-1-one (3k)

Mp 172–175 °C (decomp., lit.²⁹ 173–174 °C).

IR (neat): 3279, 2968, 1701, 1658, 1524, 1424, 1320, 1243, 1158, 1012 cm^{-1} .

^1H NMR: δ = 8.41 (br s, 1 NH), 7.83 (s, 1 H), 7.37 (d, J = 6 Hz, 1 H), 7.26 (d, J = 6 Hz, 1 H), 7.14 (m, 1 H), 7.05 (m, 1 H), 6.84 (d, J = 9 Hz, 1 H), 5.84 (d, J = 9 Hz, 1 H), 1.60 (d, J = 6 Hz, 3 H).

^{13}C NMR: δ = 197.7, 142.1, 139.0, 129.8, 129.0, 123.8, 122.8, 122.6, 122.2, 111.8, 102.1, 21.3.

1-(1*H*-Indol-3-yl)undec-10-en-1-one (3l)

Mp 128–131 °C.

IR (neat): 3041, 2923, 2854, 1614, 1435, 1235, 1133, 934, 901, 750 cm^{-1} .

^1H NMR: δ = 8.62 (br s, 1 NH), 8.40 (d, J = 6 Hz, 1 H), 7.87 (d, J = 6 Hz, 1 H), 7.41 (t, J = 6 Hz, 1 H), 7.40 (t, J = 6 Hz, 1 H), 7.30 (s, 1 H), 5.79 (m, 1 H), 5.01 (t, J = 4 Hz, 1 H), 4.93 (m, 1 H), 2.87 (t, J = 9 Hz, 1 H), 2.01 (m, 1 H), 1.33 (m, 4 H).

^{13}C NMR: δ = 192.3, 139.2, 137.6, 131.0, 125.7, 123.6, 122.6, 122.4, 118.0, 114.1, 111.3, 39.8, 30.5, 29.5, 29.5, 29.3, 29.1, 28.9, 25.2.

Anal. Calcd for $\text{C}_{19}\text{H}_{25}\text{NO}$: C, 80.52; H, 8.89; N, 4.94. Found: C, 80.73; H, 8.67; N, 5.03.

(1*H*-Indol-3-yl)phenylmethanone (3m)

Mp 243–245 °C (lit.²⁵ 241–244 °C).

IR (neat): 3140, 3088, 2918, 1780, 1594, 1565, 1487, 1431, 1206, 1138 cm^{-1} .

^1H NMR: δ = 10.86 (br s, 1 NH), 8.42 (d, J = 6 Hz, 1 H), 7.84–7.78 (m, 3 H), 7.62 (s, 1 H), 7.55–7.49 (m, 4 H), 7.27 (t, J = 6 Hz, 1 H).

^{13}C NMR: δ = 189.2, 141.3, 134.1, 130.3, 127.9 (overlapping peaks), 127.5 (overlapping peaks), 122.8, 121.5 (overlapping peaks), 111.1, 110.6, 108.7.

Anal. Calcd for $\text{C}_{15}\text{H}_{11}\text{NO}$: C, 81.43; H, 5.01; N, 6.33. Found: C, 81.07; H, 4.97; N, 6.32.

(4-Chlorophenyl)-(1*H*-indol-3-yl)methanone (3n)

Mp 239–242 °C (decomp., lit.³⁰ 241–242 °C).

IR (neat): 3302, 2917, 2850, 1704, 1637, 1479, 1403, 1265, 737 cm^{-1} .

^1H NMR: δ = 8.37 (br s, 1 NH), 8.03 (s, 1 H), 7.95 (d, J = 6 Hz, 1 H), 7.34 (d, J = 6 Hz, 1 H), 7.23 (d, J = 6 Hz, 1 H), 7.20 (d, J = 6 Hz, 1 H), 7.17 (d, J = 6 Hz, 1 H), 7.00 (d, J = 6 Hz, 1 H), 6.98 (t, J = 6 Hz, 1 H), 6.82 (t, J = 6 Hz, 1 H).

^{13}C NMR: δ = 221.9, 136.5, 132.6, 131.9, 131.5, 129.4, 128.9, 127.9, 126.4, 120.2, 118.5, 103.1, 100.2.

Anal. Calcd for $\text{C}_{15}\text{H}_{10}\text{ClNO}$: C, 70.46; H, 3.94; N, 5.48. Found: C, 70.11; H, 4.07; N, 5.69.

(1*H*-Indol-2-yl)-(2-methoxyphenyl)methanone (3o)

Mp 242–245 °C (decomp.).

IR (neat): 3151, 2917, 2846, 1613, 1526, 1439, 1312, 1237, 1150, 936, 745 cm^{-1} .

^1H NMR: δ = 8.99 (br s, 1 NH), 8.14 (s, 1 H), 7.71 (d, J = 6 Hz, 1 H), 7.64 (d, J = 6 Hz, 1 H), 7.41 (d, J = 6 Hz, 1 H), 7.35 (m, 1 H), 7.30 (s, 1 H), 7.19 (d, J = 6 Hz, 1 H), 7.17 (t, J = 6 Hz, 1 H), 7.15 (t, J = 6 Hz, 1 H), 3.78 (s, 1 H).

^{13}C NMR: δ = 187.3, 159.9, 131.5, 130.6, 129.5, 130.2, 128.0, 122.6, 120.4, 119.7, 118.9, 118.1, 116.5, 114.4, 111.6, 55.4.

Anal. Calcd for $\text{C}_{16}\text{H}_{13}\text{NO}_2$: C, 76.48; H, 5.21; N, 5.57. Found: C, 76.71; H, 4.92; N, 5.39.

(1*H*-Indol-3-yl)-(4-methoxyphenyl)methanone (3p)

Mp 88–89 °C (lit.³¹ 89 °C).

IR (neat): 3389, 3060, 3009, 2937, 2842, 1605, 1498, 1447, 1300, 1257, 1169, 1106, 1031, 844, 741 cm^{-1} .

^1H NMR: δ = 10.08, 8.06 (s, 1 H), 7.34 (d, J = 6 Hz, 1 H), 7.25 (d, J = 6 Hz, 1 H), 7.21 (d, J = 6 Hz, 1 H), 7.18 (d, J = 6 Hz, 1 H), 7.07 (m, 1 H), 6.97 (m, 1 H), 6.90 (d, J = 6 Hz, 1 H), 6.73 (d, J = 6 Hz, 1 H), 3.86 (s, 3 H).

^{13}C NMR: δ = 180.3, 136.5, 132.3, 128.8, 127.2, 126.5, 126.3, 123.1, 122.1, 121.9, 119.6, 118.6, 113.6, 112.3, 111.2, 55.6.

(1*H*-Indol-3-yl)-(4-nitrophenyl)methanone (3q)

Mp 233–237 °C (decomp.).³²

IR (neat): 3033, 2428, 1936, 1639, 1593, 1431, 1204 cm^{-1} .

^1H NMR: δ = 8.77 (br s, 1 NH), 8.34 (d, J = 6 Hz, 1 H), 8.35 (d, J = 6 Hz, 1 H), 8.33 (s, 1 H), 8.08 (d, J = 4 Hz, 1 H), 7.96 (d, J = 6 Hz, 1 H), 7.64 (d, J = 6 Hz, 1 H), 7.56 (d, J = 6 Hz, 1 H), 7.48 (t, J = 6 Hz, 1 H), 7.37 (t, J = 6 Hz, 1 H).

^{13}C NMR: δ = 185.4, 158.6, 131.7, 131.3, 129.5, 128.7, 128.2, 127.6, 127.0, 126.2, 125.8, 124.5, 123.6.

Anal. Calcd for $\text{C}_{15}\text{H}_{10}\text{N}_2\text{O}_3$: C, 67.67; H, 3.79; N, 10.52. Found: C, 67.32; H, 3.97; N, 10.75.

1-(1*H*-Indol-3-yl)-2-phenoxyethanone (3r)

Mp 206–208 °C.

IR (neat): 3172, 3053, 2902, 2252, 2125, 1923, 1792, 1650, 1523, 1428, 1313, 1237, 1154, 1059, 936, 797, 746, 690 cm^{-1} .

^1H NMR: δ = 8.51 (s, 1 NH), 8.16 (d, J = 9 Hz, 1 H), 7.51 (d, J = 6 Hz, 1 H), 7.31–7.19 (m, 5 H), 6.99–6.91 (m, 3 H), 5.29 (s, 2 H).

^{13}C NMR: δ = 189.7, 158.2, 136.4, 134.0, 129.4, 125.4, 123.1, 122.0, 121.2, 120.7, 114.5, 113.4, 112.3, 69.9.

Anal. Calcd for $\text{C}_{16}\text{H}_{13}\text{NO}_2$: C, 76.48; H, 5.21; N, 5.57. Found: C, 76.56; H, 5.19; N, 5.70.

(1*H*-Indol-3-yl)-(3-trifluoromethylphenyl)methanone (3s)

Mp 252–255 °C.

IR (neat): 3400, 1663, 1508, 1333, 1170, 1129, 1068, 917, 815 cm^{-1} .

^1H NMR: δ = 9.08 (br s, 1 H), 8.39 (s, 1 H), 8.30 (s, 1 H), 7.88 (d, J = 6 Hz, 1 H), 7.81 (d, J = 6 Hz, 1 H), 8.06 (d, J = 6 Hz, 1 H), 7.34 (d, J = 6 Hz, 1 H), 7.24 (m, 1 H), 6.98 (m, 1 H).

^{13}C NMR: δ = 207.3, 168.5, 141.3, 134.6, 130.6, 129.8, 129.1, 127.6, 127.0, 125.4, 124.6, 124.2, 122.8, 119.3 (q), 111.6.

Anal. Calcd for $\text{C}_{16}\text{H}_{10}\text{F}_3\text{NO}$: C, 66.44; H, 3.48; N, 4.84. Found: C, 66.27; H, 3.34; N, 4.57.

(1*H*-Indol-3-yl)-(4-trifluoromethylphenyl)methanone (3t)

Mp 202–204 °C.

IR (neat): 3410, 1667, 1511, 1338, 1167, 1078, 815, 752 cm^{-1} .

^1H NMR: δ = 9.27 (br s, 1 H), 8.15 (s, 1 H), 7.76 (d, J = 6 Hz, 2 H), 7.61 (d, J = 6 Hz, 2 H), 7.54 (d, J = 6 Hz, 1 H), 7.32 (d, J = 6 Hz, 1 H), 7.26 (m, 1 H), 6.99 (m, 1 H).

^{13}C NMR: δ = 191.4, 134.7, 134.1, 133.4, 130.1, 127.8, 124.7, 124.0, 123.2, 121.3, 121.2, 118.3 (q), 102.7.

Anal. Calcd for $\text{C}_{16}\text{H}_{10}\text{F}_3\text{NO}$: C, 66.44; H, 3.48; N, 4.84. Found: C, 66.52; H, 3.59; N, 4.49.

(1*H*-Indol-3-yl)pentafluorophenylmethanone (3u)

Mp 183–186 °C.

IR (neat): 3314, 1616, 1512, 1435, 1239, 1166, 1131, 988, 742 cm^{-1} .

^1H NMR: δ = 9.08 (br s, 1 NH), 8.45 (s, 1 H), 7.59 (d, J = 6 Hz, 1 H), 7.47 (d, J = 6 Hz, 1 H), 7.40 (m, 1 H), 7.26 (m, 1 H).

^{13}C NMR: δ = 194.4, 137.0, 136.0, 135.3, 126.1, 124.9, 123.8, 122.3, 115.3, 111.7, 104.5, 101.6, 98.8.

Anal. Calcd for $\text{C}_{15}\text{H}_6\text{F}_5\text{NO}$: C, 57.89; H, 1.94; N, 4.50. Found: C, 57.54; H, 2.27; N, 4.71.

(1*H*-Indol-3-yl)thiophen-2-ylmethanone (3v)

Mp 180–183 °C (lit.³³ 181 °C).

IR (neat): 3056, 1735, 1616, 1524, 1408, 1354, 1296, 1192 cm^{-1} .

^1H NMR: δ = 9.12 (br s, 1 H), 8.41 (t, J = 6 Hz, 1 H), 7.88 (d, J = 6 Hz, 1 H), 7.70 (d, J = 4 Hz, 1 H), 7.60 (d, J = 6 Hz, 1 H), 7.30 (d, J = 6 Hz, 1 H), 7.19 (s, 1 H), 7.18 (t, J = 6 Hz, 1 H), 7.16 (t, J = 6 Hz, 1 H).

^{13}C NMR: δ = 179.0, 165.0, 157.4, 147.9, 146.4, 131.7, 131.4, 127.6, 124.0, 123.3, 122.4, 111.4, 99.7.

(1*H*-Indol-3-yl)pyridin-3-ylmethanone (3w)

Mp 203–207 °C (lit.³⁴ 210–211 °C).

IR (neat): 3376, 1648, 1501, 1431, 1373, 1331, 1254, 1089, 992, 800, 746 cm^{-1} .

^1H NMR: δ = 9.85 (br s, 1 NH), 8.83 (d, J = 6 Hz, 1 H), 8.71 (d, J = 6 Hz, 1 H), 7.98 (d, J = 6 Hz, 1 H), 7.68 (d, J = 6 Hz, 1 H), 7.35 (d, J = 6 Hz, 1 H), 7.24 (d, J = 6 Hz, 1 H), 6.94 (s, 1 H), 6.55 (m, 1 H), 6.42 (m, 1 H).

^{13}C NMR: δ = 181.2, 157.9, 153.1, 136.2, 134.7, 129.4, 128.4 (overlapping peaks), 123.8, 121.5 (overlapping peak), 108.4, 101.9.

Anal. Calcd for $\text{C}_{14}\text{H}_{10}\text{N}_2\text{O}$: C, 75.66; H, 4.54; N, 12.60. Found: C, 75.31; H, 4.16; N, 12.29.

1,6-Bis-(1*H*-indol-3-yl)hexane-1,6-dione (3x)

Mp 284–289 °C [decomp., lit.³⁵ 290 °C (decomp.)].

IR (neat): 3168, 2929, 2422, 1621, 1407, 1125, 742, 595 cm^{-1} .

^1H NMR (acetone- d_6): δ = 10.31 (br s, 2 H), 8.26 (s, 2 H), 7.58–7.15 (m, 8 H), 2.44 (m, 4 H), 1.56 (m, 4 H).

^{13}C NMR (acetone- d_6): δ = 195.9, 135.4, 134.7, 125.0, 122.3, 121.4 (overlapping peaks), 116.1 (overlapping peaks), 111.6, 102.1, 38.7, 38.4, 23.9, 23.7.

Anal. Calcd for $\text{C}_{22}\text{H}_{20}\text{N}_2\text{O}_2$: C, 76.74; H, 5.81; N, 8.14. Found: C, 77.13; H, 5.67; N, 7.81.

1-(1*H*-Indol-3-yl)ethanone (3y)

Mp 192–193 °C (lit.²⁵ 191–193 °C).

IR (neat): 3314, 3041, 1673, 1372, 851 cm^{-1} .

^1H NMR: δ = 9.53 (br s, 1 H), 8.37 (s, 1 H), 7.71–6.81 (m, 4 H), 2.47 (s, 3 H).

^{13}C NMR: δ = 198.3, 132.7, 131.9, 122.3, 121.5, 119.2, 111.9, 111.2, 28.1.

2,2,2-Trifluoro-1-(1H-indol-3-yl)ethanone (3z)

Mp 207–211 $^{\circ}\text{C}$ (lit.³⁶ 209–212 $^{\circ}\text{C}$).

IR (neat): 3407, 1650, 1527, 1450, 1339, 1246, 1196, 1158, 1092, 1046, 896, 728 cm^{-1} .

^1H NMR: δ = 9.12 (br s, 1 NH), 8.41 (d, J = 9 Hz, 1 H), 7.86 (d, J = 6 Hz, 1 H), 7.64 (d, J = 6 Hz, 1 H), 7.41 (m, 1 H), 7.29 (m, 1 H).

^{13}C NMR: δ = 196.9, 137.8, 128.4 (t), 127.1, 123.0, 121.3, 120.9, 120.3, 109.6, 101.5.

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