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Synthesis of Hydroxybenzoic Acids and Their Esters by Reaction of Phenols with Carbon Tetrachloride and Alcohols in the Presence of Iron Catalysts

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Abstract—Alkyl esters of hydroxy-, methoxy-, and ethoxybenzoic and cresotic acids have been synthesized by reaction of phenols, anisole, phenetole, and cresols with carbon tetrachloride and alcohols in the presence of iron catalysts.

Keywords: hydroxy- and alkoxybenzoic acids, cresotic acids, salicylic acid, phenols, iron catalysts

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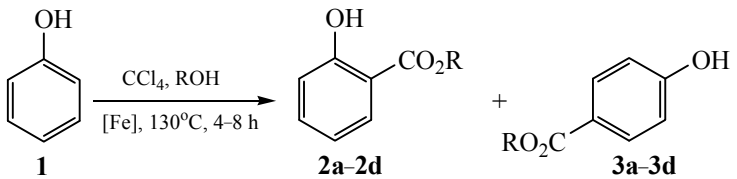
Hydroxy- and methoxybenzoic and cresotic acids and their esters are used in medicine and perfumery and are components of foods, cosmetics, and pharmacological agents. They exhibit antiseptic and anesthetic properties and are used for the treatment of rheumatism [1].

The most widely known method of synthesis of hydroxybenzoic acids is based on carboxylation of phenols with carbon dioxide under pressure (Kolbe–Schmitt reaction) [2]. Another method consists of carboxylation of phenols with metal alkyl carbonates [3, 4]. The latter are obtained by reaction of carbon dioxide with alkali metal alkoxides. The use of gaseous carbon dioxide is associated with large difficulties in the design of equipment for industrial processes, which creates serious impediments to wide implementation of these methods for preparative purposes. Therefore, studies are carried out with the goal of developing efficient alternative methods for the synthesis of aromatic carboxylic acids and their derivatives.

Komiyama and Hirai [5–8] reported a procedure for the synthesis of aromatic carboxylic acids from phenols and carbon tetrachloride in the presence of copper powder and β-cyclodextrin in alkaline medium. The reaction occurs in the β-cyclodextrin cavity having a definite size, and the selectivity for 4-hydroxybenzoic acid attains ~100%.

Our study was aimed as synthesizing alkyl esters of hydroxy-, methoxy-, and ethoxybenzoic and cresotic acids by reaction of phenol, cresols, anisole, and phenetole with carbon tetrachloride and alcohols in the presence of iron salts and complexes. This procedure was successfully applied previously to naphthalene, phenanthrene, and thiophene as substrates [9–12].

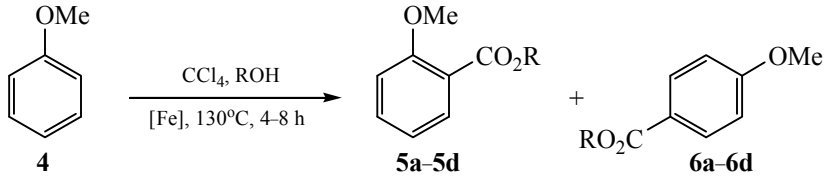
Scheme 1.



1 **2a–2d** **3a–3d**

R = Me (**a**), Et (**b**), *n*-Pr (**c**), *n*-Bu (**d**).

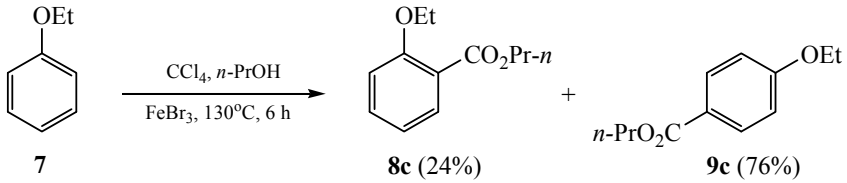
Scheme 2.



4 **5a**–**5d** **6a**–**6d**

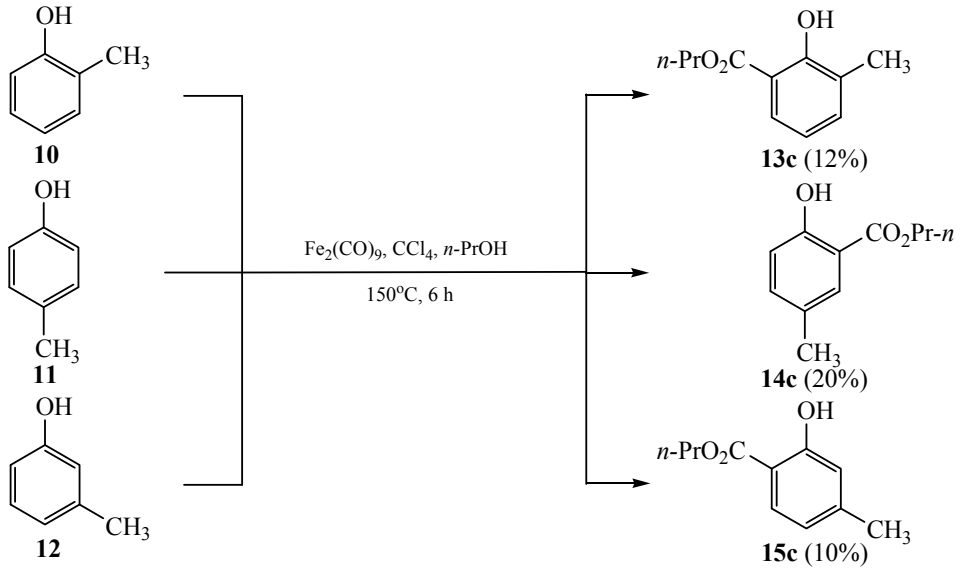
R = Me (**a**), Et (**b**), *n*-Pr (**c**), *n*-Bu (**d**).

Scheme 3.



7 **8c** (24%) **9c** (76%)

Scheme 4.



The reaction of phenol **1** with carbon tetrachloride and aliphatic alcohols (MeOH, EtOH, PrOH, BuOH) in the presence of an iron catalyst [130°C, 4–8 h, molar ratio Fe–phenol–CCl_4–alcohol = (1–10) : 100 : (100–1000) : (100–1000)] afforded 2-hydroxybenzoic (salicylic) and 4-hydroxybenzoic acid esters **2a**–**2d** and **3a**–**3d** (Scheme 1).

The optimal conditions, including reactant and catalyst concentrations, were determined using the reaction of phenol with propan-1-ol and CCl_4 as model reaction. The following iron compounds were tested as catalysts: $FeBr_3$, $FeCl_3 \cdot 6H_2O$, $Fe_2(CO)_9$, $FeCl_2$, $FeCl_3$, $Fe(acac)_3$, $FeCl_2 \cdot 4H_2O$] (Table 1). No reaction occurred in the absence of a catalyst. The most efficient catalyst for the alkoxycarbonylation of phenol was $Fe_2(CO)_9$. When the molar ratio $Fe_2(CO)_9$–PhOH–CCl_4–PrOH was 5 : 100 : 500 : 500, the conversion of phenol was 100%, and the yields of propyl esters **2c** and **3c** were 34 and 66%, respectively. The quantitative overall yield of **2c** and **3c** was achieved in 6 h.

Anisole (**4**) readily reacted with CCl_4 and PrOH in the presence of iron catalysts to give a mixture of propyl 2-methoxybenzoate (**5c**) and propyl 4-methoxybenzoate (**6c**). The most efficient catalysts were $FeBr_3$ and $FeCl_3 \cdot 6H_2O$ (Table 2). The overall yield of **5c** and **6c** was 91% (1 : 5) in the presence of

Table 1. Reaction of phenol with alcohols and carbon tetrachloride in the presence of iron catalysts[a]

Catalyst	ROH	Molar ratio [Fe] : [PhOH] : [CCl_4] : [ROH]	Yield, %	
			2a–2d	**3a–3d**
$Fe_2(CO)_9$	PrOH	5 : 100 : 500 : 500	34	66
$FeCl_3 \cdot 6H_2O$	″	1 : 100 : 500 : 500	13	5
$FeCl_2 \cdot 4H_2O$	″	10 : 100 : 1000 : 1000	10	17
$FeCl_3$	″	″	19	59
	″	1 : 100 : 500 : 500	6	7
$FeBr_3$	″	10 : 100 : 1000 : 1000	14	26
$FeCl_2$	″	1 : 100 : 500 : 500	20	22
$FeBr_2$	″	″	22	20
$Fe(acac)_3$	″	10 : 100 : 1000 : 1000	35	65
	″	10 : 100 : 500 : 500	28	43
	″	1 : 100 : 1000 : 1000	9	26
	″	1 : 100 : 500 : 500	7	15
$Fe_2(CO)_9$	″	10 : 100 : 1000 : 1000	40	60
	″	1 : 100 : 1000 : 1000	17	32
	″	10 : 100:300:300	30	50
	″	1 : 100 : 500 : 500	24	29
	″	5 : 100 : 500 : 500	34	66
	″	″	25[b]	41[b]
	″	″	31[c]	59[c]
	MeOH	5 : 100 : 500 : 500	18	20
	EtOH	″	28	45
	BuOH	″	38	62

[a] 130°C, 6 h. [b] 130°C, 4 h. [c] 130°C, 8 h.

$FeCl_3 \cdot 6H_2O$ and 100% (1 : 3.3) in the presence of $FeBr_3$ (Fe–**4**–CCl_4–PrOH molar ratio 1 : 100 : 500 : 500; 30°C, 6 h). Under analogous conditions, the reactions of **4** with methanol, ethanol, and butan-1-ol gave methyl (**5a**, **6a**), ethyl (**5b**, **6b**), and butyl methoxybenzoates (**5d**, **6d**) (Scheme 2, Table 2).

Likewise, by reaction of phenetole (**7**) with CCl_4 and PrOH in the presence of $FeBr_3$ we obtained propyl 2- and 4-ethoxybenzoates **8c** and **9c** in 24 and 76% yields, respectively (Scheme 3).

Unlike phenol (**1**), cresols **10**–**12** reacted with carbon tetrachloride and alcohols in a non-selective manner, regardless of the iron catalyst. The conditions were optimized using the reaction of *o*-cresol (**10**) with propanol and carbon tetrachloride catalyzed by $FeBr_3$, $Fe_2(CO)_9$, $FeCl_2$, $FeCl_3$, and $Fe(acac)_3$. There was no reaction in the absence of a catalyst. In the reaction catalyzed by $Fe_2(CO)_9$ at a $Fe_2(CO)_9$–**10**–CCl_4–PrOH molar ratio of 10 : 100 : 300 : 300 (150°C, 6 h), propyl 2-hydroxy-3-methylbenzoate **13c** was formed in s 12% yield (Scheme 4), whereas the main part of the substrate was converted to tars.

Under analogous conditions, from *p*- and *m*-cresols **11** and **12** we obtained propyl 2-hydroxy-5-methylbenzoate (**14c**) and propyl 2-hydroxy-4-methylbenzoate (**15c**) in 20 and 10% yields, respectively. The

Table 2. Reaction of anisole with alcohols and carbon tetrachloride in the presence of iron catalysts[a]

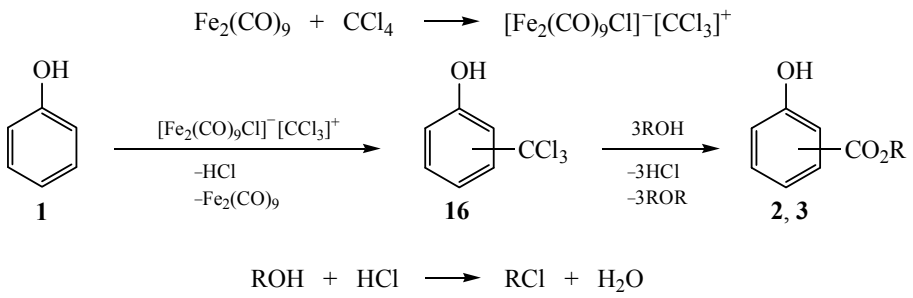
Catalyst	ROH	Molar ratio Fe : PhOMe : CCl_4 : ROH	Yield, %	
			5a–5d	**6a–6d**
$FeCl_3 \cdot 6H_2O$	PrOH	10 : 100 : 1000 : 1000	37	62
	″	1 : 100 : 1000 : 1000	27	46
	″	1 : 100 : 500 : 500	15	76
	MeOH	"	4	19
	EtOH	"	5	54
	BuOH	"	9	46
$Fe_2(CO)_9$	PrOH	10 : 100 : 1000 : 1000	37	42
	″	1 : 100 : 1000 : 1000	27	73
	″	10 : 100 : 500 : 500	24	76
	″	1 : 100 : 500 : 500	13	48
$FeCl_3$(anhydrous)	″	10 : 100 : 1000 : 1000	14	47
$FeBr_3$	″	″	15	77
	″	10 : 100 : 500 : 500	40	51
	″	1 : 100 : 1000 : 1000	35	65
	″	1 : 100 : 500 : 500	23	77
	″	1 : 100:400:400	22	37
	″	1 : 100:200:200	22	54
	″	1 : 100 : 100 : 100	14	36
	″	1 : 100 : 500 : 500	6[b]	36[b]
	″	″	21[c]	79[c]
	MeOH	″	15	46
	EtOH	″	2	17
	PrOH	″	23	77
	BuOH	″	12	82
$FeCl_2$	PrOH	″	23	43
$FeBr_2$	"	″	20	36
$Fe(acac)_3$	"	″	24	34
$FeCl_2 \cdot 4H_2O$	"	″	35	56
$Fe(OAc)_2$	"	″	14	36
$Fe(OAc)_2 \cdot 4\ H_2O$	"	″	8	17

[a] 130°C, 6 h. [b] 130°C, 4 h. [c] 130°C, 8 h.

substrate conversion was complete, and a large amount of tarry products was formed. In all cases, the formation of hydrogen chloride and ethers derived from the corresponding alcohols was observed.

Taking into account the composition of the reaction products, the following mechanism of formation of ester group may be proposed. In the first stage, phenol **1** is alkylated with carbon tetrachloride, and the

Scheme 5.



resulting isomeric trichloromethylphenols **16** undergo alcoholysis to give esters **2** and **3** (Scheme 5).

In summary, we have developed a new method for the introduction of ester group into phenol, anisole, phenetole, and *o*-, *p*-, and *m*-cresol molecule via iron-catalyzed reaction with carbon tetrachloride and alcohols. The product structure was confirmed by NMR and mass spectra, as well as by comparing with authentic samples and reference data.

EXPERIMENTAL

The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance-400 spectrometer at 400.13 and 100.62 MHz, respectively, using $CDCl_3$ as solvent and tetramethylsilane as internal standard. The mass spectra were obtained on a Shimadzu GCMS-QP 2010Plus instrument (SPB-5 capillary column, 30 m × 0.25 mm, carrier gas helium; oven temperature programming from 40 to 300°C at a rate of 8 deg/min; injector temperature 280°C, ion source temperature 200°C; electron impact, 70 eV). Gas chromatographic analysis was performed with Shimadzu GC-9A and GC-2014 instruments (2-m × 3-mm column packed with 5% SE-30 on Chromaton N-AW-HMDS; oven temperature programming from 50 to 270°C at a rate of 8 deg/min; carrier gas helium, flow rate 47 mL/min). Gaseous products were analyzed using a Shimadzu GCMS-QP2010Ultra instrument (Supel-Q PLOT caipllary column, 30 m × 0.53 mm; oven temperature programming from 37 to 250°C at a rate of 10 deg/min; carrier gas helium, flow rate 3 mL/min; ion source temperature 200°C, electron impact, 70 eV).

Commercial solvents and reagents of analytical grade were used.

Alkyl esters of hydroxy-, methoxy-, and ethoxybenzoic and cresotic acids 2a–2d, 3a–3d, 5a–5d, 6a–6d, 8c, 9c, 13c, 14c, and 15c *(general procedure)*. The reactions were carried out in 10-mL glass ampules which were placed in a 17-mL stainless-steel high-pressure micro reactor with controlled heating. An ampule was charged under argon with 1–10 mmol of the catalyst [$FeCl_3$, $FeBr_3$, $FeCl_2$, $FeBr_2$, $FeCl_3·6H_2O$, $FeCl_3·4H_2O$, Fe(acac), or $Fe_2(CO)_9$], 100 mmol of phenol, anisole, phenetole, or *o*-, *m*-, or *p*-cresol, 100–1000 mmol of CCl_4, and 100–1000 mmol of methanol, ethanol, propan-1-ol, or butan-1-ol. The ampule was sealed and placed into the reactor which was hermetically closed and heated for 4–8 h at 130°C with continuous stirring. The reactor was cooled to 20°C, the ampule was opened, and the mixture was neutralized with Na_2CO_3, treated with boiling petroleum ether for 10–15 min, and filtered through a filter paper. The solvent was distilled off, and the residue was distilled under reduced pressure or subjected to chromatography in a column (h = 21, d = 1.2 cm) charged with silica gel using petroleum ether as eluent. Analytical samples were obtained by recrystallization from ethanol.

Methyl 2-hydroxybenzoate (2a). Yield 18%, bp 100–102°C (12 mm); published data [13]: bp 40–50°C (3 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.95 s (3H, CH_3), 6.95–7.20 m (1H, 5-H), 6.90–7.20 m (1H, 3-H), 7.40–7.60 m (1H, 4-H), 7.90–8.0 m (1H, 6-H), 10.98 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 52.52 (OCH_3), 112.46 (C^1), 117.58 (C^3), 119.58 (C^5), 130.09 (C^6), 135.98 (C^4), 161.22 (C^2), 170.86 (C=O). Mass spectrum, m/z (I_{rel}, %): 152 (40) $[M]^+$, 120 (100), 92 (60), 65 (20), 53 (5).

Ethyl 2-hydroxybenzoate (2b). Yield 28%, bp 106–108°C (12 mm); published data [14]: bp 125–130°C (18 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.57–1.63 m (3H, CH_3), 4.37–4.45 m (2H, OCH_2), 6.95–6.97 m (1H, 5-H), 6.95–6.97 m (1H, 3-H), 7.46–7.50 m (1H, 4-H), 7.89 d (1H, 6-H, J = 8 Hz), 10.96 br. s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 14.21 ($CH_2\mathbf{C}H_3$), 61.56 (OCH_2), 115.60 (C^1), 117.55 (C^3),

119.27 (C^5), 129.90 (C^6), 135.70 (C^4), 161.52 (C^2), 171.02 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 166 (30) $[M]^+$, 138 (15), 120 (100), 92 (30), 65 (15), 41 (10).

Propyl 2-hydroxybenzoate (2c). Yield 34%, bp 120–122°C (12 mm); published data [15]: bp 238–240°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.65–1.2 m (3H, CH_3), 1.75–1.90 m (2H, C**H**$_2$CH$_3$), 4.25–4.40 m (2H, OCH_2), 6.70–7.20 m (1H, 5-H), 6.93 d (1H, 3-H, *J* = 6.9 Hz), 7.20–7.55 m (1H, 4-H), 7.83 d (1H, 6-H, *J* = 8.0 Hz), 10.94 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 10.45 (CH$_2$**C**H$_3$), 21.98 (**C**H$_2$CH$_3$), 66.65 (OCH_2), 115.30 (C^1), 117.75 (C^3), 119.26 (C^5), 129.93 (C^6), 135.68 (C^4), 161.49 (C^2), 170.37 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 180 (15) $[M]^+$, 138 (15), 120 (100), 92 (30), 65 (15), 41 (10).

Butyl 2-hydroxybenzoate (2d). Yield 38%, bp 145–147°C (16 mm). Published data [15]: bp 259–260°C. ^{1}H NMR spectrum ($CDCl_3$), δ_C, ppm: 0.70–1.1 m (3H, CH_3), 1.20–1.70 m (2H, C**H**$_2$CH$_3$), 1.65–1.80 m (2H, OCH$_2$C**H**$_2$), 4.20–4.45 m (2H, OCH_2), 6.90 t (1H, 5-H, *J* = 7.6 Hz), 7.24 br.s (1H, 3-H), 7.47 t (1H, 4-H, *J* = 7.6 Hz), 7.95 br.s (1H, 6-H), 10.90 br.s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 18.87 (CH$_2$**C**H$_3$), 19.29 (**C**H$_2$CH$_3$), 30.59 (OCH$_2$**C**H$_2$), 64.70 (OCH_2), 115,25 (C^1), 117.54 (C^3), 119.17 (C^5), 129.89 (C^6), 135.62 (C^4), 161.57 (C^2), 170.30 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 194 (20) $[M]^+$, 138 (25), 120 (100), 92 (20), 65 (15), 41 (10).

Methyl 4-hydroxybenzoate (3a). Yield 20%, mp 129–131°C; published data [15]: mp 131°C, bp 270–280°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.99 s (3H, CH_3), 5.31 br.s (1H, OH), 6.90–7.2 m (2H, 3-H, 5-H), 7.91–7.99 m (2H, 2-H, 6-H). ^{13}C NMR spectrum, δ_C, ppm: 52.42 (OCH_3), 115.49 (C^3, C^5), 121.83 (C^1), 132.82 (C^2, C^6), 160.67 (C^4), 168.32 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 152 (30) $[M]^+$, 121 (100), 93 (25), 65 (20), 53 (2).

Ethyl 4-hydroxybenzoate (3b). Yield 45%, mp 115–116°C; published data [15]: mp 116°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.39–1.47 m (3H, CH_3), 4.37–4.46 m (2H, C**H**$_2$CH$_3$), 5.31 br.s (1H, OH), 6.87–6.89 m (2H, 3-H, 5-H), 7.97 d (2H, 2-H, 6-H, *J* = 7.2 Hz). ^{13}C NMR spectrum, δ_C, ppm: 14.32 (CH_3), 61.15 (OCH_2), 115.31 (C^3, C^5), 122.43 (C^1), 131.97 (C^2, C^6), 160.30 (C^4), 167.31 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 166 (15) $[M]^+$, 138 (45), 121 (100), 93 (15), 65 (25), 41 (5).

Propyl 4-hydroxybenzoate (3c). Yield 66%, mp 95–97°C; published data [16]: mp 93–95°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.65–1.2 m (3H, CH_3), 1.75–1.90 m (2H, C**H**$_2$CH$_3$), 4.25–4.40 m (2H, OCH_2), 5.31 br.s (1H, OH), 6.88 d (2H, 3-H, 5-H, *J* = 7.8 Hz), 7.97 d (2H, 2-H, 6-H, *J* = 8.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 10.52 (CH_3), 22.11 (**C**H$_2$CH$_3$), 67.03 (OCH_2), 115.38 (C^3, C^5), 120.62 (C^1), 131.93 (C^2, C^6), 160.45 (C^4), 167.31 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 180 (5) $[M]^+$, 138 (45), 121 (100), 93 (15), 65 (29), 41 (5).

Butyl 4-hydroxybenzoate (3d). Yield 62%, mp 65–67°C; published data [17]: mp 64–66°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.70–1.1 m (3H, CH_3), 1.20–1.70 m (2H, C**H**$_2$CH$_3$), 1.65–1.80 m (2H, OCH$_2$C**H**$_2$), 4.20–4.45 m (2H, OCH_2), 5.31 br.s (1H, OH), 6.99 d (2H, 3-H, 5-H, *J* = 8.4 Hz), 7.87 d (2H, 2-H, 6-H, *J* = 8.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 18.87 (CH_3), 19.33 (**C**H$_2$CH$_3$), 30.81 (OCH$_2$**C**H$_2$), 65.27 (OCH_2), 115.37 (C^3, C^5), 120.35 (C^1), 131.83 (C^2, C^6), 160.71 (C^4), 166.99 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 194 (10) $[M]^+$, 138 (80), 121 (100), 93 (15), 65 (20), 41 (10).

Methyl 2-methoxybenzoate (5a). Yield 15%, bp 118–120°C (12 mm); published data [18]: bp 76–78°C (1 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.81 s (3H, OCH_3), 3.99 s (3H, OCH_3), 7.0–7.24 m (1H, 3-H), 7.0–7.24 m (1H, 4-H), 7.45–7.60 m (1H, 4-H), 7.92 d (1H, 6-H, *J* = 8.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 53.44 (OCH_3), 55.95 (2-OCH_3), 112.05 (C^3), 120.17 (C^5), 120.51 (C^1), 129.63 (C^6), 133.62 (C^4), 159.23 (C^2), 166.15 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 166 (25) $[M]^+$, 135 (100), 120 (5), 92 (15), 77 (60), 51 (20), 45 (2).

Ethyl 2-methoxybenzoate (5b). Yield 32%, bp 135–136°C (12); published data [15]: bp 246–248°C (732 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.38 t (3H, CH$_2$C**H**$_3$, *J* = 8.0 Hz), 3.93 s (3H, OCH_3) 4.30–4.45 m (2H, OCH_2), 6.95–7.5 m (1H, 5-H), 6.95–7.5 m (1H, 3-H), 7.45–7.55 m (1H, 4-H), 7.81 d (1H, 6-H, *J* = 6.4 Hz). ^{13}C NMR spectrum, δ_C, ppm: 14.32 (CH$_2$**C**H$_3$), 55.99 (OCH_3), 60.80 (OCH_2), 112.06 (C^3), 120.50 (C^1), 120.55 (C^5), 131.48 (C^6), 133.32 (C^4), 159.13 (C^2), 166.38 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 180 (10) $[M]^+$, 165 (2), 135 (100), 133 (45), 105 (20), 77 (45), 64 (10), 51 (10).

Propyl 2-methoxybenzoate (5c). Yield 40%, bp 140–146°C (10 mm); published data [19]: bp 114.8–115.5°C (1.5 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.03 t (3H, CH$_2$C**H**$_3$, *J* = 6.0 Hz), 1.72–1.84 m (2H, C**H**$_2$CH$_3$), 3.91 s (3H, OCH_3), 4.23–4.28 m (2H, OCH_2), 6.95–7.02 m (1H, 5-H), 6.99–7.02 m (1H,

3-H), 7.42–7.50 m (1H, 4-H), 7.77–7.85 m (1H, 6-H). ^{13}C NMR spectrum, δ_C, ppm: 10.53 ($CH_2\mathbf{C}H_3$), 22.16 ($\mathbf{C}H_2CH_3$), 55.94 (OCH_3), 66.40 (OCH_2), 112.02 (C^3), 117.54 (C^1), 120.83 (C^5), 133,31 (C^6), 135.57 (C^4), 159.11 (C^2), 166.34 (COO). Mass spectrum, *m*/*z* (I_{rel}, %): 194 (15) $[M]^+$, 152 (5), 135 (100), 123 (30), 105 (25), 77 (40), 64 (7), 51 (10).

Butyl 2-methoxybenzoate (5d). Yield 12%, bp 120–122°C (2 mm); published data [19]: bp 112°C (1.2 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.90–1.0 m (3H, $CH_2C\mathbf{H}_3$), 1.45–1.80 m (2H, $C\mathbf{H}_2CH_3$), 1.45–1.80 m (2H, $OCH_2C\mathbf{H}_2$), 3.90 s (3H, OCH_3), 4.25–4.35 m (2H, OCH_2), 6.8–7.0 m (1H, 5-H), 6.8–7.0 m (1H, 3-H), 7.40–7.50 m (1H, 4-H), 7.79 d (1H, 6-H, J = 8.8 Hz). ^{13}C NMR spectrum, δ_C, ppm: 13.84 ($CH_2\mathbf{C}H_3$), 18.90 ($\mathbf{C}H_2CH_3$), 30.74 ($OCH_2\mathbf{C}H_2$), 55.90 (OCH_3), 62.63 (OCH_2), 112.03 (C^3), 120.07 (C^5), 120.62 (C^1), 132.14 (C^6), 133.35 (C^4), 159.14 (C^2), 166.39 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 208 (15) $[M]^+$, 152 (10), 105 (25), 92 (20), 77 (40), 51 (5), 41 (10).

Methyl 4-methoxybenzoate (6a). Yield 46%, bp 123–124°C (10 mm); published data [15]: bp 256°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.89 s (3H, OCH_3), 3.94 s (3H, OCH_3), 6.92–7.0 m (2H, 3-H, 5-H), 8.05 d (2H, 2-H, 6-H, J = 8.8 Hz). ^{13}C NMR spectrum, δ_C, ppm: 51.91 (OCH_3), 55.41 (4-OCH_3), 113.66 (C^3, C^5), 121.51 (C^1), 131.65 (C^2, C^6), 163.63 (C^4), 167.06 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 166 (30) $[M]^+$, 135 (100), 107 (15), 92 (15), 77 (25), 64 (15).

Ethyl 4-methoxybenzoate (6b). Yield 68%, bp 133–134°C (10 mm); published data [15]: bp 263°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.38 t (3H, $CH_2C\mathbf{H}_3$, J = 8.0 Hz), 3.88 s (3H, OCH_3), 4.30–4.35 m (2H, OCH_2), 6.9 d (2H, 3-H, 5-H, J = 8.8 Hz), 8.03 d (2H, 2-H, 6-H, J = 8.8 Hz). ^{13}C NMR spectrum, δ_C, ppm: 14.39 ($CH_2\mathbf{C}H_3$), 55.24 (OCH_3), 60.64 (OCH_2), 113.55 (C^3, C^5), 122.98 (C^1), 131.54 (C^2, C^6), 163.26 (C^4), 166.42 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 180 (30) $[M]^+$, 165 (2), 152 (15), 135 (100), 107 (10), 92 (15), 77 (20), 64 (5).

Propyl 4-methoxybenzoate (6c). Yield 78%, bp 112–115°C (2 mm); published data [15]: bp 176°C (45 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.05 t (3H, $CH_2C\mathbf{H}_3$, J = 7.6 Hz), 1.7–1.85 m (2H, $C\mathbf{H}_2CH_3$), 3.88 s (3H, OCH_3), 4.27 t (2H, OCH_2, J = 6.8 Hz), 6.93 d (2H, 3-H, 5-H, J = 8.0 Hz), 8.02 d (2H, 2-H, 6-H, J = 8.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 10.54 ($CH_2\mathbf{C}H_3$), 22.17 ($\mathbf{C}H_2CH_3$), 55.41 (OCH_3), 66.24 (OCH_2), 113.55 (C^3, C^5), 122.9 (C^1), 131.54 (C^2, C^6), 163.50 (C^4), 166.46 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 194 (15) $[M]^+$, 152 (50), 135 (100), 121 (5), 107 (10), 77 (20), 64 (5), 51 (10).

Butyl-4-methoxybenzoate (6d). Yield 82%, bp 124–126°C (2 mm); published data [15]: bp 183°C (40 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.98 t (3H, $CH_2C\mathbf{H}_3$, J = 7.2 Hz), 1.45–1.80 m (2H, $C\mathbf{H}_2CH_3$), 1.45–1.80 m (2H, $OCH_2C\mathbf{H}_2$), 3.85 s (3H, OCH_3), 4.25–4.35 m (2H, OCH_2), 6.92 d (2H, 3-H, 5-H, J = 8.4 Hz), 8.01 d (2H, 2-H, 6-H, J = 8.8 Hz). ^{13}C NMR spectrum, δ_C, ppm: 13.75 ($CH_2\mathbf{C}H_3$), 19.28 ($\mathbf{C}H_2CH_3$), 30.82 ($OCH_2\mathbf{C}H_2$), 55.37 (OCH_3), 64.54 (OCH_2), 113.55 (C^3, C^5), 122.92 (C^1), 131.52 (C^2, C^6), 163.27 (C^4), 166.51 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 208 (15) $[M]^+$, 152 (90), 135 (100), 107 (15), 92 (20), 77 (25), 64 (10), 41 (10).

Propyl 2-ethoxybenzoate (8c). Yield 40%, bp 112–114°C (1 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.05 t (3H, CH_3, J = 6.0 Hz), 1.41 t ($OCH_2C\mathbf{H}_3$, J = 6.2 Hz), 1.73–1.87 m (2H, $CH_2C\mathbf{H}_2CH_3$), 4.05 q ($OC\mathbf{H}_2$·CH_3, J = 6.4 Hz), 4.20–4.29 m (2H, $OC\mathbf{H}_2CH_2CH_3$), 6.95–7.04 m (1H, 5-H), 6.97–7.03 m (1H, 3-H), 7.40–7.49 m (1H, 4-H), 7.75–7.85 m (1H, 6-H). ^{13}C NMR spectrum, δ_C, ppm: 10.56 ($CH_2CH_2\mathbf{C}H_3$), 15.65 (OCH_2·$\mathbf{C}H_3$), 22.36 ($CH_2\mathbf{C}H_2CH_3$), 65.42 ($O\mathbf{C}H_2CH_3$), 66.54 ($O\mathbf{C}H_2CH_2CH_3$), 112.18 (C^3), 118.07 (C^1), 120.87 (C^5), 133.58 (C^6), 135.69 (C^4), 159.53 (C^2), 166.59 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 208 (15) $[M]^+$, 194 (10), 152 (5), 135 (100), 123 (34), 105 (30), 77 (44), 64 (5), 51 (10).

Propyl 4-ethoxybenzoate (9c). Yield 78%, bp 125–127°C (2 mm); published data [20]: bp 155–157°C (14 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.08 t (3H, CH_3, J = 7.4 Hz), 1.36 t ($OCH_2C\mathbf{H}_3$, J = 6.2 Hz), 1.72–1.87 m (2H, $CH_2C\mathbf{H}_2CH_3$), 4.01 q ($OC\mathbf{H}_2CH_3$, J = 6.4 Hz), 4.36 t (2H, $OC\mathbf{H}_2CH_2CH_3$, J = 6.8 Hz), 6.97 d (2H, 3-H, 5-H, J = 8.0 Hz), 8.08 d (2H, 2-H, 6-H, J = 8.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 10.55 ($CH_2CH_2\mathbf{C}H_3$), 13.98 ($OCH_2\mathbf{C}H_3$), 22.24 ($CH_2\mathbf{C}H_2CH_3$), 62.58 ($O\mathbf{C}H_2CH_3$), 66.63 ($O\mathbf{C}H_2CH_2CH_3$), 113.78 (C^3, C^5), 122.86 (C^1), 131.58 (C^2, C^6), 164.11 (C^4), 166.89 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 208 (15) $[M]^+$, 194 (10), 152 (50), 135 (100), 121 (8), 107 (10), 77 (21), 64 (8), 51 (12).

Propyl 2-hydroxy-3-methylbenzoate (13c). Yield 10%, bp 122–125°C (6 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.06 t (3H, $CH_2C\mathbf{H}_3$, J = 7.2 Hz), 1.77–1.86 m (2H, $C\mathbf{H}_2CH_3$), 2.29 s (3H, 3-CH_3), 4.32 t (2H, OCH_2, J = 6.6 Hz), 6.90 t (1H, 5-H, J = 8 Hz), 7.33 d (1H, 6-H, J = 7.24 Hz), 7.73 d (1H, 4-H, J =

7.24 Hz). ^{13}C NMR spectrum, δ_C, ppm: 10.52 ($CH_2\mathbf{C}H_3$), 15.66 (3-CH_3), 22.03 ($CH_2\mathbf{C}H_2CH_3$), 66.89 (OCH_2), 114.67 (C^3), 118.61 (C^5), 126.61 (C^1), 127.43 (C^4), 136.52 (C^6), 165.47 (C^2), 172.2 (C=O). Mass spectrum, m/z (I_{rel}, %): 194 (10) $[M]^+$, 152 (45), 135 (100), 107 (25), 77 (40), 51 (5), 41 (10).

Propyl 4-hydroxy-5-methylbenzoate (14c). Yield 98%, bp 125–127°C (6 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.0 t (3H, $CH_2C\mathbf{H}_3$, J = 8.0 Hz), 1.48–1.7 m (2H, $C\mathbf{H}_2CH_3$), 2.32 s (3H, 5-CH_3), 4.33 t (2H, OCH_2, J = 6.4 Hz), 6.9 d (1H, 5-H, J = 8.4 Hz), 7.20–7.30 m (1H, 6-H), 7.66 s (1H, 2-H), 10.67 s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 10.47 ($CH_2\mathbf{C}H_3$), 20.40 (5-CH_3), 22.0 ($\mathbf{C}H_2CH_3$), 66.82 (OCH_2), 112.19 (C^3), 117.33 (C^5), 128.24 (C^1), 129.51 (C^2), 136.55 (C^6), 159.57 (C^4), 170.28 (C=O). Mass spectrum, m/z (I_{rel}, %): 194 (30) $[M]^+$, 152 (10), 134 (100), 121 (5), 106 (20), 77 (20), 63 (5), 50 (2).

Propyl 3-hydroxy-4-methylbenzoate (15c). Yield 10%, bp 124–126°C (6 mm). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.06 t (3H, $CH_2C\mathbf{H}_3$, J = 6.4 Hz), 1.78–1.88 m (2H, $C\mathbf{H}_2CH_3$), 2.36 s (3H, 4-CH_3), 4.32 t (2H, OCH_2, J = 4.9 Hz), 6.73 d (1H, 6-H), 6.83 s (1H, 2-H), 7.75 d (1H, 5-H), 10.85 s (1H, OH). ^{13}C NMR spectrum, δ_C, ppm: 11.01 ($CH_2\mathbf{C}H_3$), 21.98 ($\mathbf{C}H_2CH_3$), 22.01 (4-CH_3), 66.74 (OCH_2), 110.10 (C^4), 117.70 (C^2), 120.43 (C^6), 129.41 (C^5), 146.94 (C^1), 161.56 (C^3), 170.31 (C=O). Mass spectrum, m/z (I_{rel}, %): 194 (22) $[M]^+$, 152 (11), 134 (100), 121 (6), 106 (25), 77 (25), 51 (5).

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