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Enantioresolution of a Series of Chiral Benzyl Alcohols by HPLC on a Dinitrobenzoylphenylglycine Stationary Phase after Achiral Pre-Column Derivatization*

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Abstract

High performance liquid chromatography method for the separation of a series of chiral benzyl alcohols on *N*-(3,5-dinitrobenzoyl)-*D*-phenylglycine stationary phase (Macherey Nagel, Chiral-2) after pre-column achiral derivatization was developed. Cheap and easy available aromatic acid chlorides were used as derivatization agents. Good to excellent separations of the enantiomers were achieved in all cases in relatively short analytical runs. It was shown that the enantiorecognition depends on the substituents both in the starting alcohol and in the acid chloride. The method presents an efficient alternative to the direct analyses on polysaccharide and cyclodextrine-derived stationary phases.

Keywords: HPLC, DNBPG, Enantioseparation, Benzyl Alcohols, Achiral Pre-Column Derivatization, Benzoates, Chlorobenzoates, Naphthoates

1. Introduction

Chiral benzyl alcohols are an important class of organic compounds, which exist as structural subunits in many natural and biologically active compounds. They are also widespread products from variety of test transformations used for determination of asymmetric induction caused by different asymmetric catalysts [1-7]. Therefore; the determination of the enantiomeric purity of the products is a crucial step in the preparation of single-enantiomer drugs and chiral catalysts and the development of new and more versatile methods continues to attract attention.

High performance liquid chromatography (HPLC) on chiral stationary phases (CSPs) is among the most general and powerful techniques for separation of optical isomers [8-13]. The efficiency of the separation is strongly dependant on the structure of the stationary phase (SP) used. Of the numerous CSPs available on the market, Brush- type or Pirkle-type columns, containing a low-molecular-weight chiral molecule (chiral selector) covalently bound to the silica gel surface, are the most widely investigated [14-16]. Among them, the phases based on derivatives of α-amino acids, inexpensive and readily available enantiomerically pure materials, are the most broadly exploited. "Pirkle I-phases" based on dinitrobenzoylphenylglycine (DNBPG) selector, covalently bonded to aminopropyl silica via a spacer, are one of the first and intensively used. The main advantages of these phases are the relatively low cost of the columns and their availability in both enantiomeric forms, which is of great importance for trace analysis where the small peak should be eluted first. However, their application is limited in respect to analyte character. DNBPG has two amide groups, which can undergo dipole-dipole interactions and/or hydrogen bonding with suitable molecules. As these interactions are responsible for the separation, the phases are generally inefficient for direct analysis of some important classes of compounds, such as amines, amino acids, alcohols, amino alcohols, etc.

The enantiomeric distributions of chiral benzyl alcohols were usually analyzed by direct HPLC on polysaccharide [17-25] or cyclodextrine-derived [26-30] stationary phases, while the records on the application of Brush-type CSPs are quite limited. Enantiomers of arylalkylcarbinols have been resolved upon a CSP comprised of DNBPG ionically bonded directly to γ-aminopropyl silica [31-33]. Sterically congested diarylcarbinols have been resolved by using Pirkle DNBPG ionic or covalent columns and has suggested that the efficient enantiorecognition was achieved due to steric hindrance

*Dedicated to the 75th anniversary of Prof. Maria Lyapova

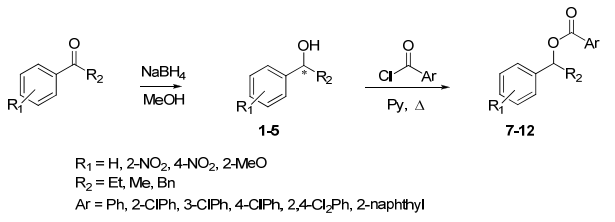
and hydrogen bonding [34]. Phenyl and anthranyl alkanols have been efficiently resolved on SPs with chiral quinidine-carbamate selectors [35-37]. Phases, obtained via immobilization of (*R*,*R*)-3,5-dinitrobenzoyl-1,2-diphenylethane-1,2-diamine with anchoring groups of varied length and structural type, have been efficiently applied in the enantiorecognition of a series of arylalkylcarbinols [38-42]. Such a CSP, (*S*,*S*)-Whelk-O 1, has been used both for the direct resolution of diarylmethanols and for their indirect analyzes as acetates and pivalates, the latter being more efficient [43]. Esters, carbonates and carbamates are among the most popular derivatives for indirect resolution of carbinols [44-50]. The diastereoisomers obtained after chiral derivatizations have been analyzed on a variety of phases [51-59], while achirally derivatized carbinols have resolved mainly on polysaccharide-derived CSPs [60-63] and only few articles reported on the application of Pirkle-type phases for the separation of ethers [64], esters [43,65], carbamates [66-68]. To the best of our knowledge, the enantiorecognition of 3,5-dinitro benzoates [65] is the only record in the literature on the resolution of chiral benzyl alcohols as esters of aromatic acids on DNBPG.

In this paper, we present an effective liquid chromatography method for enantioseparation of benzyl alcohols on one of the cheapest dinitrobenzoylphenylglycine chiral stationary phase (Macherey Nagel, Chiral-2) after achiral pre-column derivatizations as benzoates, chlorobenzoates and naphthoates. The protocol, we believe, is of practical significance as an alternative to the highly efficient direct enantiorecognitions on polysaccharide and cyclodextrine-derived phases.

2. Results and Discussion

A series of known racemic chiral benzyl alcohols **1-5** was obtained by reduction of the parent ketones with $NaBH_4$ according to a standard procedure. The alcohols were easily converted into the ester derivatives **7-11** by refluxing with an acid chloride in pyridine, as shown on **Scheme 1**.

These derivatization agents were chosen in an attempt to increase the interactions between the analyte and the π-acceptor DNBPG stationary phase. Two alternative work-up protocols were applied for the isolation of the products. When ethyl acetate was used for extraction, the esters **7-11** were isolated in high to excellent yields (80-95%) after purification by HPFC on silica gel. In the second scheme, hexane was used instead of ethyl acetate and the target derivatives were isolated in lower yields (50-65%) due to their limited solubility in hexane, but pure enough to be analyzed without chromatography purification, which shortened significantly the general analyzing process. Despite reducing the yield of the esters, the results are explicit as indicated by the same chromatograms obtained after both purification ways. The latter shows that the hexane extraction is the preferable work-up, except for alcohols available in a highly limited scale.



Scheme 1. Preparation of benzyl alcohols 1-5 and derivatives 7-12.

The ester derivatives **7-11** were analyzed by HPLC on Chiral-2 MN column, consisting DNBPG chiral selector, at 25℃ with mobile phases composed of hexane, *i*-propanol, and trifluoroacetic acid (TFA) in varied proportions. Excellent to very good separations were achieved in all cases (**Table 1**). The retention factors k_1 and k_2 were recalculated towards T_o, which was determined by using benzene as a standard. All resolution parameters were calculated by the software, adjacent to the apparatus, ChemStation for LC 3D Rev. B.01.01.

As a first series, the esters with phenyl alcohols **1-3**, derivatives possessing substituents only at the acid component, were analyzed. The derivatives **7-9** were eluted with hexane/iPr-OH/TFA 100:0.03:0.05 and effective separations were achieved in fast analytical runs, retention times of 5-16 min.

Our expectations were to observe better separation when increasing the π-character of the molecule; naphthoates vs benzoates, chlorobenzoates vs benzoates, dichlorobenzoates vs monochlorobenzoates. However, benzoates and naphthoates showed commensurable efficiency (**Table 1**), while a chlorine substituent led to better separation only when ortho-positioned (**7b-9b**), contrary to 3-chloro and 4-chlorobenzoates (**7c-9c** and **7d-9d**), which were the less effective derivatives. Moreover, the insertion of a second chlorine substituent led to lower resolution, **7e-9e** vs **7b-9b**. The best resolution factors within this series were obtained for 2-chlorobenzoates, 2.86, 2.07 and 1.85 for **7b**, **8b** and **9b**, followed by 2,4-dichlorobenzoates, 2.52, 1.82 and 1.48 for **7e**, **8e** and **9e**, respectively. The most effective enantioseparations are illustrated on **Figure 1**.

As a second series, the esters of alcohols containing nitro-substituent at the aromatic ring, **4** and **5**, were obtained and analyzed. To achieve effective combination separation/retention time, more polar mobile phase was used, hexane/iPr-OH/TFA 100:0.1:0.05. As seen on **Table 1**, the two groups of derivatives, **10a-10f** and **11a-11f**, follow different separation patterns. Commensurable resolution factors were obtained for the esters with 2-nitrophenyl alcohol **10a-10f**. The retention times of 25-

Table 1. Resolution of the enantiomers of the benzyl alcohol derivatives 7-12.

Alcohols			Derivatives		Resolution of the enantiomers[a]			
Compd	R_1	R_2	Compd	Ar	k_1	k_2	α	R_S
1	H	Et	**7a**	Ph	2.87	3.30	1.11	2.41
			7b	2-ClPh	4.05	4.69	1.13	2.86
			7c	3-ClPh	1.79	2.07	1.11	1.88
			7d	4-ClPh	1.90	2.20	1.11	1.83
			7e	2,4-Cl_2Ph	1.78	2.10	1.11	2.52
			7f	2-naphtyl	3.82	4.39	1.12	2.48
2	H	Me	**8a**	Ph	3.33	3.67	1.08	1.65
			8b	2-ClPh	4.68	5.21	1.09	2.07
			8c	3-ClPh	1.22	1.38	1.07	1.12
			8d	4-ClPh	0.83	0.91	1.05	1.01
			8e	2,4-Cl_2Ph	2.14	2.41	1.08	1.82
			8f	2-naphtyl	4.42	4.87	1.08	1.68
3	H	Bn	**9a**	Ph	3.55	3.83	1.07	1.42
			9b	2-ClPh	4.78	5.26	1.08	1.85
			9c	3-ClPh	1.55	1.67	1.05	1.08
			9d	4-ClPh	2.31	2.50	1.06	1.19
			9e	2,4-Cl_2Ph	2.19	2.40	1.07	1.48
			9f	2-naphtyl	4.79	5.18	1.07	1.21
4	2-NO_2	Me	**10a**	Ph	12.67	13.73	1.08	1.73
			10b	2-ClPh	8.49	9.24	1.08	1.79
			10c	3-ClPh	8.07	8.68	1.07	1.60
			10d	4-ClPh	8.63	9.28	1.07	1.75
			10e	2,4-Cl_2Ph	8.35	8.90	1.06	1.34
			10f	2-naphtyl	18.70	20.29	1.08	1.79
5	4-NO_2	Me	**11a**	Ph	15.33	16.26	1.06	1.34
			11b	2-ClPh	8.31	8.68	1.04	0.78
			11c	3-ClPh	7.10	7.43	1.04	0.97
			11d	4-ClPh	7.13	7.49	1.04	0.97
			11e	2,4-Cl_2Ph	7.93	8.25	1.04	0.78
			11f	2-naphtyl	14.34	15.25	1.06	1.32
6	2-MeO	Et	**12a**	Ph	1.08	1.33	1.17	1.23
			12b	2-ClPh	1.70	1.97	1.13	2.11
			12c	3-ClPh	0.76	0.93	1.15	1.65
			12d	4-ClPh	0.76	0.96	1.17	1.85
			12e	2,4-Cl_2Ph	0.79	0.96	1.14	1.47
			12f	2-naphtyl	1.98	2.39	1.18	3.22

[a]Flow rate: 1 mL/min; Detection: 280 nm UV; Column temperature: 25℃; Eluent: hexane/iPr-OH/TFA 100:0.03:0.05 for **7-9**; hexane/iPr-OH/TFA 100:0.1:0.05 for **10** and **11**; hexane/iPr-OH/TFA 100:0.5:0.05 for **12**; k_1: retention factor of the first eluted enantiomer; k_2: retention factor of the second eluted enantiomer; α: separation factor; R_S: resolution factor.

27 min were observed for **10b-10e**, while slower elution was detected for **10a** and **10f**, 36-40 and 53-57 min, respectively. These results show that the monochlorobenzoates **10b-10d** are the derivatives of choice within this series, **10b** being the preferable example. In the case of the esters with 4-nitrophenyl alcohol **5**, the simple benzoate **11a** and naphthoate **11f** showed the best resolution factors, 1.34 and 1.32, respectively (**Table 1**), while 2-chlorobenzoate **11b** and 2,4-dichlorobenzoate **11e** were the less effective derivatives, 0.78. Thus, **11a** and **11f** are the preferred derivatives of **5** despite the slower elution process in respect to **11b-11e**, 40-46 vs 21-26 min. The separations of the enantiomers of **10b** and **11a** are illustrated on **Figure 2**.

The method was further extended towards the non-racemic 1-(2-methoxyphenyl)propanol **6**, obtained by addition of diethylzink to the corresponding aldehyde in the presence of a chiral catalyst by our colleagues [69], who supplied us with a sample. The unknown ester derivatives **12a-12f** were obtained and purified via the same protocols (**Scheme 1**) and were afterward analyzed. Relatively polar mobile phase was used, hexane/iPr-OH/TFA 100:0.5:0.05, and efficient separations were achieved in very fast elution, 4-8 min. As seen on **Table 1**, benzoate **12a** was the less effective, 1.23, while the best separation was achieved for naphthoate **12f**, R_S 3.22, which is consistent with the initial expectations. Inside chlorinated derivatives, 2-chlorobenzoate **12b** showed the best resolution factor, while dichlorosubstituted compound **12e** was the less efficient. The chromatograms of the frontier examples **12a** and **12f** are given on **Figure 3**.

As seen, the separation is good enough even in the case of **12a** to be used for an explicit determination of the enantiomeric excess. The latter is confirmed by the fact that the obtained *ee* values of the derivatives **12a-12f** are in full congruence with the enantiomeric excess of the starting alcohol **6**, determined by chiral GC analysis [69]. The

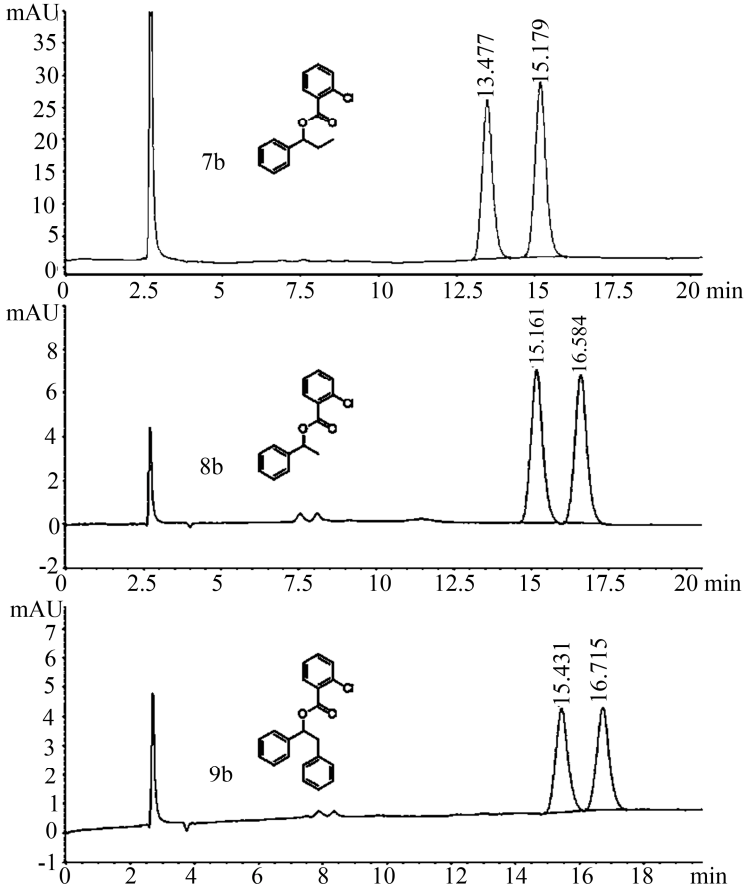


Figure 1. Chromatographic resolution of 1-phenyl-1-alkanol derivatives 7b, 8b and 9b.

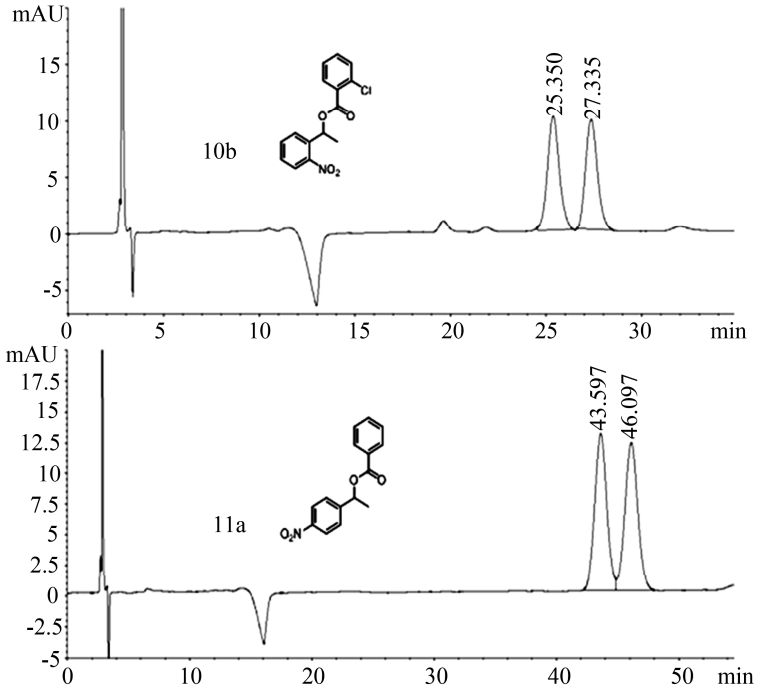


Figure 2. Chromatographic resolution of 1-(nitrophenyl)propanol derivatives 10b and 11a

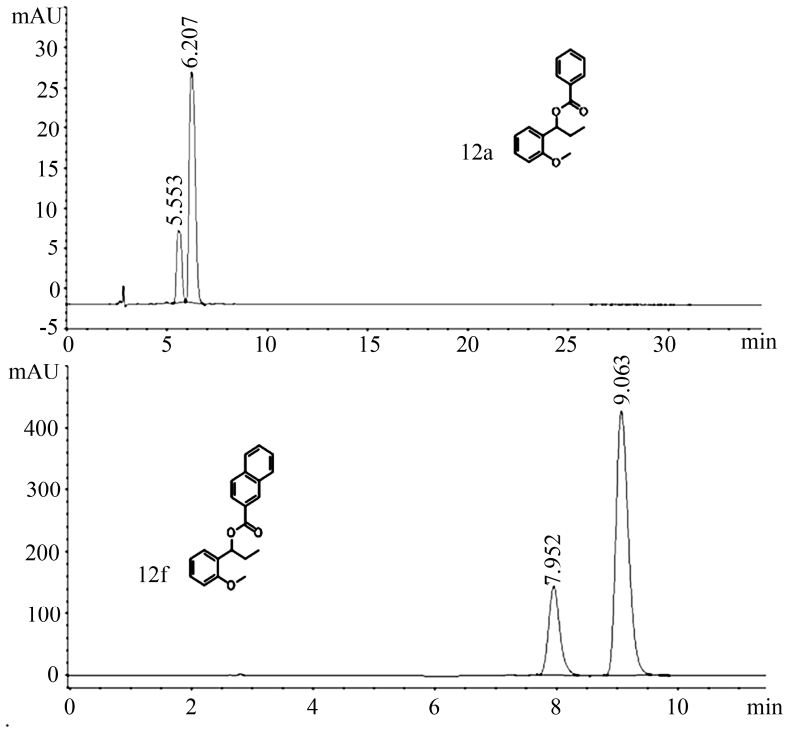


Figure 3. Chromatographic resolution of 1-(2-methoxyphenyl)propanol derivatives 12a and 12f.

appearance of the minor (*R*)-isomer as a first signal presents an additional advantage of the particular analysis protocol especially when high degree of enantioselectivity is achieved. The same pattern is valid for the non-racemic derivatives **7**, where the minor (*R*)-enantiomer elutes first.

3. Conclusions

A series of chiral racemic benzyl alcohols and a non-racemic example were analyzed by liquid chromatography on DNBPG stationary phases after achiral pre-column derivatization. Bulk chemistry acid chlorides were used as derivatization agents and the corresponding esters were obtained in high yields after fast and simple synthetic protocol. Good to excellent separations of the enantiomers were achieved in all cases in relatively short analytical runs. The presented method gives possibility to determine the enantiomeric purity or enantioselectivity in the preparation of benzyl alcohols on one of the cheapest and widely exploited stationary phases in a fast, simple, and explicit procedure. Despite being slower than the direct enantiorecognition, we believe, the protocol should be useful to the synthetic community as an alternative way, especially when other chiral columns are not available in the laboratory. Additionally, the obtained broad library of chiral benzyl alcohol esters offers possibility to select a convenient derivative according to the available reagents.

4. Experimental

General: All reagents were purchased from Aldrich, Merck and Fluka and were used without any further purification. Fluka silica gel/TLC-cards 60778 with fluorescent indicator 254 nm were used for TLC chromatography and Rf-values determination. The high performance flash chromatography (HPFC) purifications were carried out on a Biotage HorizonTM system (Charlottesville, Virginia, USA) on silica gel. The melting points were determined in capillary tubes on SRS MPA100 OptiMelt (Sunnyvale, CA, USA) automated melting point system. The NMR spectra were recorded on a Bruker Avance DRX 250 and Bruker Avance II+ 600 (where indicated) spectrometers (Rheinstetten, Germany) in deuterochloroform; the chemical shifts were quoted in ppm in δ-values against tetramethylsilane (TMS) as an internal standard and the coupling constants were calculated in Hz.

The high performance liquid chromatography (HPLC) enantioseparations were performed on an Agilent 1100 System fitted with diode array detector and manual injector with a 20 μL injection loop. A stainless-steel Nucleosil Chiral-2 column (Macherey-Nagel GmbH &Co. KG, Düren, Germany) was used; 250 × 4 mm, particle size 5 μm, pore size 100 Å, chiral selector *N*-(3,5-dinitrobenzoyl)-*D*-phenylglycine. The analyses were performed at 25℃ with a flow rate of 1.0 mL/min. The HPLC grade solvents were purchased from

Sigma-Aldrich and Labscan.

Synthesis of chiral racemic benzyl alcohols **1-5**: To a solution of a ketone (20 mmol) in MeOH (20 mL) $NaBH_4$ (30 mmol) was added portionwise and the mixture was stirred at room temperature for 0.5-1 h. The solvent was removed in vacuo and the products were partitioned between water and CH_2Cl_2. The organic layer was dried over Na_2SO_4, evaporated to dryness, and purified by HPFC on silica gel.

1-Phenyl-1-propanol **1** [70]: 92% yield; R_f 0.48 (hexane:EtOAc 80:20); ^{1}H NMR 0.88 (t, 3H, J 7.4, C*H*$_3$), 1.75 (m, 2H, C*H*$_2$), 2.24 (bd, 1H, J 1.7, O*H*), 4.53 (td, 1H, J 1.7, 7.3, C*H*), 7.32 (m, 5H, C*H*-Ph).

1-Phenylethanol **2** [71]: 93% yield; R_f 0.38 (hexane: EtOAc 80:20); ^{1}H NMR 1.47 (d, 3H, J 6.5, C*H*$_3$), 2.12 (bs, 1H, O*H*), 4.85 (q, 1H, J 6.5, 12.9, C*H*), 7.33 (m, 5H, C*H*-Ph).

1,2-Diphenylethanol **3** [72]: 59% yield; R_f 0.48 (hexane: EtOAc 80:20); ^{1}H NMR 2.02 (bs, 1H, O*H*), 2.98 (m, 2H, C*H*$_2$), 4.86 (dd, 1H, J 5.5, 7.8, C*H*), 7.24 (m, 10H, C*H*-Ph).

1-(2-Nitrophenyl)ethanol **4** [73]: 88% yield; R_f 0.35 (CH_2Cl_2); ^{1}H NMR 1.52 (d, 3H, J 6.4, C*H*$_3$), 2.99 (s, 1H, O*H*), 5.37 (q, 1H, J 6.2, 12.5, C*H*), 7.39 (ddd, 1H, J 1.5, 7.4, 8.1, C*H*-Ar), 7.62 (ddd, 1H, J 1.3, 7.4, 7.9, C*H*-Ar), 7.80 (dd, 1H, J 1.5, 7.9, C*H*-Ar), 7.85 (dd, 1H, J 1.3, 8.1, C*H*-Ar).

1-(4-Nitrophenyl)ethanol **5** [74]: 97% yield; R_f 0.40 (CH_2Cl_2); ^{1}H NMR 1.52 (d, 3H, J 6.5, C*H*$_3$), 2.26 (bd, 1H, J 3.4, O*H*), 5.02 (qd, 1H, J 3.4, 6.5, 13.0, C*H*), 7.54 (dt, 2H, J 2.4, 8.8, C*H*-Ar), 8.18 (dt, 2H, J 2.4, 8.8, C*H*-Ar).

Synthesis of the derivatives **7-12**: To a solution of a benzyl alcohol 1-6 (1 mmol) in pyridine (2 mL) an acid chloride (1.1 mmol) was added and the mixture was refluxed for 30 min. Sat. aq. K_2CO_3 was added and the mixture was stirred for 15 min at room temperature. Work-up:

Method 1: The products were partitioned between water and EtOAc. The organic layer was dried over Na_2SO_4, evaporated to dryness, and purified by HPFC on silica gel.

Method 2: The products were partitioned between water and hexane. The organic layer was dried over Na_2SO_4 and evaporated to dryness.

1-Phenylpropyl benzoate **7a** [75]: 91% yield; R_f 0.56 (CH_2Cl_2); ^{1}H NMR 0.94 (t, 3H, J 7.4, C*H*$_3$), 1.99 (m, 2H, C*H*$_2$), 5.94 (t, 1H, J 6.8, C*H*-O), 7.35 (m, 8H, C*H*-Ar), 8.08 (m, 2H, C*H*-Ar); ^{13}C NMR 9.8 (*C*H$_3$), 29.4 (*C*H$_2$), 77.7 (*C*H-O), 126.3 (2 *C*H-Ar), 127.7 (*C*H-Ar), 128.2 (2 *C*H-Ar), 128.3 (2 *C*H-Ar), 129.4 (2 *C*H-Ar), 130.4 (C_{quat}), 132.7 (*C*H-Ar), 140.5 (C_{quat}), 165.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 10.33 and t_R-2 11.47 min.

1-Phenylpropyl 2-chlorobenzoate **7b:** 82% yield; R_f 0.72 (CH_2Cl_2); ^{1}H NMR 0.94 (t, 3H, J 7.4, C*H*$_3$), 2.00 (m, 2H, C*H*$_2$), 5.94 (t, 1H, J 6.8, C*H*-O), 7.26 (m, 8H, C*H*-Ar), 7.80 (dd, 1H, J 1.9, 7.6, C*H*-Ar); ^{13}C NMR 9.8 (*C*H$_3$), 29.2 (*C*H$_2$), 78.6 (*C*H-O), 126.3 (*C*H-Ar), 126.5 (2 *C*H-Ar), 127.7 (*C*H-Ar), 128.2 (2 *C*H-Ar), 130.2 (C_{quat}), 130.8 (*C*H-Ar), 131.2 (*C*H-Ar), 132.2 (*C*H-Ar), 133.4 (C_{quat}), 139.9 (C_{quat}), 164.7 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 13.48 and t_R-2 15.18 min.

1-Phenylpropyl 3-chlorobenzoate **7c:** 81% yield; R_f 0.65 (hexane:CH_2Cl_2 60:40); m. p. 63-64℃; ^{1}H NMR 0.96 (t, 3H J 7.4, C*H*$_3$), 2.02 (2H, m, C*H*$_2$), 5.91 (t, 1H, J 6.8, C*H*-O), 7.35 (m, 6H, C*H*-Ar), 7.52 (ddd, 1H, J 1.2, 2.0, 8.0, C*H*-Ar), 7.96 (dt, 1H, J 1.3, 7.7, C*H*-Ar), 8.04 (t, 1H, J 1.8, C*H*-Ar); ^{13}C NMR 9.9 (*C*H$_3$), 29.4 (*C*H$_2$), 78.5 (*C*H-O), 126.5 (2 *C*H-Ar), 127.8 (*C*H-Ar), 128.0 (*C*H-Ar), 128.5 (2 *C*H-Ar), 129.6 (*C*H-Ar), 129.7 (*C*H-Ar), 132.3 (C_{quat}), 132.9 (*C*H-Ar), 134.5 (C_{quat}), 140.2 (C_{quat}), 164.7 (*C*=O); HPLC: eluent hexane/iPr-OH/ TFA 100:0.03:0.05, retention times t_R-1 7.45 and t_R-2 8.20 min.

1-Phenylpropyl 4-chlorobenzoate **7d:** 60% yield; R_f 0.53 (hexane:EtOAc 90:10); ^{1}H NMR 0.95 (t, 3H, J 7.4, C*H*$_3$), 2.01 (m, 2H, C*H*$_2$), 5.91 (t, 1H, J 6.8, C*H*-O), 7.31 (m, 7H, C*H*-Ar), 8.01 (dt, 2H, J 2.3, 9.0, C*H*-Ar); ^{13}C NMR 9.9 (*C*H$_3$), 29.4 (*C*H$_2$), 78.2 (*C*H-O), 126.4 (2 *C*H-Ar), 127.9 (*C*H-Ar), 128.4 (2 *C*H-Ar), 128.6 (2 *C*H-Ar), 129.0 (C_{quat}), 131.0 (2 *C*H-Ar), 139.3 (C_{quat}), 140.3 (C_{quat}), 165.0 (*C*=O); HPLC: eluent hexane/ iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 7.73 and t_R-2 8.54 min.

1-Phenylpropyl 2,4-dichlorobenzoate **7e:** 96% yield; R_f 0.72 (CH_2Cl_2); ^{1}H NMR 0.94 (t, 3H, J 7.4, C*H*$_3$), 2.00 (m, 2H, C*H*$_2$), 5.92 (t, 1H, J 6.8, C*H*-O), 7.23 (dd, 1H, J 2.0, 8.4, C*H*-Ar), 7.33 (m, 5H, C*H*-Ar), 7.41 (d, 1H, J 2.0, C*H*-Ar), 7.79 (d, 1H, J 8.4, C*H*-Ar); ^{13}C NMR 9.8 (*C*H$_3$), 29.2 (*C*H$_2$), 79.0 (*C*H-O), 126.5 (2 *C*H-Ar), 126.8 (*C*H-Ar), 127.9 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.5 (C_{quat}), 130.8 (*C*H-Ar), 132.4 (*C*H-Ar), 134.7 (C_{quat}), 138.0 (C_{quat}), 139.8 (C_{quat}), 163.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 7.43 and t_R-2 8.27 min.

1-Phenylpropyl 2-naphthoate **7f** [76]: 79% yield; R_f 0.80 (CH_2Cl_2); ^{1}H NMR 0.97 (t, 3H J 7.4, C*H*$_3$), 2.04 (m, 2H, C*H*$_2$), 6.01 (t, 1H, J 6.8, C*H*-O), 7.30 (m, 3H, C*H*-Ar), 7.44 (m, 4H, C*H*-Ar), 7.77 (dd, 2H, J 7.0, 8.6, C*H*-Ar), 7.87 (dd, 1H, J 2.2, 6.9, C*H*-Ar), 8.10 (dd, 1H, J 1.7, 8.6, C*H*-Ar), 8.63 (s, 1H, C*H*-Ar); ^{13}C NMR 9.8 (*C*H$_3$), 29.4 (*C*H$_2$), 77.8 (*C*H-O), 125.1 (*C*H-Ar), 126.3 (2 *C*H-Ar), 126.4 (*C*H-Ar), 127.5 (*C*H-Ar), 127.6 (C_{quat}), 127.7 (*C*H-Ar), 127.9 (*C*H-Ar),128.0 (*C*H-Ar), 128.3 (2 *C*H-Ar), 129.1 (*C*H-Ar), 130.8 (*C*H-Ar), 132.3 (C_{quat}), 135.3 (C_{quat}), 140.5 (C_{quat}), 165.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 12.87 and t_R-2 14.39 min.

1-Phenylethyl benzoate **8a** [77]: 51% yield; R_f 0.40 (hexane:CH_2Cl_2 60:40); ^{1}H NMR 1.66 (d, 3H, J 6.6,

CH_3), 6.14 (q, 1H, J 6.6, 13.2, C*H*-O), 7.38 (m, 8H, C*H*-Ar), 8.08 (m, 2H, C*H*-Ar); ^{13}C NMR 22.3 (*C*H$_3$), 72.8 (*C*H-O), 126.0 (2 *C*H-Ar), 127.8 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.5 (2 *C*H-Ar), 129.6 (2 *C*H-Ar), 130.5 (C_{quat}), 132.8 (*C*H-Ar), 141.7 (C_{quat}), 165.7 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 11.56 and t_R-2 12.47 min.

1-Phenylethyl 2-chlorobenzoate **8b:** 45% yield; R_f 0.59 (hexane:CH_2Cl_2 60:40); ^{1}H NMR 1.68 (d, 3H, J 6.6, CH_3), 6.14 (q, 1H, J 6.6, 13.2, C*H*-O), 7.35 (m, 8H, C*H*-Ar), 7.82 (ddd, 1H, J 0.5, 1.7, 7.7, C*H*-Ar); ^{13}C NMR 22.2 (*C*H$_3$), 73.8 (*C*H-O), 126.2 (2 *C*H-Ar), 126.5 (*C*H-Ar), 128.0 (*C*H-Ar), 128.5 (2 *C*H-Ar), 130.4 (C_{quat}), 131.0 (*C*H-Ar), 131.3 (*C*H-Ar), 132.4 (*C*H-Ar), 133.6 (C_{quat}), 141.2 (C_{quat}), 164.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 15.16 and t_R-2 16.58 min.

1-Phenylethyl 3-chlorobenzoate **8c** [78]: 48% yield; R_f 0.64 (hexane:CH_2Cl_2 60:40); m. p. 134-136℃; ^{1}H NMR 1.69 (d, 3H, J 6.6, CH_3), 6.14 (dd, 1H, J 6.6, 13.2, C*H*-O), 7.41 (m, 6H, C*H*-Ar), 7.53 (ddd, 1H, J 1.2, 2.1, 8.0, C*H*-Ar), 7.96 (dt, 1H, J 1.4, 7.8, C*H*-Ar), 8.05 (t, 1H, J 2.0, C*H*-Ar); ^{13}C NMR 22.2 (*C*H$_3$), 73.5 (*C*H-O), 126.1 (2 *C*H-Ar), 127.8 (*C*H-Ar) 128.0 (*C*H-Ar) 128.6 (2 *C*H-Ar), 129.6 (*C*H-Ar), 132.3 (*C*H-Ar), 132.9 (*C*H-Ar), 133.7 (C_{quat}), 134.5 (C_{quat}), 141.4 (C_{quat}), 164.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 5.94 and t_R-2 6.35 min.

1-Phenylethyl 4-chlorobenzoate **8d:** 99% yield; R_f 0.72 (hexane:CH_2Cl_2 40:60); ^{1}H NMR 1.69 (d, 3H, J 6.6, CH_3), 6.14 (dd, 1H, J 6.6, 13.2, C*H*-O) 7.37 (m, 7H, C*H*-Ar), 8.02 (ddd, 2H, J 2.0, 2.3, 8.4, C*H*-Ar); ^{13}C NMR 22.3 (*C*H$_3$), 73.2 (*C*H-O), 126.0 (2 *C*H-Ar), 128.0 (*C*H-Ar), 128.5 (2 *C*H-Ar), 128.6 (2 *C*H-Ar), 129.0 (C_{quat}), 131.0 (2 *C*H-Ar), 139.3 (C_{quat}), 141.5 (C_{quat}), 164.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 4.88 and t_R-2 5.10 min.

1-Phenylethyl 2,4-dichlorobenzoate **8e:** 86% yield; R_f 0.70 (hexane:CH_2Cl_2 60:40); ^{1}H NMR 1.67 (d, 3H, J 6.6, CH_3), 6.12 (q, 1H, J 6.6, 13.2, C*H*-O), 7.34 (m, 7H, C*H*-Ar), 7.79 (d, 1H, J 8.4, C*H*-Ar); ^{13}C NMR 22.2 (*C*H$_3$), 74.1 (*C*H-O), 126.2 (2 *C*H-Ar), 126.9 (*C*H-Ar), 128.1 (*C*H-Ar), 128.5 (2 *C*H-Ar), 128.6 (C_{quat}), 130.9 (*C*H-Ar), 132.5 (*C*H-Ar), 134.9 (C_{quat}), 138.2 (C_{quat}), 141.0 (C_{quat}), 164.0 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 8.39 and t_R-2 9.10 min.

1-Phenylethyl 2-naphthoate **8f** [79]: 50% yield; R_f 0.63 (hexane:CH_2Cl_2 40:60); ^{1}H NMR 1.71 (d, 3H, J 6.6, CH_3), 6.20 (q, 1H, J 6.6, 13.2, C*H*-O), 7.32 (m, 3H, C*H*-Ar), 7.50 (m, 4H, C*H*-Ar), 7.82 (m, 2H, C*H*-Ar), 7.91 (dd, 1H, J 1.7, 7.3, C*H*-Ar), 8.09 (dd, 1H, J 1.7, 8.6, C*H*-Ar), 8.63 (s, 1H, C*H*-Ar); ^{13}C NMR 22.3 (*C*H$_3$), 73.0 (*C*H-O), 125.2 (*C*H-Ar), 126.0 (2 *C*H-Ar), 126.5 (*C*H-Ar), 127.6 (*C*H-Ar), 127.7 (C_{quat}), 127.8 (*C*H-Ar), 128.0 (*C*H-Ar), 128.1 (*C*H-Ar), 128.5 (2 *C*H-Ar) 129.3 (*C*H-Ar), 131.0 (*C*H-Ar), 132.4 (C_{quat}), 135.4 (C_{quat}), 141.8 (C_{quat}), 165.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 14.48 and t_R-2 15.68 min.

1,2-Diphenylethyl benzoate **9a** [80]: 73% yield; R_f 0.43 (hexane:EtOAc 90:10); m. p. 67-68℃ (lit. [80] 70℃); ^{1}H NMR 3.19 (A part of ABX, 1H, J_{AX} 6.0, J_{AB} 13.8, ½ CH_2), 3.35 (B part of ABX, 1H, J_{BX} 7.8, J_{AB} 13.8, ½ CH_2), 6.18 (dd, 1H, J 6.0, 7.6, C*H*-O), 7.18 (m, 5H, C*H*-Ar), 7.30 (m, 5H, C*H*-Ar), 7.41 (m, 2H, C*H*-Ar), 7.53 (m, 1H, C*H*-Ar), 8.04 (m, 2H, C*H*-Ar); ^{13}C NMR 43.2 (*C*H$_2$), 77.2 (*C*H-O), 126.5 (2 *C*H-Ar), 126.6 (*C*H-Ar), 127.9 (*C*H-Ar), 128.2 (2 *C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 129.6 (4 *C*H-Ar), 130.4 (C_{quat}), 132.9 (*C*H-Ar), 136.9 (C_{quat}), 140.1 (C_{quat}), 165.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 12.14 and t_R-2 12.97 min.

1,2-Diphenylethyl 2-chlorobenzoate **9b:** 65% yield; R_f 0.63 (hexane:EtOAc 90:10); ^{1}H NMR 3.19 (A part of ABX, 1H, J_{AX} 6.4, J_{AB} 13.7, ½ CH_2), 3.36 (B part of ABX, 1H, J_{BX} 7.6, J_{AB} 13.7, ½ CH_2), 6.20 (dd, 1H, J 6.4, 7.6, C*H*-O), 7.28 (m, 13H, C*H*-Ar), 7.73 (ddd, 1H, J 0.6, 1.5, 8.0, C*H*-Ar); ^{13}C NMR 43.0 (*C*H$_2$), 78.1 (*C*H-O), 126.5 (*C*H-Ar), 126.6 (*C*H-Ar), 126.7 (2 *C*H-Ar), 128.1 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 129.6 (2 *C*H-Ar), 130.2 (C_{quat}), 131.0 (*C*H-Ar), 131.4 (*C*H-Ar), 132.4 (*C*H-Ar), 133.8 (C_{quat}), 136.7 (C_{quat}), 139.6 (C_{quat}), 164.7 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 15.43 and t_R-2 16.72 min.

1,2-Diphenylethyl 3-chlorobenzoate **9c:** 56% yield; R_f 0.40 (hexane:EtOAc 90:10); m. p. 73-74℃; ^{1}H NMR 3.19 (A part of ABX, 1H, J_{AX} 6.1, J_{AB} 13.8, ½ CH_2), 3.35 (B part of ABX, 1H, J_{BX} 7.7, J_{AB} 13.8, ½ CH_2), 6.17 (dd, 1H, J 6.1, 7.7, C*H*-O), 7.17 (m, 5H, C*H*-Ar), 7.33 (m, 6H, C*H*-Ar), 7.51 (dd, 1H, J 1.2, 2.1, C*H*-Ar), 7.90 (dt, 1H, J 1.4, 7.8, C*H*-Ar), 7.99 (td, 1H, J 1.6, 2.1, C*H*-Ar); ^{13}C NMR 43.1 (*C*H$_2$), 77.8 (*C*H-O), 126.5 (2 *C*H-Ar), 126.7 (*C*H-Ar), 127.7 (*C*H-Ar), 128.1 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 129.5 (2 *C*H-Ar),129.6 (*C*H-Ar), 129.7 (*C*H-Ar), 132.1 (C_{quat}), 132.9 (*C*H-Ar), 134.5 (C_{quat}), 136.7 (C_{quat}), 139.7 (C_{quat}), 164.4 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 6.80 and t_R-2 7.12 min.

1,2-Diphenylethyl 4-chlorobenzoate **9d:** 80% yield; R_f 0.49 (hexane:EtOAc 90:10); m. p. 100-101℃; ^{1}H NMR 3.18 (A part of ABX, 1H, J_{AX} 6.0, J_{AB} 13.8, ½ CH_2), 3.34 (B part of ABX, 1H, J_{BX} 7.6, J_{AB} 13.8, ½ CH_2), 6.16 (dd, 1H, J 6.0, 7.6, C*H*-O), 7.17 (m, 5H, C*H*-Ar), 7.32 (m, 5H, C*H*-Ar), 7.39 (dd, 2H, J 0.6, 8.4, C*H*-Ar), 7.96 (dd, 2H, J 0.6, 8.4, C*H*-Ar); ^{13}C NMR 43.1 (*C*H$_2$), 77.5 (*C*H-O), 126.5 (2 *C*H-Ar), 126.6 (*C*H-Ar), 128.91 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 128.7 (2 *C*H-Ar), 128.8

(C_{quat}), 129.5 (2 *C*H-Ar), 133.0 (2 *C*H-Ar), 136.8 (C_{quat}), 139.4 (C_{quat}), 139.8 (C_{quat}), 164.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 8.85 and t_R-2 9.34 min.

1,2-Diphenylethyl 2,4-dichlorobenzoate **9e:** 75 % yield; R_f 0.42 (hexane:EtOAc 90:10); ^{1}H NMR 3.18 (A part of ABX, 1H, J_{AX} 6.3, J_{AB} 13.8, ½ CH_2), 3.34 (B part of ABX, 1H, J_{BX} 7.7, J_{AB} 13.8, ½ CH_2), 6.19 (dd, 1H, J 6.3, 7.7, C*H*-O), 7.13 (m, 2H, C*H*-Ar), 7.24 (m, 5H, C*H*-Ar), 7.33 (m, 4H, C*H*-Ar), 7.44 (d, 1H, J 2.0, C*H*-Ar), 7.69 (d, 1H, J 8.4, C*H*-Ar); ^{13}C NMR 43.0 (*C*H$_2$), 78.4 (*C*H-O), 126.6 (*C*H-Ar), 126.7 (2 *C*H-Ar), 126.9 (*C*H-Ar), 128.2 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 129.5 (2 *C*H-Ar), 131.0 (*C*H-Ar), 132.5 (*C*H-Ar), 134.9 (C_{quat}), 136.6 (C_{quat}), 138.2 (C_{quat}), 139.4 (C_{quat}), 163.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 8.51 and t_R-2 9.09 min.

1,2-Diphenylethyl 2-naphthoate **9f:** 70% yield; R_f 0.67 (hexane:EtOAc 85:15); m. p. 99-100℃; ^{1}H NMR 3.24 (A part of ABX, 1H, J_{AX} 6.1, J_{AB} 13.8, ½ CH_2), 3.41 (B part of ABX, 1H, J_{BX} 7.5, J_{AB} 13.8, ½ CH_2), 6.25 (dd, 1H, J 6.1, 7.5, C*H*-O), 7.18 (m, 5H, C*H*-Ar), 7.34 (m, 5H, C*H*-Ar), 7.41 (m, 2H, C*H*-Ar), 7.54 (tdd, 2H, J 1.6, 6.9, 12.3, C*H*-Ar), 7.85 (d, 2H, J 8.6, C*H*-Ar), 7.94 (dd, 1H, J 1.8, 7.7, C*H*-Ar), 8.05 (dd, 1H, J 1.6, 8.6, C*H*-Ar), 8.59 (s, 1H, C*H*-Ar); ^{13}C NMR 43.2 (*C*H$_2$), 77.4 (*C*H-O), 125.2 (*C*H-Ar), 126.5 (2 *C*H-Ar), 126.6 (2 *C*H-Ar), 127.6 (C_{quat}), 127.7 (*C*H-Ar), 128.0 (*C*H-Ar), 128.1 (*C*H-Ar), 128.2 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.4 (2 *C*H-Ar), 129.4 (*C*H-Ar), 129.6 (2 *C*H-Ar), 131.1 (*C*H-Ar), 132.5 (C_{quat}), 135.5 (C_{quat}), 136.9 (C_{quat}), 140.1 (C_{quat}), 165.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.03:0.05, retention times t_R-1 15.45 and t_R-2 16.49 min.

1-(2-Nitrophenyl)ethyl benzoate **10a** [81]: 80% yield; R_f 0.32 (hexane:CH_2Cl_2 50:50); ^{1}H NMR (600 MHz) 1.79 (d, 3H, J 6.5, CH_3), 6.57 (q, 1H, J 6.5, 12.9, C*H*-O), 7.43 (t, 1H, J 7.3, C*H*-Ar), 7.45 (t, 2H, J 7.8, C*H*-Ar), 7.58 (t, 1H, J 7.4, C*H*-Ar), 7.62 (t, 1H, J 7.4, C*H*-Ar), 7.74 (d, 1H, J 7.9, C*H*-Ar), 7.97 (d, 1H, J 8.2, C*H*-Ar), 8.07 (d, 2H, J 7.3, C*H*-Ar); ^{13}C NMR 22.1 (*C*H$_3$), 68.7 (*C*H-O), 124.4 (*C*H-Ar), 127.1 (*C*H-Ar), 128.3 (*C*H-Ar), 128.4 (2 *C*H-Ar), 129.6 (2 *C*H-Ar), 129.8 (C_{quat}), 133.2 (*C*H-Ar), 133.6 (*C*H-Ar), 138.1 (C_{quat}), 147.6 (C_{quat}), 165.4 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 36.51 and t_R-2 39.34 min.

1-(2-Nitrophenyl)ethyl 2-chlorobenzoate **10b:** 82% yield; R_f 0.30 (hexane:CH_2Cl_2 50:50); m. p. 64-65℃; ^{1}H NMR 1.79 (d, 3H, J 6.5, CH_3), 6.62 (q, 1H, J 6.5, 12.9, C*H*-O), 7.433 (m, 1H, C*H*-Ar), 7.44 (m, 3H, C*H*-Ar), 7.64 (tdd, 1H, J 0.4, 1.3, 7.8, C*H*-Ar), 7.79 (dd, 1H, J 1.5, 7.9, C*H*-Ar), 7.84 (ddd, 1H, J 0.6, 1.7, 7.6, C*H*-Ar), 7.98 (dd, 1H, J 1.3, 8.2, C*H*-Ar); ^{13}C NMR 22.1 (*C*H$_3$), 69.6 (*C*H-O), 124.5 (*C*H-Ar), 126.6 (*C*H-Ar), 127.5 (*C*H-Ar), 128.5 (*C*H-Ar), 129.8 (C_{quat}), 131.1 (*C*H-Ar), 131.5 (*C*H-Ar), 131.6 (C_{quat}), 132.7 (*C*H-Ar), 133.7 (*C*H-Ar), 137.6 (C_{quat}), 147.6 (C_{quat}), 164.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 25.35 and t_R-2 27.34 min.

1-(2-Nitrophenyl)ethyl 3-chlorobenzoate **10c:** 86% yield; R_f 0.48 (hexane:CH_2Cl_2 50:50); ^{1}H NMR 1.79 (d, 3H, J 6.5, CH_3), 6.57 (q, 1H, J 6.5, 12.9, C*H*-O), 7.39 (t, 1H, J 7.7, C*H*-Ar), 7.44 (ddd, 1H, J 1.6, 7.2, 8.2, C*H*-Ar), 7.54 (ddd, 1H, J 1.2, 2.2, 8.0, C*H*-Ar), 7.63 (td, 1H, J 1.3, 7.9, C*H*-Ar), 7.70 (td, 1H, J 1.7, 7.9, C*H*-Ar), 7.95 (m, 2H, C*H*-Ar), 8.02 (td, 1H, J 1.7, 2.0, C*H*-Ar); ^{13}C NMR 22.0 (*C*H$_3$), 69.2 (*C*H-O), 124.5 (*C*H-Ar), 127.0 (*C*H-Ar), 127.7 (*C*H-Ar), 128.5 (*C*H-Ar), 129.6 (2 *C*H-Ar), 129.8 (*C*H-Ar), 131.6 (C_{quat}), 133.2 (*C*H-Ar), 133.7 (*C*H-Ar), 134.6 (C_{quat}), 137.6 (C_{quat}), 147.7 (C_{quat}), 164.2 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 24.22 and t_R-2 25.84 min.

1-(2-Nitrophenyl)ethyl 4-chlorobenzoate **10d:** 79% yield; R_f 0.31 (hexane:CH_2Cl_2 50:50); ^{1}H NMR (600 MHz) 1.79 (d, 3H, J 6.5, CH_3), 6.56 (q, 1H, J 6.5, 13.0, C*H*-O), 7.42 (d, 2H, J 8.5, C*H*-Ar), 7.45 (td, 1H, J 0.8, 8.2, C*H*-Ar), 7.63 (t, 1H, J 7.6, C*H*-Ar), 7.70 (d, 1H, J 7.6, C*H*-Ar), 7.97 (d, 1H, J 8.4, C*H*-Ar), 7.99 (d, 2H, J 8.5, C*H*-Ar); ^{13}C NMR 22.1 (*C*H$_3$), 69.1 (*C*H-O), 124.6 (*C*H-Ar), 127.1 (*C*H-Ar), 128.3 (C_{quat}), 128.5 (*C*H-Ar), 128.8 (2 *C*H-Ar), 131.2 (2 *C*H-Ar), 133.7 (*C*H-Ar), 137.8 (C_{quat}), 139.7 (C_{quat}), 147.7 (C_{quat}), 164.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 25.70 and t_R-2 27.46 min.

1-(2-Nitrophenyl)ethyl 2,4-dichlorobenzoate **10e:** 76% yield; R_f 0.32 (hexane:CH_2Cl_2 50:50); mp: 69-71℃; ^{1}H NMR 1.79 (d, 3H, J 6.5, CH_3), 6.60 (q, 1H, J 6.5, 12.9, C*H*-O), 7.31 (dd, 1H, J 2.0, 8.4, C*H*-Ar), 7.45 (ddd, 1H, J 1.5, 7.3. 8.2, C*H*-Ar), 7.48 (d, 1H, J 2.1, C*H*-Ar), 7.64 (ddd, 1H, J 1.2, 7.6, 8.0, C*H*-Ar), 7.75 (dd, 1H, J 1.5, 7.9, C*H*-Ar), 7.82 (d, 1H, J 8.4, C*H*-Ar), 7.98 (dd, 1H, J 1.2, 8.2, C*H*-Ar); ^{13}C NMR 22.1 (*C*H$_3$), 69.9 (*C*H-O), 124.6 (*C*H-Ar), 127.1 (*C*H-Ar), 127.4 (*C*H-Ar), 128.0 (C_{quat}), 128.6 (*C*H-Ar), 131.1 (*C*H-Ar), 132.6 (*C*H-Ar), 133.7 (*C*H-Ar), 134.9 (C_{quat}), 137.4 (C_{quat}), 138.6 (C_{quat}), 147.7 (C_{quat}), 163.7 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 24.97 and t_R-2 26.44 min.

1-(2-Nitrophenyl)ethyl 2-naphthoate **10f:** 70% yield; R_f 0.34 (hexane:CH_2Cl_2 50:50); m. p. 80-82℃; ^{1}H NMR 1.84 (d, 3H, J 6.5, CH_3), 6.64 (q, 1H, J 6.5, 12.9, C*H*-O), 7.42 (ddd, 1H, J 1.5, 7.4, 8.2, C*H*-Ar), 7.58 (m, 3H, C*H*-Ar), 7.78 (dd, 1H, J 1.5, 7.9, C*H*-Ar), 7.88 (m, 2H, C*H*-Ar), 7.96 (m, 1H, C*H*-Ar), 7.97 (dd, 1H, J 1.4, 8.2, C*H*-Ar), 8.06 (dd, 12H, J 1.7, 8.6, C*H*-Ar), 8.62 (s, 1H, C*H*-Ar); ^{13}C NMR 22.1 (*C*H$_3$), 68.9 (*C*H-O), 124.5 (*C*H-Ar), 125.1 (*C*H-Ar), 126.7 (*C*H-Ar), 127.1 (*C*H-Ar), 127.8 (*C*H-Ar), 128.2 (*C*H-Ar), 128.4 (2 *C*H-Ar), 129.3 (*C*H-Ar), 129.9 (C_{quat}), 131.2 (*C*H-Ar), 132.4 (C_{quat}), 133.6 (*C*H-Ar), 135.6 (C_{quat}), 138.1 (C_{quat}), 147.8 (C_{quat}), 165.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA

100:0.1:0.05, retention times t_R-1 52.59 and t_R-2 56.85 min.

1-(4-Nitrophenyl)ethyl benzoate **11a** [82]: 82% yield; R_f 0.40 (hexane:CH_2Cl_2 40:60); m. p. 94-95℃ (lit. [82] 94.8-95.5℃); ^{1}H NMR 1.70 (d, 3H, J 6.7, CH_3), 6.18 (q, 1H, J 6.6, 13.2, C*H*-O), 7.46 (m, 2H, C*H*-Ar), 7.59 (m, 3H, C*H*-Ar), 8.09 (dt, 2H, J 1.4, 7.0, C*H*-Ar), 8.23 (dt, 2H, J 1.9, 8.8, C*H*-Ar); ^{13}C NMR 22.4 (*C*H_3), 71.8 (*C*H-O), 124.0 (2 *C*H-Ar), 126.7 (2 *C*H-Ar), 128.5 (2 *C*H-Ar), 129.7 (2 *C*H-Ar), 129.9 (C_{quat}), 133.3 (*C*H-Ar), 147.5 (C_{quat}), 149.1 (C_{quat}), 165.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 43.59 and t_R-2 46.09 min.

1-(4-Nitrophenyl)ethyl 2-chlorobenzoate **11b:** 66% yield; R_f 0.60 (hexane:CH_2Cl_2 40:60); m. p. 52-53℃; ^{1}H NMR 1.71 (d, 3H, J 6.6, CH_3), 6.19 (q, 1H, J 6.6, 13.3, C*H*-O), 7.33 (m, 1H, C*H*-Ar), 7.45 (m, 2H, C*H*-Ar), 7.62 (dt, 2H, J 1.7, 8.6, C*H*-Ar), 7.85 (ddd, 1H, J 0.5, 1.6, 8.6, C*H*-Ar), 8.23 (dt, 2H, J 2.0, 8.8, C*H*-Ar); ^{13}C NMR 22.3 (*C*H_3), 72.7 (*C*H-O), 123.9 (2 *C*H-Ar), 126.7 (*C*H-Ar), 126.9 (2 *C*H-Ar), 129.7 (C_{quat}), 131.2 (*C*H-Ar), 131.4 (*C*H-Ar), 132.8 (*C*H-Ar), 133.8 (C_{quat}), 147.6 (C_{quat}), 148.5 (C_{quat}), 164.7 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1: 0.05, retention times t_R-1 24.86 and t_R-2 25.85 min.

1-(4-Nitrophenyl)ethyl 3-chlorobenzoate **11c:** 88% yield; R_f 0.53 (hexane:CH_2Cl_2 40:60); m. p. 54-55℃; ^{1}H NMR 1.71 (d, 3H, J 6.6, CH_3), 6.17 (q, 1H, J 6.6, 13.3, C*H*-O), 7.40 (t, 1H, J 7.9, C*H*-Ar), 7.55 (ddd, 1H, J 1.2, 2.2, 8.1, C*H*-Ar), 7.59 (dt, 2H, J 2.2, 8.8, C*H*-Ar), 7.96 (dt, 1H, J 1.4, 7.7, C*H*-Ar), 8.04 (dd, 1H, J 1.7, 2.0, C*H*-Ar), 8.23 (dt, 2H, J 2.2, 8.8, C*H*-Ar); ^{13}C NMR 22.2 (*C*H_3), 72.3 (*C*H-O), 123.9 (2 *C*H-Ar), 126.7 (2 *C*H-Ar), 127.8 (*C*H-Ar), 129.6 (*C*H-Ar), 129.8 (*C*H-Ar), 131.6 (C_{quat}), 133.3 (*C*H-Ar), 134.6 (C_{quat}), 147.6 (C_{quat}), 148.6 (C_{quat}), 164.3 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1: 0.05, retention times t_R-1 21.62and t_R-2 22.50 min.

1-(4-Nitrophenyl)ethyl 4-chlorobenzoate **11d:** 64% yield, R_f 0.50 (hexane:CH_2Cl_2 40:60); m. p. 61-63℃; ^{1}H NMR 1.70 (d, 3H, J 6.6, CH_3), 6.16 (q, 1H, J 6.6, 13.3, C*H*-O), 7.43 (dt, 2H, J 2.2, 8.7, C*H*-Ar), 7.59 (dt, 2H, J 2.2, 8.7, C*H*-Ar), 8.01 (dt, 2H, J 2.2, 8.7, C*H*-Ar), 8.23 (dt, 2H, J 2.2, 8.7, C*H*-Ar); ^{13}C NMR 22.3 (*C*H_3), 72.2 (*C*H-O), 124.0 (2 *C*H-Ar), 126.8 (2 *C*H-Ar), 128.3 (C_{quat}), 128.9 (2 *C*H-Ar), 131.0 (2 *C*H-Ar), 139.9 (C_{quat}), 147.6 (C_{quat}), 148.8 (C_{quat}), 164.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.1:0.05, retention times t_R-1 21.71 and t_R-2 22.66 min.

1-(4-Nitrophenyl)ethyl 2,4-dichlorobenzoate **11e:** 22% yield; R_f 0.63 (hexane:CH_2Cl_2 60:40); m. p. 111-113℃; ^{1}H NMR 1.71 (d, 3H, J 6.6, CH_3), 6.17 (q, 1H, J 6.6, 13.2, C*H*-O), 7.32 (dd, 1H, J 2.0, 8.4, C*H*-Ar), 7.49 (d, 1H, J 2.0, C*H*-Ar), 7.61 (dt, 2H, J 2.2, 8.7, C*H*-Ar), 7.83 (d, 1H, J 8.4, C*H*-Ar), 8.23 (dt, 2H, J 2.2, 8.7, C*H*-Ar); ^{13}C NMR 22.2 (*C*H_3), 73.0 (*C*H-O), 123.9 (2 *C*H-Ar), 126.9 (2 *C*H-Ar), 127.1 (*C*H-Ar), 127.9 (C_{quat}), 131.1 (*C*H-Ar), 132.6 (*C*H-Ar), 135.0 (C_{quat}), 138.7 (C_{quat}), 147.6 (C_{quat}), 148.2 (C_{quat}), 163.8 (*C*=O); HPLC: eluent hexane/iPr-OH/ TFA 100:0.1:0.05, retention times t_R-1 23.85 and t_R-2 24.70 min.

1-(4-Nitrophenyl)ethyl 2-naphthoate **11f:** 17% yield; R_f 0.54 (hexane:CH_2Cl_2 40:60); m. p. 65-66℃; ^{1}H NMR 1.74 (d, 3H, J 6.6, CH_3), 6.23 (q, 1H, J 6.6, 13.3, C*H*-O), 7.57 (m, 2H, C*H*-Ar), 7.62 (dt, 2H, J 2.2, 8.9, C*H*-Ar), 7.88 (m, 2H, C*H*-Ar), 7.96 (ddd, 1H, J 0.6, 1.6, 7.6, C*H*-Ar), 8.08 (dd, 1H, J 1.7, 8.6, C*H*-Ar), 8.22 (dt, 2H, J 2.1, 8.9, C*H*-Ar), 8.64 (s, 1H, C*H*-Ar); ^{13}C NMR 22.3 (*C*H_3), 71.9 (*C*H-O), 123.9 (2 *C*H-Ar), 125.0 (*C*H-Ar), 126.7 (2 *C*H-Ar), 126.8 (*C*H-Ar), 127.0 (C_{quat}), 127.8 (*C*H-Ar), 128.3 (*C*H-Ar), 128.4 (*C*H-Ar), 129.3 (*C*H-Ar), 131.2 (*C*H-Ar), 132.4 (C_{quat}), 135.6 (C_{quat}), 147.5 (C_{quat}), 149.1 (C_{quat}), 165.7 (*C*=O); HPLC: eluent hexane/iPr-OH/ TFA 100:0.1:0.05, retention times t_R-1 40.97 and t_R-2 43.40 min.

1-(2-Methoxyphenyl)propyl benzoate **12a:** 66% yield; R_f 0.46 (hexane:CH_2Cl_2 60:40); ^{1}H NMR (600 MHz) 0.98 (t, 3H, J 7.4, CH_3), 1.97 (m, 2H, CH_2), 3.85 (s, 3H, OCH_3), 6.37 (t, 1H, J 6.4, C*H*-O), 6.88 (d, 1H, J 8.2, C*H*-Ar), 6.93 (t, 1H, J 7.4, C*H*-Ar), 7.23 (ddd, 1H, J 1.5, 7.8, 8.3, C*H*-Ar), 7.39 (dd, 1H, J 1.4, 7.6, C*H*-Ar), 7.44 (t, 2H, J 7.6, C*H*-Ar), 7.54 (tt, 1H, J 1.4, 7.4, C*H*-Ar), 8.11 (dd, 2H, J 1.2, 8.4, C*H*-Ar); ^{13}C NMR 9.9 (*C*H_3), 28.6 (*C*H_2), 55.5 (O*C*H_3), 72.3 (*C*H-O), 110.5 (*C*H-Ar), 120.5 (*C*H-Ar), 126.1 (*C*H-Ar), 128.3 (2 *C*H-Ar), 128.5 (*C*H-Ar), 129.4 (C_{quat}), 129.6 (2 *C*H-Ar), 130.7 (C_{quat}), 132.8 (*C*H-Ar), 156.2 (C_{quat}), 165.8 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 5.55 and t_R-2 6.21 min.

1-(2-Methoxyphenyl)propyl 2-chlorobenzoate **12b:** 99 % yield; R_f 0.20 (hexane:CH_2Cl_2 70:30); ^{1}H NMR (600 MHz) 0.99 (t, 3H, J 7.4, CH_3), 1.98 (m, 2H, CH_2), 3.86 (s, 3H, OCH_3), 6.40 (t, 1H, J 6.4, C*H*-O), 6.88 (d, 1H, J 8.2, C*H*-Ar), 6.94 (t, 1H, J 7.4, C*H*-Ar), 7.25 (ddd, 1H, J 1.4, 7.2, 8.7, C*H*-Ar), 7.30 (dd, 1H, J 1.1, 7.4, C*H*-Ar), 7.41 (m, 3H, C*H*-Ar), 7.864 (dd, 1H, J 1.5, 7.7, C*H*-Ar); ^{13}C NMR 9.9 (*C*H_3), 28.4 (*C*H_2), 55.5 (O*C*H_3), 73.2 (*C*H-O), 110.5 (*C*H-Ar), 120.5 (*C*H-Ar), 126.5 (2 *C*H-Ar), 128.6 (*C*H-Ar), 128.9 (C_{quat}), 130.6 (C_{quat}), 131.0 (*C*H-Ar), 131.4 (*C*H-Ar), 132.3 (*C*H-Ar), 133.6 (C_{quat}), 156.3 (C_{quat}), 165.0 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 7.20 and t_R-2 7.92 min.

1-(2-Methoxyphenyl)propyl 3-chlorobenzoate **12c:** 95 % yield; R_f 0.11 (hexane:CH_2Cl_2 70:630); ^{1}H NMR (600 MHz) 0.98 (t, 3H, J 7.4, CH_3), 1.98 (m, 2H, CH_2), 3.86 (s, 3H, OCH_3), 6.36 (t, 1H, J 6.4, C*H*-O), 6.88 (d, 1H, J 8.3, C*H*-Ar), 6.94 (t, 1H, J 7.5, C*H*-Ar), 7.25 (ddd, 1H, J 1.0, 7.3, 8.2, C*H*-Ar), 7.37 (m, 2H, C*H*-Ar), 7.51 (dt, 1H, J 0.8, 8.0, C*H*-Ar), 7.98 (d, 1H, J 7.7, C*H*-Ar), 8.07 (s, 1H, C*H*-Ar); ^{13}C NMR 9.9 (*C*H_3), 28.5 (*C*H_2), 55.5 (O*C*H_3), 72.9 (*C*H-O), 110.6 (*C*H-Ar), 120.6 (*C*H-Ar), 126.2 (*C*H-Ar), 127.8 (*C*H-Ar), 128.7 (*C*H-Ar), 129.0 (C_{quat}), 129.6 (*C*H-Ar), 129.7 (*C*H-Ar), 132.5 (C_{quat}), 132.8

(*C*H-Ar), 134.4 (C_{quat}), 156.2 (C_{quat}), 165.6 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 4.69 and t_R-2 5.15 min.

1-(2-Methoxyphenyl)propyl 4-chlorobenzoate **12d:** 99% yield; R_f 0.19 (hexane:CH_2Cl_2 70:30); m. p. 169- 170℃; ^{1}H NMR (600 MHz) 0.97 (t, 3H, J 7.4, CH_3), 1.98 (m, 2H, CH_2), 3.86 (s, 3H, OCH_3), 6.35 (t, 1H, J 6.4, C*H*-O), 6.88 (d, 1H, J 8.2, C*H*-Ar), 6.94 (t, 1H, J 7.5, C*H*-Ar), 7.24 (ddd, 1H, J 1.5, 7.6, 8.3, C*H*-Ar), 7.36 (dd, 1H, J 1.2, 7.5, C*H*-Ar), 7.41 (d, 2H, J 8.5, C*H*-Ar), 8.041 (d, 2H, J 8.5, C*H*-Ar); ^{13}C NMR 9.9 (*C*H_3), 28.5 (*C*H_2), 55.5 (O*C*H_3), 72.6 (*C*H-O), 126.2 (*C*H-Ar), 128.6 (*C*H-Ar), 128.7 (2 *C*H-Ar), 129.1 (C_{quat}), 129.2 (C_{quat}), 129.4 (*C*H-Ar), 131.0 (2 *C*H-Ar), 131.9 (*C*H-Ar), 139.2 (C_{quat}), 156.2 (C_{quat}), 164.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 4.71 and t_R-2 5.22 min.

1-(2-Methoxyphenyl)propyl 2,4-dichlorobenzoate **12e:** 99% yield; R_f 0.27 (hexane:CH_2Cl_2 70:30); ^{1}H NMR (600 MHz) 0.98 (t, 3H, J 7.4, CH_3), 1.97 (m, 2H, CH_2), 3.86 (s, 3H, OCH_3), 6.38 (t, 1H, J 6.4, C*H*-O), 6.89 (d, 1H, J 8.2, C*H*-Ar), 6.95 (t, 1H, J 7.5, C*H*-Ar), 7.26 (ddd, 1H, J 1.57, 7.6, 8.1, C*H*-Ar), 7.29 (dd, 1H, J 2.0, 8.4, C*H*-Ar), 7.38 (dd, 1H, J 1.6, 7.6, C*H*-Ar), 7.47 (d, 1H, J 2.0, C*H*-Ar), 7.84(d, 1H, J 8.4, C*H*-Ar); ^{13}C NMR 9.9 (*C*H_3), 28.4 (*C*H_2), 55.5 (O*C*H_3), 72.5 (*C*H-O), 110.5 (*C*H-Ar), 120.5 (*C*H-Ar), 126.5 (*C*H-Ar), 127.0 (*C*H-Ar), 128.6 (C_{quat}), 128.7 (*C*H-Ar), 128.9 (C_{quat}), 131.0 (*C*H-Ar), 132.6 (*C*H-Ar), 134.8 (C_{quat}), 138.1 (C_{quat}), 156.3 (C_{quat}), 164.1 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 4.79 and t_R-2 5.23 min.

1-(2-Methoxyphenyl)propyl 2-naphthoate **12f:** 94% yield; R_f 0.22 (hexane:CH_2Cl_2 70:30); m. p. 73-75℃; ^{1}H NMR (600 MHz) 1.02 (t, 3H, J 7.4, CH_3), 2.02 (m, 2H, CH_2), 3.85 (s, 3H, OCH_3), 6.44 (t, 1H, J 6.4, C*H*-O), 6.87 (d, 1H, J 8.3, C*H*-Ar), 6.94 (t, 1H, J 7.5, C*H*-Ar), 7.24 (ddd, 1H, J 1.6, 7.8, 8.8, C*H*-Ar), 7.46 (dd, 1H, J 1.6, 7.6, C*H*-Ar), 7.51 (td, 1H, J 1.6, 8.2, C*H*-Ar), 7.55 (td, 1H, J 1.1, 8.1, C*H*-Ar), 7.86 (t, 2H, J 9.0, C*H*-Ar), 7.95 (d, 1H, J 8.1, C*H*-Ar), 8.13 (dd, 1H, J 1.6, 8.6, C*H*-Ar), 8.67 (s, 1H, C*H*-Ar); ^{13}C NMR 10.0 (*C*H_3), 28.6 (*C*H_2), 55.5 (O*C*H_3), 72.4 (*C*H-O), 110.5 (*C*H-Ar), 120.5 (*C*H-Ar), 125.3 (*C*H-Ar), 126.2 (*C*H-Ar), 126.6 (*C*H-Ar), 127.7 (*C*H-Ar), 128.0 (C_{quat}), 128.1 (*C*H-Ar), 128.2 (*C*H-Ar), 128.5 (*C*H-Ar), 129.3 (*C*H-Ar), 129.4 (C_{quat}), 131.0 (*C*H-Ar), 132.5 (C_{quat}), 135.5 (C_{quat}), 156.2 (C_{quat}), 165.9 (*C*=O); HPLC: eluent hexane/iPr-OH/TFA 100:0.5:0.05, retention times t_R-1 7.95 and t_R-2 9.06 min.

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