A facile demethylation of ortho substituted aryl methyl ethers promoted by $AlCl_3$

Zhen-Ting Du[a]*, Jing Lu[a], Hong-Rui Yu[a], Yan Xu[a]* and An-Pai Li[b]

[a]*College of Science, Northwest A&F University, Yangling, Shaanxi 712100, P.R. China*

[b]*Synthetics Technologica Pte Ltd, 3 Phillip Street, #18-00 Commerce Point, 048693, Singapore*

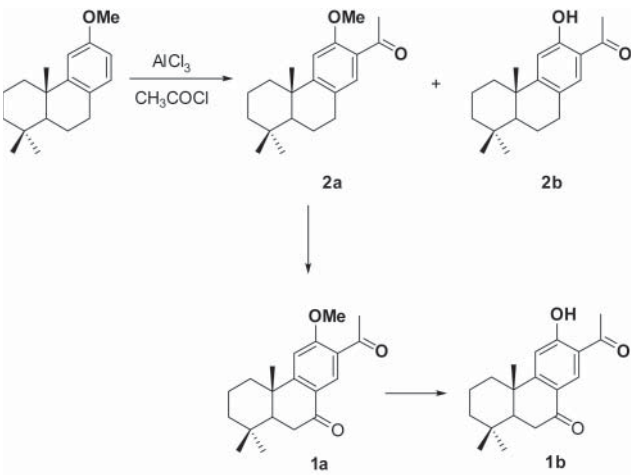
An efficient and practical demethylation of ortho substituted aryl methyl ethers using $AlCl_3$ has been developed. This method gives a high conversion, is simple to operate and is cost-effective. A mechanism involving the complexation of $AlCl_3$ with the OMe and the adjacent electron withdrawing group is proposed. Many functional groups can be tolerated in the demethylation process, and 29 examples gave a demethylated product in a yield of 90–98%.

Keywords: demethylation, aluminium chloride, phenol methyl ethers, nimbosidione

The methyl ether of a phenol is one of the most used protecting groups due to its stability and easy preparation. However, its application is often restricted because of the difficulty in removal, especially in multifunctional molecules. Many methods have been reported to cleave phenol ethers.[1] These include strong Brønsted acid, such as HBr/HOAc,[2] H_2SO_4,[3] $MeSO_3H$,[4] CF_3SO_3H,[5] and strong nucleophilic reagents, such as EtSNa,[6] salts of PhSeH,[7] and methods based on Lewis acid, such as BX_3,[8] Me_3SiI[9] and $AlBr_3$.[10] Most of these methods suffer from some drawbacks, such as the use of toxic materials, commercially unavailable reagents, low selectivity or limited applicability. Although $AlCl_3$[11] has been reported to cleave the ether bond between a phenol and an alkyl group, the scope of the reaction was not investigated. We now report the use of $AlCl_3$ as a demethylating agent.

Nimbosidione **1b** is a natural product isolated from the stem bark of *Azadirachta indica* by Siddiqui.[12] In our effort to synthesise this kind of naturally occurring terpenoids[13–15], compound **1a** was obtained by a Jones' oxidation of the key intermediate **2a**. In our original plan, we intended to synthesise **2a** by a conventional acetylation reaction of compound **4** with AcCl and $AlCl_3$. (Scheme 1) To our surprise, when the reaction was performed with 1 equiv. AcCl and 1 equiv. $AlCl_3$ in CH_2Cl_2 at room temperature, there were two products after workup, the desired compound **2a** and a demethylation byproduct **2b** at a ratio 3:7.

In the light of this observation, we checked the reaction conditions and studied the mechanism. The reaction conditions were simplified and a demethylation method was developed.



Scheme 1 Synthesis of nimbosidione

* Correspondent. E-mail: jamesduh@gmail.com

Here, we report this simple and effective methodology to selectively remove the methyl group phenolic methyl ethers.

Results and discussion

Initially, we suspected that the ease of formation of the demethylated byproduct **2b** may be facilitated by the adjacent acetyl group. In order to have a better understanding of this reaction, we designed a model reaction in which 2-methoxy acetophenone was treated with 1.5 equiv. $AlCl_3$, and $CDCl_3$ was employed as solvent, as shown in Scheme 2, The reaction was carried out in a NMR sample tube and monitored by ^1H NMR; each NMR spectrum was recorded every hour and was plotted on one page for comparison. As shown in Fig. 1, it is quite clear that the signal at 3.02 ppm gradually increased during the reaction. The formation of chloromethane was inferred in both ^1H and ^{13}C NMR spectra during the reaction NMR scan (the chemical shift of CH_3Cl is 3.02 ppm in ^1H NMR, 25.88 ppm in ^{13}C NMR, respectively). At the same time, the GC-MS analysis of the gas in reaction vessel illustrated the existence of chloromethane in the demethylation reactions (*m/z*: 50). On the other hand, the methyl signal of the acetyl group shown at 2.61 ppm immediately shifted to 2.75 ppm upon mixing of aluminum chloride with 2-methoxyacetophenone. This phenomenon indicates the chelation of $AlCl_3$ with the acetyl group that made the carbonyl group more electron deficient and the methyl signal of acetyl group shifted down field. We also found that the methyl signal of acetyl group was gradually shifted to 2.93 ppm after 2 hours and become obscured after 3 hours of reaction; the methyl signal of –OMe diminished gradually and almost disappeared after 5 hours. Therefore, $AlCl_3$ was established as the demethylation reagent with the assistance of an adjacent electron withdrawing group.

Next, the demethylation of several phenol methyl ethers was investigated (Table 1). The ethers which had *ortho* electron withdrawing groups gave excellent yields at room temperature in presence of 1.5 equiv. $AlCl_3$. In contrast, demethylation was sluggish for the phenol methyl ethers without *ortho* electron withdrawing groups; 3 or 4 nitro substituted phenyl methyl ether gave a little demethylation product under the same conditions.

Finally we examined the demethylation of 2-methoxyacetophenone in CH_2Cl_2 at room temperature using molar ratios of 2-methoxyacetophenone/$AlCl_3$ of 1:1, 1:1.5, 1:2 equiv., respectively. It was found that a molar ratio of 1:1.5 is sufficient to carry out the demethylation successfully to afford the desire product in 97% yield in a short time (Table 2, entry 3). If the amount of $AlCl_3$ was decreased, the demethylation period may be longer or the yield will be worse, but using too much $AlCl_3$ leads to a troublesome workup. Note that this method is more convenient and easier to perform than the reported ones.

Using these optimised cost-effective reaction conditions, the scope of the $AlCl_3$ promoted demethylation was then

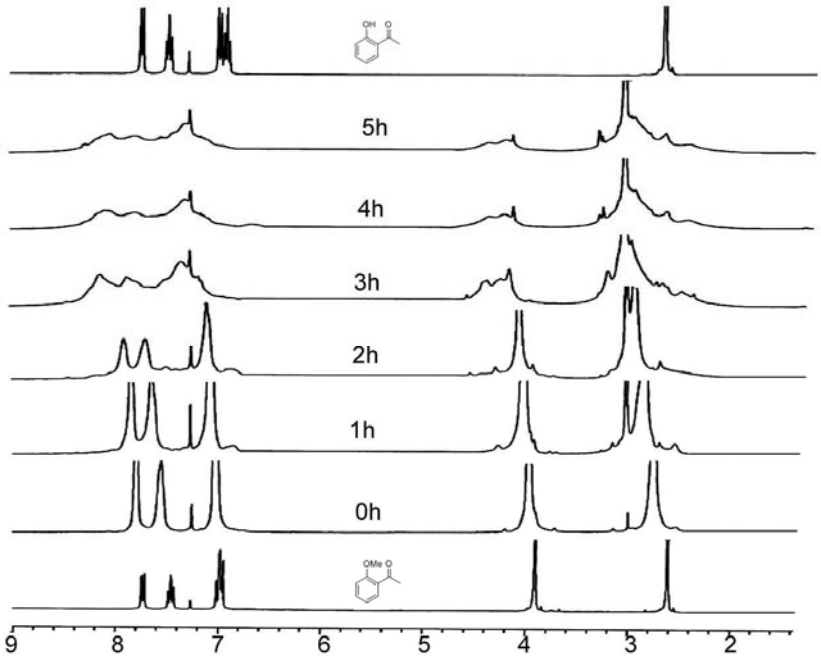
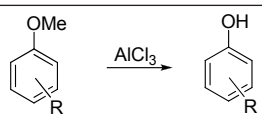
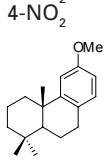


Fig. 1 NMR spectrum in demethylation process of 2-methoxyacetophenone.

explored (Table 2). A wide range of structurally diverse *ortho* methoxy derivative of benzene and naphthalene, including -CHO, -COMe, -CO_2Me, -NO_2 were subjected to demethylation under this protocol using 1.5 equiv. $AlCl_3$ in CH_2Cl_2. The demethylation of the derivatives of diphenylketone (entries 15–16) and the derivatives of *ortho* nitro anisole (entries 12–14) were much easier than others. This may be because of the stronger electron withdrawing effect. For the substituted 2-methoxyacetophenone, the electron-neutral (entry 5)-deficient (entry 9) and -rich substituted groups (entry 8) did not influence the reaction. The acetophenones (entries 5–11), diphenylketones (entries 15–16) and the 2-methoxy-1-acetylnaphathlene (entry 17) were prepared through Friedel-Crafts reaction. Some simple starting materials or products (entries 3–5, 8, 12–14, 16–18) were purchased from chemical vendor.

Table 1 Demethylation of phenol methyl ether by $AlCl_3$[a]



Entry	R	time	Yields(%)[b]
1	H	12	0
2	2-$COCH_3$	3	96
3	Cl	12	0
4	Br	12	0
5	I	12	0
6	2-NO_2	1	93
7	3-NO_2	8	6
8	4-NO_2	8	8
9		8	0

[a] The reaction was performed at room temperature in CH_2Cl_2.
[b] Isolated yields.

The nitrobenzene derivatives (entries 13–14) were prepared by nitration of corresponding phenyl methyl ether. The 2-methoxy-1-formylnaphthalene and 1-methoxy-2-formylnaphthalene (entries 17–18) were prepared through the Reimer–Tiemann reaction and then subsequent conventional methylation protocol. Other substrates are commercially available or prepared by conventional methylation protocol from commercially available starting materials.

As the results in Table 2 indicate, the demethylation products were obtained exclusively in all cases in high yields of 90–98%. A variety of functional groups on the benzene ring were tolerated under the reaction conditions. For most of the substrates, the conversion proceeded smoothly within several hours at room temperature. Most of the products (Table 2, entries 2–18) are known compounds, and all the products in our reactions listed in Table 2 were easily characterised on the basis of physical and spectral data and also by comparison with authentic samples.

Note that the salient characteristic of our method is selective demethylation of the methoxy group in the *ortho* position of an electron withdrawing group in a multifunctional ring (Table 2, entries 19–29). Compared to the low yields or multi-step to synthesise this kind of products reported in these studies, our present method has proven to be more efficient and should be helpful for exploring further applications in synthetic chemistry.

Conclusions

In conclusion, an extremely efficient and practical demethylation method has been developed. This method affords high conversions and yields, is simple to operate and is cost-effective. More significantly, this reaction can be used to achieve selective demethylation of multiple aryl methyl ethers. Thus, we believe that this novel methodology will be a practical alternative to the existing demethylation procedures. Further work is in progress to broaden the scope of this demethylation method.

Table 2 Demethylation of phenol methyl ether with *ortho* electron withdrawing groups by $AlCl_3$

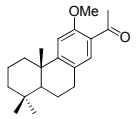
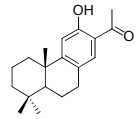
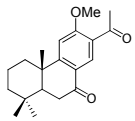
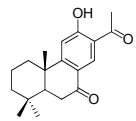
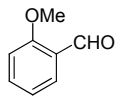
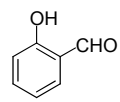
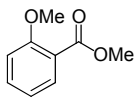
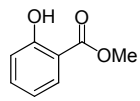
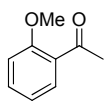
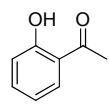
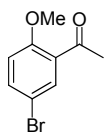
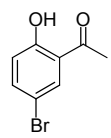
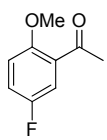
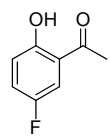
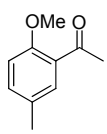
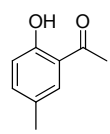
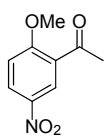
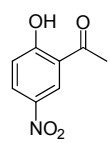
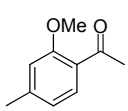
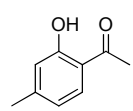
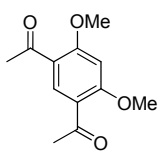
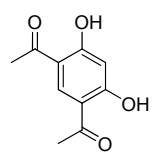
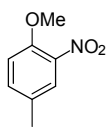
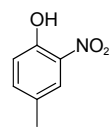
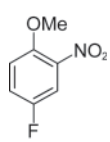
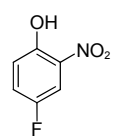
Entry	Substrate	Time/h	Product	Yield/%[a]
1		5		94
2		4		96
3		3		97
4		5		94
5		3		96
6		6		98
7		5		90
8		6		93
9		4		94
10		3		90
11		5		98[b]
12		4		93
13		4		93

Table 2 *Continued*

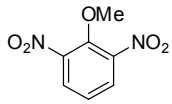
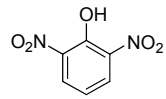
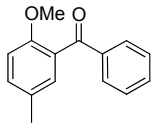
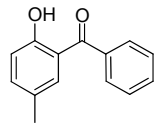
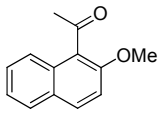
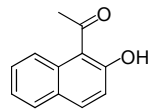
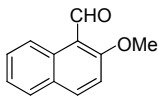
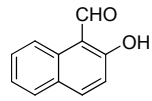
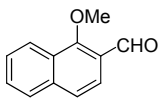
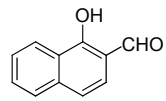
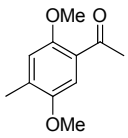
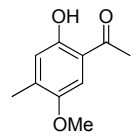
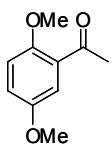
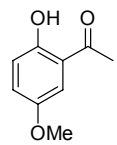
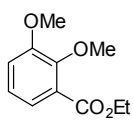
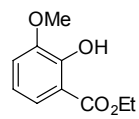
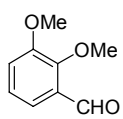
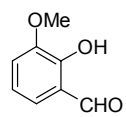
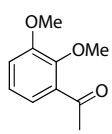
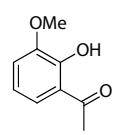
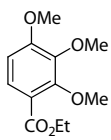
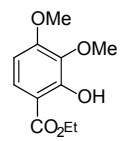
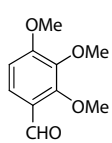
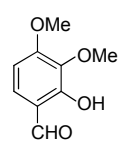
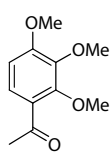
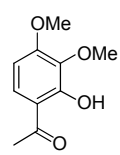
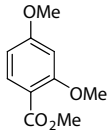
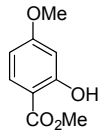
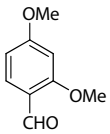
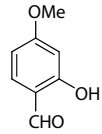
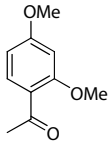
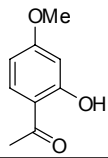
Entry	Substrate	Time/h	Product	Yield/%[a]
14		4		92
15		2		90
16		4		91
17		4		90
18		5		90
19		4		92
20		2		95
21		4		90
22		4		94
23		5		95
24		6		90
25		4		92
26		5		90

Table 2 *Continued*

Entry	Substrate	Time/h	Product	Yield/%[a]
27		5		93
28		3		94
29		4		93

[a] Isolated yield.
[b] Molar ratio of substrate:$AlCl_3$ = 1:4.

Experimental

Melting points were measured on a Kofler apparatus and were uncorrected. The ^{1}H NMR and ^{13}C NMR data were recorded in $CDCl_3$ solution with Bruker AM-200 or AM-400 MHz spectrometers. The chemical shifts are reported in ppm relative to TMS or $CDCl_3$. Mass spectra were recorded on a ZAB-HS mass spectrometer (EI). Microanalyses were performed on a MOD-1106 elemental analyser. Column chromatography was generally performed on silica gel (200–300 mesh) eluting with petroleum ether:ethyl acetate mixtures.

Demethylation by $AlCl_3$; general procedure

To a solution of substrate (1.0 mmol) in CH_2Cl_2 (5mL) was added $AlCl_3$ (200 mg, 1.5 mmol, 1.5 equiv.) in one portion at –5 °C. After being stirred at the same temperature for 5 minutes, the mixture was warmed up to 25 °C and stirred for a further period (see Table 2). The reaction mixture was then poured into cold water and extracted with CH_2Cl_2. The combined organic layer was washed successively with saturated $NaHCO_3$ and brine, and then dried with Na_2SO_4. The solvent was evaporated under vacuum and the crude product was purified by column chromatography on silica gel eluting with a mixture of petroleum ether and ethyl acetate.

1-(3-Hydroxy-4b,8,8-trimethyl-4b,5,6,7,8,8a,9,10-octahydrophenanthren-2-yl)ethanone (Table 2, entry 1): ^{1}H NMR: ($CDCl_3$, 400 MHz) ppm 0.94 (s, 3H), 0.96 (s, 3H), 1.18 (s, 3H), 1.20–2.25 (m, 9H), 2.58 (s, 3H), 2.82–2.92 (m, 2H), 6.67 (s, 1H), 7.40 (s, 1H), 11.93 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 19.0, 19.1, 21.7, 24.2, 26.4, 29.3, 33.2, 33.6, 38.5, 38.6, 41.5, 49.7, 113.5, 115.3, 117.7, 126.1, 130.6, 163.1, 203.8. PSI-MS: Found M+H = 287.2003, $C_{19}H_{26}O_2$ requires M+H = 287.2006. IR: 2926, 1642, 1566, 1485, 1265 cm^{-1}.

7-acetyl-6-hydroxy-1,1,4a-trimethyl-2,3,4,4a,10,10a-hexahydrophenanthren-9(1H)-one (Table 2, entry 2): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 0.90 (s, 3H), 0.95 (s, 3H), 1.18 (s, 3H), 1.23–2.26 (m, 7H), 2.63 (s, 3H), 2.55–2.66 (m, 2H), 6,89 (s, 1H), 8.43 (s, 1H), 12.55 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 18.7, 21.4, 22.9, 26.6, 32.5, 33.4, 35.9, 37.5, 38.7, 41.1, 48.6, 113.0, 118.0, 123.3, 131.7, 164.5, 166.4, 197.4, 204.6. PSI-MS: Found M+H = 301.1789, $C_{19}H_{24}O_3$ requires M+H = 301.1798. IR: 2957, 1684, 1649, 1564, 1475, 1361, 1290, 1219 cm^{-1}.

5-Bromo-2-hydroxyacetophenone (Table 2, entry 6): ^{1}H NMR: 2.63 (s, 3H), 6.90 (d, 1H, *J* = 8.8 Hz), 7.54 (dd, 1H, *J* = 8.8 Hz, *J* = 2.4 Hz), 7.83 (d, 1H, *J* = 2.4 Hz), 12.18 (s, 1H). EI-MS: 214(M$^+$).

5-Fluoro-2-hydroxyacetophenone (Table 2, entry 7): ^{1}H NMR: 2.63 (s, 3H), 6.96 (dd, 1H, *J* = 8.8Hz, *J* = 4.4Hz), 7.54 (ddd, 1H, *J* = 8.8Hz, *J* = 4.4Hz, *J* = 2.8Hz), 7.40 (dd, 1H, *J* = 8.8Hz, *J* = 2.8Hz), 11.98 (s, 1H). EI-MS: 154(M$^+$).

5-Methyl-2-hydroxyacetophenone (Table 2, entry 8): ^{1}H NMR: 2.32 (s, 3H), 2.63 (s, 3H), 6.90 (d, 1H, *J* = 8.4 Hz), 7.29 (dd, 1H, *J* = 8.4 Hz, *J* = 2.0 Hz), 7.51 (s, 1H), 12.10 (s, 1H). EI-MS: 150 (M$^+$).

5-Nitro-2-hydroxyacetophenone (Table 2, entry 9): ^{1}H NMR: 2.76 (s, 3H), 6.90 (d, 1H, *J* = 8.4 Hz), 8.24 (dd, 1H, *J* = 8.4 Hz, *J* = 2.0 Hz), 8.60 (s, 1H), 12.77 (s, 1H). EI-MS: 181(M$^+$), m.p. 94–96 °C (lit.[16] 101–102 °C).

4-Methyl-2-hydroxyacetophenone (Table 2, entry 10): ^{1}H NMR: 2.35 (s, 3H), 2.60 (s, 3H), 6.71 (d, 1H, *J* = 8.0 Hz), 6.80 (s, 1H), 7.61 (d, 1H, *J* = 8.0 Hz), 12.30 (s, 1H). EI-MS: 150 (M$^+$)

1,1'-(4,6-Dihydroxy-1,3-phenylene)diethanone (Table 2, entry 11): ^{1}H NMR: 2.64 (s, 3H), 6.44 (s, 1H), 8.21 (s, 1H), 12.93 (s, 1H). EI-MS: 194(M$^+$), m.p. 204–206 °C (lit.[17] 178–180 °C).

4-Fluoro-2-nitrophenol (Table 2, entry 13): ^{1}H NMR: 2.35 (s, 3H), 7.05 (d, 1H, *J* = 8.4 Hz), 7.40 (dd, 1H, *J* = 8.4 Hz, *J* = 2.0 Hz), 7.90 (d, 1H, *J* = 2.0 Hz), 10.43 (s, 1H). EI-MS: 157(M$^+$), m.p. 70–72 °C (lit.[18] 72.5 °C).

2-Hydroxy-5-methylphenyldiphenylketone (Table 2, entry 15): ^{1}H NMR: 2.27 (s, 3H), 7.00 (d, 1H, *J* = 8.4 Hz), 7.32–7.37 (m, 2H), 7.51–7.54 (m, 2H), 7.58–7.70 (m, 3H), 11.86 (s, 1H). EI-MS: 212(M$^+$), m.p. 79–80 °C (lit.[19] 82–83 °C).

2-Hydroxy-4-methyl-5-methoxyacetophenone (Table 2, entry 19): ^{1}H NMR: 2.35 (s, 3H), 2.38 (s, 3H), 3.86 (s, 3H), 6.88 (s, 1H), 7.21 (s, 3H). EI-MS: 180(M$^+$), m.p:110–112 °C (lit.[20] 110–112 °C).

2-Hydroxy-5-methoxyacetophenone (Table 2, entry 20): ^{1}H NMR: 2.62 (s, 3H), 3.80 (s, 3H), 6.92 (d, 1H, *J* = 8.4Hz), 7.12 (dd, 1H, *J* = 8.4Hz, *J* = 2.0Hz), 7.16 (d, 1H, *J* = 2.0Hz), 11.86 (s, 1H), EI-MS: 166(M$^+$), m.p. 49–50 °C (lit.[21] 51–52 °C).

Ethyl 2-hydroxy-3-methoxybenzoate(Table 2, entry 21): ^{1}H NMR (200 MHz): 1.34 (t, 3H, *J* = 7.2Hz), 3.86 (s, 3H), 4.32 (q, 2H, *J* = 7.2Hz), 6.74 (t, 1H, *J* = 8.0Hz), 6.98 (d, 1H, *J* = 8.0Hz), 7.39 (d, 1H, *J* = 8.0Hz), 11.09 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100MHz) ppm 13.7, 55.7, 61.2, 112.4, 116.1, 118.1, 120.7, 148.1, 151.8, 170.1. PSI-MS: Found M+Na = 219.0624, $C_{10}H_{12}O_4$ requires M+Na = 219.0628. IR: 3265, 2984, 1678, 1464, 1250 cm^{-1}.

2-Hydroxy-3-methoxybenzaldehyde (Table 2, entry 22): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 3.92 (s, 3H), 6.95 (t, 1H, *J* = 8.0Hz), 7.11 (d, 1H, *J* = 8.0Hz), 7.17 (d, 1H, *J* = 8.0Hz), 9.92 (s, 1H), 11.13 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100MHz) ppm 55.9, 117.6, 119.3, 120.4, 124.2, 147.8, 151.2, 196.3. PSI-MS: Found M+H = 153.0547, $C_8H_8O_3$ requires M+H = 153.0546. IR: 3420, 2644, 1650, 1462, 1256 cm^{-1}.

2-Hydroxy-3-methoxyacetophenone(Table 2, entry 23): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 2.63 (s, 3H), 3.89 (s, 3H), 6.82–6.86 (m, 1H), 7.04 (d, 1H, *J* = 7.6Hz), 7.32 (d, 1H, *J* = 8.2Hz), 12.58 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100MHz) ppm 27.0, 56.1, 116.9, 118.2, 119.6, 121.6, 148.8, 152.7, 204.9. PSI-MS: M+Na = 189.0519, $C_9H_{10}O_3$ requires M+Na = 189.0522. IR: 2907, 1698, 1457, 1365, 1261 cm^{-1}.

Ethyl 2-hydroxy-3,4-dimethoxybenzoate (Table 2, entry 24): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 1.37 (t, 3H, 7.2Hz), 3.88 (s, 3H), 3.96

9s, 3H), 4.53 (q, 2h, *J* = 7.2 Hz), 6.46 (d, 1H, *J* = 9.0 Hz), 7.59 (d, 1H, *J* = 9.0 Hz), 11.01 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 14.2, 56.0, 60.7, 61.2, 103.0, 106.5, 125.6, 136.5, 156.0, 158.0, 170.1. PSI-MS: Found M+H = 227.0916, $C_{11}H_{14}O_5$ requires M+H = 227.0914. IR: 3467, 2981, 1667, 1459, 1284 cm^{-1}.

2-Hydroxy-3,4-dimethoxybenzaldehyde (Table 2, entry 25): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 3.91 (s, 3H), 3.95 (s, 3H), 6.60 (d, 1H, *J* = 8.4Hz), 7.29 (d, 1H, *J* = 8.4Hz), 9.75 (s, 1H), 11.22 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100MHz) ppm 53.7, 58.1, 101.5, 114.0, 127.7, 133.6, 153.1, 156.6, 192.4. PSI-MS: Found M+H = 183.0653 $C_9H_{10}O_4$ requires M+H = 183.0652. IR: 3105, 2847, 1699, 1511, 1422, 1292 cm^{-1}.

2-Hydroxy-3,4-dimethoxyacetophenone (Table 2, entry 26): ^{1}H NMR: ($CDCl_3$, 400 MHz) ppm 2.54 (s, 3H), 3.86 (s, 3H), 3.90 (s, 3H), 6.46 (d, 1H, *J* = 9.0 Hz), 7.46 (d, 1H, *J* = 9.0 Hz), 12.54 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 26.2, 56.0, 60.5, 102.8, 115.2, 126.9, 136.3, 156.9, 158.4, 203.2. PSI-MS: Found M+H = 197.0802, $C_{10}H_{12}O_4$ requires M+H = 197.0808. IR: 3004, 2937, 1636, 1504, 1450, 1361, 1283 cm^{-1}.

Methyl 2-hydroxy-4-methoxybenzoate (Table 2, entry 27): ^{1}H NMR: ($CDCl_3$, 200MHz) ppm 3.82 (s, 3H), 3.91 (s, 3H), 6.41–6.45 (m, 2H), 7.71 (d, 1H, *J* = 9.0 Hz), 10.97 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 51.6, 55.3, 100.6, 105.3, 107.4, 131.1, 163.7, 165.5, 170.3. PSI-MS: M+H = 183.0653, $C_9H_{10}O_4$ requires M+H = 183.0652. IR: 3184, 1668, 1509, 1442, 1344, 1255 cm^{-1}.

2-Hydroxy-4-methoxybenzaldehyde (Table 2, entry 28): ^{1}H NMR: ($CDCl_3$, 200MHz) ppm 3.87 (s, 3H), 6.44 (d, 1H, *J* = 2.4 Hz), 6.53 (dd, 1H, *J* = 8.6 Hz, 2.4 Hz), 7.42 (d, 1H, *J* = 8.6 Hz), 9.73 (s, 1H), 11.51 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 55.6, 100.6, 108.3, 115.1, 135.2, 164.5, 166.8, 194.4. PSI-MS: Found M+H = 153.0542, $C_8H_8O_3$ requires M+H = 153.0546. IR: 2899, 1699, 1455, 1439, 1323 cm^{-1}.

2-hydroxy-4-methoxyacetophenone (Table 2, entry 29): ^{1}H NMR: ($CDCl_3$, 400MHz) ppm 2.56 (s, 3H), 3.84 (s, 3H), 6.41–6.46 (m, 2H), 7.62 (d, 1H, *J* = 8.6 Hz), 12.76 (s, 1H). ^{13}C NMR: ($CDCl_3$, 100 MHz) ppm 26.1, 55.5, 100.6, 107.6, 113.9, 132.3, 165.2, 166.1, 202.5. PSI-MS: M+H = 167.0702, $C_9H_{10}O_3$ requires M+H = 167.0703. IR: 2959, 1629, 1503, 1370, 1257 cm^{-1}.

The authors are grateful to Program for Excellent Young Talents in Northwest A&F University (2111020712) as well as the National Natural Science Foundation of China (No. 20802058) for financial support.

Received 28 December 2009; accepted 22 March 2010
Paper 090930 *doi: 10.3184/030823410X12708998015900*
Published online: 28 April 2010

References

1 M.V. Bhatt and S.U. Kulkarni, *Synthesis*, 1983, 249.
2 D. Landini, F. Montanari and F. Rolla, *Synthesis*, 1978, 771.
3 C. Li, E. Lobkovsky and J.J.A. Porco, *J. Am. Chem. Soc.*, 2000, **122**, 10484.
4 N. Fujii, H. Irie and H. Yajima, *J. Chem. Soc., Perkin Trans.*, 1977, 2288.
5 Y. Kiso, S. Nakamura, K. Ito, K. Ukawa, K. Kitagawa, T. Akita and H. Moritoki, *J. Chem. Soc., Chem. Commun.*, 1979, 971.
6 G.I. Feutrill and R.N. Mirrington, *Tetrahedron Lett.*, 1970, **11**, 1327.
7 A.K. Chakraborti, M.K. Nayak and L. Sharma, *J. Org. Chem.*, 2002, **67**, 1776.
8 J.F.W. McOmie and D.E. West, *Org. Syn., Collect.*, **5**, 1973, 412.
9 M.E. Yung and M.A. Lyster, *J. Org. Chem*., 1977, **42**, 3761.
10 M. Node, K. Nishide, K. Fuji and E. Fujita, *J. Org. Chem*., 1980, **45**, 4275.
11 Y. Kawamura, H. Takatsuki, F. Torii and T. Horie, *Bull. Chem. Soc. Jpn*, 1994, **67**, 511.
12 I. Ara and B S. Siddiqui, *J. Nat. Prod*., 1990, **53**, 816–820.
13 Z.T. Du, G.R.Yue, A.P. Li, J.Y. Ma, T.X. Wu, X.G. She and X.F. Pan, *J. Chin. Chem. Soc.*, 2004, **51**, 505.
14 A.P. Li, X.G. She, J.Y. Zhang, T.X. Wu and X.F. Pan, *Tetrahedron*, 2003, **59**, 5737.
15 Z.T. Du, G.R. Yue, J.Y. Ma, X.G. She, T.X. Wu and X.F. Pan, *J. Chem. Res.*, 2004, 427.
16 E. Matsumura, M. Ariga and Y. Tohda, *Tetrahedron Lett.*, 1979, 1393.
17 A.A.A. Emara, A.A. Saleh and O.M.I. Adly, *Spectrochim. Acta, A*, 2007, **68A**, 592.
18 J.S. Anderson and K.C. Brown, *Synth. Commun.*, 1983, **13**, 233.
19 M.S. Newman and A.G. Pinkus, *J. Org. Chem.*, 1954, **19**, 985.
20 R. Royer, P. Demerseman, A. Cheutin, E. Allegrini and R. Michelet, *Bull. Soc. Chim. Fr.*, 1957, 1379.
21 A.H. Chen, W.B. Kuo and C.W. Chen, *J. Chin. Chem. Soc.*, 2004, **51**, 1389.