Synthesis of Aliphatic Hydroxyaryl Ketones or (Hetero)aryl Hydroxyaryl Ketones by Acylation of Organometallic Reagents

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Abstract: Diverse hydroxyarenecarboxylic acids afford stable *N*-(hydroxyaroyl)benzotriazoles that react with heteroaryl, alkyl, and aryl Grignard or lithium reagents to give the corresponding hydroxyaryl ketones in 51–94% yields.

Key words: hydroxyarenecarboxylic acids, *N*-(hydroxyaroyl)benzotriazoles, Grignard reagents, lithium, hydroxyaryl ketones

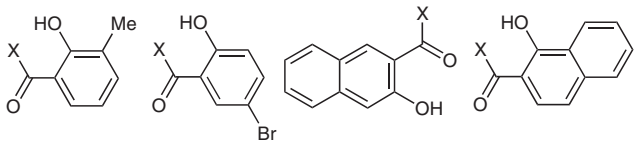
Hydroxyaryl ketones[1] are precursors for the synthesis of biologically active chalcones,[2] flavones,[2b,3] isoflavones,[4] and xanthones.[5] Aryl *o*-hydroxyaryl ketones exhibit protein kinase B inhibitor,[6] cyclin-dependent kinase inhibitor,[7] and cysteine protease modulator activities.[8] Aryl hydroxyaryl ketone moieties occur in natural products such as cotoin,[9] balanol,[10] and daunorubicin.[11] Many aryl hydroxyaryl ketones including dioxybenzone,[12] mexenone,[13] oxybenzone,[14] benzophenone-6,[15] and benzoresorcinol[16] are used as ultraviolet screens.

The conventional Friedel–Crafts acylation of phenols and naphthols with acid chlorides in the presence of Lewis acid catalysts[5,17] and Fries-type rearrangement of suitable aryl esters,[18] which are both frequently used for the preparation of hydroxyaryl ketones, are often unselective in that *ortho*- and *para*-acylation of phenols and naphthols result leading to mixture of products. Moreover, acid chlorides are sensitive to moisture and hence they are difficult to handle.[19] Alternative, less frequently used, syntheses of hydroxyaryl ketones include (i) palladium-catalyzed coupling of *o*-hydroxyaryl aldehydes with hypervalent iodonium salts[20] and (ii) intramolecular acyl radical [1,6]-*ipso*-substitution reactions.[21]

N-Acylbenzotriazoles are easily prepared activated derivatives of carboxylic acids.[22] Applications of *N*-acylbenzotriazoles include: (i) N-acylation of amines,[23] amides,[23,24] and sulfonamides,[25] (ii) O-acylation of aldehydes,[26] steroids,[27] hydroxyterpenes and alcohols,[28] (iii) many C-acylations of, for example, pyrroles and indoles,[29] ketones and heteroaromatics,[30] alkyl sulfones,[31] alkyl cyanides,[32] alkyl azines,[33] α-nitroalkanes,[34] furan and thiophene;[35] syntheses of (iv) peptides,[36] (v) oxazolines,[37] (vi) esters,[38] (vii) benzodioxin-4-ones,[39] (viii) ketones,[40] (ix) benzodiazepin-2-ones,[41] (x) thiol esters,[42] (xi) alcohols,[43] (xii) acyl azides and hydrazides,[44] (xiii) heteroaromatics,[45] and (xiv) heterocycles.[46]

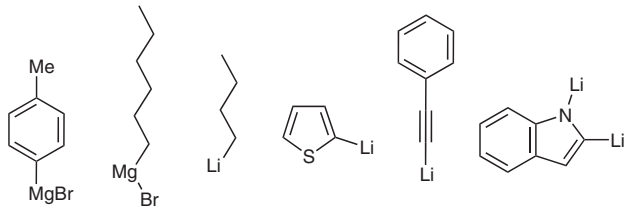
Our approach to a general method for the synthesis of a variety of ketones involved the use of *N*-acylbenzotriazoles as stable alternatives to the corresponding acid chlorides. We now report the synthesis of aliphatic or (hetero)aryl hydroxyaryl ketones in good yields from easily accessible *N*-(hydroxylacyl)benzotriazoles **2a–d** with Grignard reagents **3a**,**b** or lithiums reagents **4c–f** without any side reactions.

N-(Hydroxyaroyl)benzotriazoles **2a–d** (Figure 1) were readily prepared from benzotriazole (BtH) and the corresponding carboxylic acids **1a–d** in 72–84% yields according to a literature procedure.[38,39] *N*-(Hydroxyaroyl)benzotriazoles **2a–d** were previously isolated and utilized for the direct synthesis of esters and amides.[38,39]



1a (X = OH) **2a** (X = Bt) **1b** (X = OH) **2b** (X = Bt) **1c** (X = OH) **2c** (X = Bt) **1d** (X = OH) **2d** (X = Bt)

Figure 1 Carboxylic acids **1a–d** and *N*-acylbenzotriazoles **2a–d**



3a **3b** **4c** **4d** **4e** **4f**

Figure 2 Grignard reagents **3a**,**b** and organolithium reagents **4c–f**

Grignard and organolithium reagents were freshly prepared in tetrahydrofuran immediately before use (Figure 2). Reaction of 2-(1*H*-benzotriazol-1-ylcarbonyl)-6-methylphenol (**2a**, 1 mmol) with freshly prepared 4-tolylmagnesium bromide (**3a**, 2.2 mmol) at 25 °C for four hours gave the corresponding (2-hydroxy-3-methylphenyl)(4-tolyl)methanone (**5aa**) in 74% yield (Table 1). The ^{1}H NMR spectra of **5aa** showed the disappearance of the benzotriazolyl signals in the aromatic region, indicating the loss of the benzotriazolyl group during the reaction.

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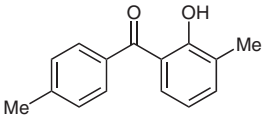
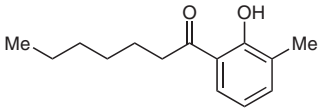
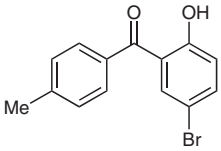
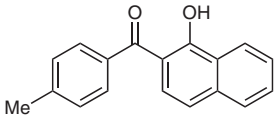
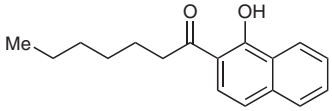
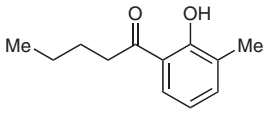
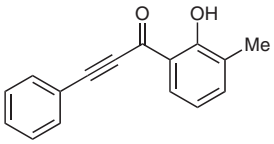
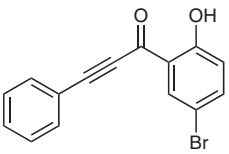
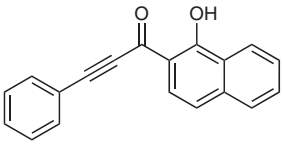
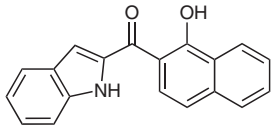
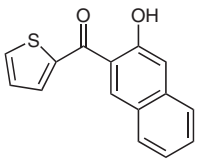
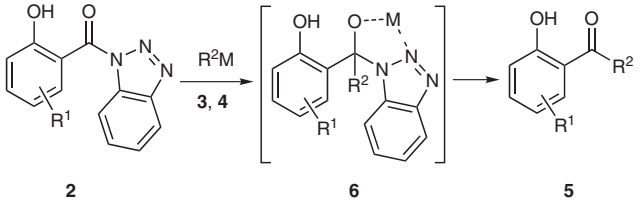
Table 1 Addition of Grignard Reagents **3a**,**b** and Organolithium **4c–f** to *N*-(Hydroxylacyl)benzotriazoles **2a–d**

Entry	R^1COBt	R^2M	Temp (°C)	Time (h)	Product		Yield[a] (%)	Mp (°C)
1	**2a**	**3a**	25	4		**5aa**	74	62–63
2	**2a**	**3b**	25	2		**5ab**	53	oil
3	**2b**	**3a**	25	4		**5ba**	66	85–87
4	**2d**	**3a**	65	12		**5da**	63	111–112
5	**2d**	**3b**	25	5		**5db**	70	53–54
6	**2a**	**4c**	–78	0.5		**5ac**	94	oil
7	**2a**	**4e**	–78	0.5		**5ae**	86	98–100
8	**2b**	**4e**	–78	0.5		**5be**	88	84–86
9	**2d**	**4e**	–78	0.5		**5de**	90	110–111
10	**2d**	**4f**	–78	0.5		**5df**	61	153–155
11	**2c**	**4d**	–78	0.5		**5cd**	72	104–105

[a] Isolated yields after column purification and determined from a single experiment.

The ^{13}C NMR spectra of **5aa** showed a signal at δ = 201.5 corresponding to the carbonyl group of the product and the disappearance of the signal at δ = 168.8 belonging to the carbonyl group at the α-position of the benzotriazolyl group in the starting material. We then explored reactions of *N*-(hydroxyaroyl)benzotriazoles **2a–d** (Figure 1) with a range of Grignard **3a**,**b** and organolithium reagents **4c–f** (Figure 2) to test the generality of this method. The results are displayed in Table 1.

Tertiary alcohols were not obtained as side products in the reaction even in the presence of excess organometallic reagent; tetrahedral intermediate **6** probably explains the preferential formation of ketones over tertiary alcohols (Scheme 1). The effective chelation of metal ion between carbonyl oxygen and nitrogen of the benzotriazole moiety would prevent the collapse of the tetrahedral intermediate **6** until the aqueous acidic work-up.



Scheme 1

Reaction of *N*-(hydroxyaroyl)benzotriazoles **2a–d** with Grignard reagents **3a**,**b** at 25–65 °C for 2–12 hours gave the corresponding ketones **5aa–db** in 53–74% yields.

Reaction of **2a–d** with organolithium reagents **4c–f** at –78 °C for 30 minutes gave the corresponding ketones **5ac–dd** in 61–94% yield.

Three of the ketones **5db**, **5ac**, and **5be** were reported previously and prepared by other methods. 1-(1-Hydroxy-2-naphthyl)heptan-1-one (**5db**) has been prepared both by the condensation of 1-naphthol and heptanoic acid in the presence of zinc chloride in 50% yield[47] and also from 1-naphthol and heptanoyl chloride in presence of zinc chloride in nitrobenzene in 40% yield.[48] Our method provided a higher yield of **5db** (70%) and avoids hygroscopic zinc chloride and toxic nitrobenzene. 1-(2-Hydroxy-3-methylphenyl)pentan-1-one (**5ac**) was prepared by Fries-type rearrangement of the corresponding ester with aluminum(III) chloride in 46% yield;[49] our method gave **5ac** in 94% yield and is more convenient. 1-(5-Bromo-2-hydroxyphenyl)-3-phenylprop-2-yn-1-one (**5be**) was previously prepared in 89% yield from phenylethynylmagnesium bromide and 2-hydroxybenzaldehyde in four hours followed by oxidation with γ-manganese(IV) oxide over a further four hours.[50] Our reaction gave the same yield (88%) of **5be** but took only 30 minutes to reach completion.

In conclusion, convenient route has been developed for the preparation of various hydroxyaryl ketones, most of which are not easily accessible by previous methods.

Melting points are uncorrected. ^1H NMR and ^{13}C NMR spectra were recorded on a FT-Bruker AT-300 instrument using TMS as an internal standard and $CDCl_3$ as solvent. Compounds were characterized by elemental analysis using a Carlo-Erba EA1112 instrument.

N-(Hydroxyaroyl)benzotriazoles 2a–d; General Procedure

Hydroxy acid **1a–d** (10 mmol) was placed in a 100-mL Schlenk flask and anhyd CH_2Cl_2 (20 mL) was added. Benzotriazole (3.63 g, 30.5 mmol) and CH_2Cl_2 (20 mL) was added followed by $SOCl_2$ (0.77 mL, 10.5 mmol). The solid precipitate was difficult to stir and so was shaken in a New Brunswick Scientific apparatus at 40 speed at r.t. overnight. The white precipitate was filtered and the filtrate was evaporated under reduced pressure to give the crude product, which was washed with anhyd Et_2O to obtain pure **2a–d** as yellow microcrystals.

2-(1*H*-Benzotriazol-1-ylcarbonyl)-6-methylphenol (2a)

Yellow crystals; yield: 72%; mp 124–126 °C (Lit.[36g] 124–126 °C).

^1H NMR (300 MHz, $CDCl_3$): δ = 11.04 (s, 1 H), 8.41 (d, *J* = 8.4 Hz, 1 H), 8.32 (d, *J* = 8.2 Hz, 1 H), 8.19 (d, *J* = 8.2 Hz, 1 H), 7.72 (t, *J* = 7.7 Hz, 1 H), 7.56 (t, *J* = 7.7 Hz, 1 H), 7.48 (d, *J* = 7.3 Hz, 1 H), 6.96 (t, *J* = 7.8 Hz, 1 H), 2.35 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 169.9, 162.3, 145.7, 138.2, 132.7, 131.6, 130.7, 127.6, 126.6, 120.6, 119.2, 115.1, 113.0, 16.2.

2-(1*H*-Benzotriazol-1-ylcarbonyl)-4-bromophenol (2b)

Yellow crystals; yield: 82%; mp 108–109 °C (Lit.[36g] 108–109 °C).

^1H NMR (300 MHz, $CDCl_3$): δ = 10.53 (s, 1 H), 8.71 (d, *J* = 2.5 Hz, 1 H), 8.21 (d, *J* = 8.4 Hz, 1 H), 8.11 (d, *J* = 8.2 Hz, 1 H), 7.64 (td, *J* = 7.3 Hz, 1.0 Hz, 1 H), 7.58 (dd, *J* = 9.1, 2.4 Hz, 1 H), 7.49 (td, *J* = 8.2 Hz, 1.0 Hz, 1 H), 6.94 (d, *J* = 8.9 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 168.3, 162.7, 145.6, 140.0, 135.9, 132.4, 131.1, 127.0, 120.7, 120.5, 115.1, 115.0, 111.6.

3-(1*H*-Benzotriazol-1-ylcarbonyl)-2-naphthol (2c)

Yellow crystals; yield: 80%; mp 157–158 °C (Lit.[36g] 157–158 °C).

^1H NMR (300 MHz, $CDCl_3$): δ = 9.95 (s, 1 H), 9.14 (s, 1 H), 8.35 (d, *J* = 8.4 Hz, 1 H), 8.20 (d, *J* = 8.2 Hz, 1 H), 7.89 (d, *J* = 8.2 Hz, 1 H), 7.76–7.70 (m, 2 H), 7.60–7.53 (m, 2 H), 7.43 (s, 1 H), 7.36 (td, *J* = 8.0, 0.8 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 169.2, 156.8, 145.7, 138.2, 137.9, 132.7, 130.9, 130.6, 130.4, 127.3, 126.9, 126.4, 124.7, 120.6, 115.6, 115.2, 112.7.

2-(1*H*-Benzotriazol-1-ylcarbonyl)-1-naphthol (2d)

Yellow crystals; yield: 84%; mp 153–155 °C (Lit.[36g] 150–151 °C).

^1H NMR (300 MHz, $CDCl_3$): δ = 12.57 (s, 1 H), 8.57 (d, *J* = 9.3 Hz, 1 H), 8.51 (d, *J* = 8.3 Hz, 1 H), 8.34 (d, *J* = 8.3 Hz, 1 H), 8.18 (d, *J* = 8.3 Hz, 1 H), 7.80 (d, *J* = 8.1 Hz, 1 H), 7.73–7.65 (m, 2 H), 7.59–7.52 (m, 2 H), 7.39 (d, *J* = 9.0 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 170.0, 165.2, 145.6, 137.7, 132.8, 131.2, 130.6, 127.6, 127.0, 126.6, 126.4, 125.0, 124.7, 120.5, 119.2, 115.2, 107.0.

Aliphatic or (Hetero)aryl Hydroxyaryl Ketones 5; General Procedure

To a stirred soln of *N*-acylbenzotriazole **2a–d** (1 mmol) in anhyd THF (5 mL) under N_2, a freshly prepared soln of Grignard reagents **3a**,**b** or organolithium reagents **4c–f** in THF (2.2 mmol) was added dropwise at the appropriate temperature. The mixture was stirred until complete reaction (followed by TLC) and then quenched by addition of sat. NH_4Cl soln. After extraction (EtOAc), the organic layer was washed with brine and H_2O, dried (anhyd $MgSO_4$), and concentrated under reduced pressure. The crude product was then

purified by column chromatography (silica gel) with the appropriate eluent to give hydroxy ketones **5aa–dd**.

(2-Hydroxy-3-methylphenyl)(4-tolyl)methanone (5aa)
Eluent: hexanes–EtOAc (10:1); yellow crystals; yield: 74%; mp 62–63 °C (Lit.[39] 62–63 °C).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.59 (d, *J* = 8.0 Hz, 2 H), 7.45 (d, *J* = 8.0 Hz, 1 H), 7.36 (d, *J* = 8.0 Hz, 1 H), 7.30 (d, *J* = 8.0 Hz, 2 H), 6.78 (t, *J* = 8.0 Hz, 1 H), 2.45 (s, 3 H), 2.32 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 201.5, 161.4, 142.5, 136.8, 135.3, 131.1, 129.4, 128.9, 127.2, 118.4, 117.8, 21.5, 15.5.

1-(2-Hydroxy-3-methylphenyl)heptan-1-one (5ab)
Eluent: hexanes–Et_2O (100:5); colorless oil; yield: 53%.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 11.12 (s, 1 H), 7.70 (d, *J* = 8.1 Hz, 1 H), 7.31 (d, *J* = 7.2 Hz, 1 H), 6.78 (t, *J* = 7.7 Hz, 1 H), 4.33 (t, *J* = 6.6 Hz, 2 H), 2.26 (s, 3 H), 1.79–1.69 (m, 2 H), 1.46–1.29 (m, 6 H), 0. 92 (t, *J* = Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 207.2, 161.0, 136.9, 127.5, 127.3, 118.4, 111.9, 65.4, 38.4, 31.6, 29.0, 24.6, 22.5, 14.0.

HRMS-FAB: *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{21}O_2$: 221.153; found: 221.151.

(5-Bromo-2-hydroxyphenyl)(4-tolyl)methanone (5ba)
Eluent: hexanes–Et_2O (10:1); white crystals; yield: 66%; mp 85–87 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 10.49 (s, 1 H), 8.18 (d, *J* = 2.4 Hz, 1 H), 7.60 (dd, *J* = 9.0, 2.7 Hz, 1 H), 7.25 (d, *J* = 8.7 Hz, 2 H), 7.08 (d, *J* = 8.7 Hz, 2 H), 6.94 (d, *J* = 9.0 Hz, 1 H), 2.39 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 168.1, 161.1, 147.6, 139.1, 136.4, 132.5, 130.2, 121.1, 119.8, 113.4, 111.1, 20.9.

Anal. Calcd for $C_{14}H_{11}BrO_2$: C, 57.76; H, 3.81. Found: C, 57.38; H, 3.97.

(1-Hydroxy-2-naphthyl)(4-tolyl)methanone (5da)
Eluent: hexanes–EtOAc (12:1); white crystals; yield: 63%; mp 111–112 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 11.78 (s, 1 H), 8.44 (d, *J* = 8.1 Hz, 1 H), 7.98 (d, *J* = 8.8 Hz, 1 H), 7.81 (d, *J* = 8.0 Hz, 1 H), 7.65 (td, *J* = 8.0 Hz, 1.2 Hz, 1 H), 7.53 (td, *J* = 8.0 Hz, 1.2 Hz, 1 H), 7.37 (d, *J* = 8.8 Hz, 1 H), 7.36 (d, *J* = 8.8 Hz, 2 H), 7.14 (d, *J* = 8.8 Hz, 2 H), 2.40 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 170.1, 161.8, 148.0, 137.5, 136.1, 130.1, 129.8, 127.5, 125.9, 124.7, 124.3, 124.0, 121.4, 118.9, 105.1, 20.9.

HRMS-FAB: *m*/*z* [M + H]$^+$ calcd for $C_{18}H_{15}O_2$: 263.106; found: 263.104.

1-(1-Hydroxy-2-naphthyl)heptan-1-one (5db)
Eluent: hexanes–Et_2O (15:1); white crystals; yield: 70%; mp 53–54 °C (Lit.[48] 52 °C).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.46 (d, *J* = 8.2 Hz, 1 H), 7.75 (d, *J* = 8.0 Hz, 1 H), 7.67 (d, *J* = 9.0 Hz, 1 H), 7.62 (td, *J* = 8.1, 1.2 Hz, 1 H), 7.53 (d, td, *J* = 8.1, 1.2 Hz, 1 H), 7.26 (d, *J* = 9.0 Hz, 1 H), 3.05 (t, *J* = 7.2 Hz, 2 H), 1.79 (quintet, *J* = 7.5 Hz, 2 H), 1.46–1.31 (m, 6 H), 0.91 (t, *J* = 6.9 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 206.8, 162.6, 137.2, 129.9, 127.3, 125.9, 125.4, 124.4, 124.4, 118.2, 112.8, 38.7, 31.6, 29.0, 24.7, 22.5, 14.1.

1-(2-Hydroxy-3-methylphenyl)pentan-1-one (5ac)[49]
Eluent: hexanes–Et_2O (12:1); colorless oil; yield: 94%.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 11.11 (s, 1 H), 7.69 (d, *J* = 8.0 Hz, 1 H), 7.31 (d, *J* = 7.2 Hz, 1 H), 6.77 (t, *J* = 8.0 Hz, 1 H), 4.34 (t, *J* = 6.6 Hz, 2 H), 2.26 (s, 3 H), 1.76 (quintet, *J* = 6.8 Hz, 2 H), 1.50 (sextet, *J* = 7.3 Hz, 2 H), 0.98 (t, *J* = 7.4 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 170.7, 160.1, 136.3, 127.3, 126.5, 118.4, 111.9, 65.1, 30.6, 19.2, 15.6, 13.7.

1-(2-Hydroxy-3-methylphenyl)-3-phenylprop-2-yn-1-one (5ae)
Eluent: hexanes–EtOAc (4:1); yellow crystals; yield: 86%; mp 98–100 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 12.04 (s, 1 H), 7.99 (d, *J* = 7.0 Hz, 1 H), 7.71–7.68 (m, 2 H), 7.50 (d, *J* = 7.0 Hz, 1 H), 7.49–7.39 (m, 3 H), 6.89 (t, *J* = 7.7 Hz, 1 H), 2.29 (s, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 182.4, 161.3, 137.9, 133.1, 131.1, 130.6, 128.7, 127.2, 120.1, 119.8, 118.8, 95.7, 85.9, 15.3.

Anal. Calcd for $C_{16}H_{12}O_2$: C, 81.34; H, 5.12. Found: C, 81.43; H, 5.12.

1-(5-Bromo-2-hydroxyphenyl)-3-phenylprop-2-yn-1-one (5be)
Eluent: hexanes–EtOAc (10:1); yellow crystals; yield: 88%; mp 84–86 °C (Lit.[50] 84–85 °C).

^{1}H NMR (300 MHz, $CDCl_3$): δ = 11.69 (s, 1 H), 8.20 (d, *J* = 1.4 Hz, 1 H), 7.72–7.70 (m, 2 H), 7.61–7.43 (m, 4 H), 6.92 (d, *J* = 7.4, Hz 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 181.1, 161.7, 139.7, 134.9, 133.3, 131.5, 128.8, 121.9, 120.2, 119.2, 110.9, 97.1, 85.3.

1-(1-Hydroxy-2-naphthyl)-3-phenylprop-2-yn-1-one (5de)
Eluent: hexanes–Et_2O (10:1); yellow crystals; yield: 90%; mp 110–111 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.48 (d, *J* = 8.2 Hz, 1 H), 8.02 (d, *J* = 8.8 Hz, 1 H), 7.79 (d, *J* = 8.1 Hz, 1 H), 7.75–7.72 (m, 2 H), 7.67 (td, *J* = 6.9, 1.2 Hz, 1 H), 7.58–7.43 (m, 4 H), 7.34 (d, *J* = 8.9 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 181.6, 163.4, 137.5, 133.3, 131.0, 130.5, 128.6, 127.5, 126.2, 126.0, 124.7, 124.4, 119.7, 118.8, 114.6, 96.6, 86.0.

Anal. Calcd for $C_{19}H_{12}O_2$: C, 83.80; H, 4.44. Found: C, 83.61; H, 4.18.

(1-Hydroxy-2-naphthyl)(1*H*-indol-2-yl)methanone (5df)
Eluent: hexanes–Et_2O (10:1); yellow crystals; yield: 61%; mp 153–155 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 11.65 (br s, 1 H), 8.48 (d, *J* = 8.4 Hz, 1 H), 8.24 (d, *J* = 8.1 Hz, 1 H), 7.80 (d, *J* = 7.8 Hz, 1 H), 7.68–7.51 (m, 5 H), 7.41–7.31 (m, 3 H), 6.69 (d, *J* = 3.6 Hz, 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 171.5, 161.8, 136.6, 136.0, 130.5, 130.0, 127.8, 127.5, 126.2, 125.5, 125.1, 124.7, 124.1, 123.9, 121.0, 118.5, 115.9, 108.8, 108.3.

Anal. Calcd for $C_{19}H_{13}NO_2$: C, 79.43; H, 4.56; N, 4.87. Found: C, 79.20; H, 4.78; N, 4.57.

(3-Hydroxy-2-naphthyl)(2-thienyl)methanone (5cd)
Eluent: hexanes–Et_2O (10:1); dark green crystals; yield: 72%; mp 104–105 °C.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 10.61 (br s, 1 H), 8.49 (s, 1 H), 7.84–7.80 (m, 3 H), 7.72 (d, *J* = 8.3 Hz, 1 H), 7.54 (t, *J* = 7.6 Hz, 1 H), 7.38–7.33 (m, 2 H), 7.27–7.24 (m 1 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 191.3, 156.5, 143.3, 142.5, 137.6, 135.2, 134.6, 129.6, 129.4, 128.1, 126.9, 126.3, 124.2, 121.6, 112.4.

Anal. Calcd for $C_{15}H_{10}O_2S$: C, 70.84; H, 3.96. Found: C, 70.44; H, 4.38.

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