Palladium-Catalyzed α-Arylation of Esters

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Abstract: A new and simple one-pot procedure for the palladium-catalyzed intermolecular α-arylation of esters is described. A number of esters can be functionalized with a wide range of aryl bromides using $Pd(OAc)_2$ or $Pd_2(dba)_3$ and bulky electron-rich *o*-biphenyl phosphines **1**−**3**. Under the reaction conditions, using LiHMDS as base, α-arylation proceeds at room temperature or at 80 °C with very good yields and high selectivities for monoarylation. Important nonsteroidal antiinflammatory drug derivatives such as (±)-naproxen *tert*-butyl ester and (±)-flurbiprofen *tert*-butyl ester can be prepared in 79% and 86% yield, respectively. The catalyst system based on the di-*tert*-butylphosphine (**2**) is also active for the α-arylation of esters using aryl chlorides. Furthermore, using (**3**) the α-arylation of trisubstituted ester enolates can be accomplished to provide compounds that have quaternary centers.

Introduction

The synthesis of α-aryl esters and their derivatives is of interest in organic chemistry.[1] In particular, α-aryl carboxylic acids are integral structural components of several pharmaceuticals with analgesic and antiinflammatory properties (e.g., ibuprofen, naproxen, ketoprofen, and flurbiprofen).[1,2] These compounds are able to reduce inflammation and pain[3] by inhibition of the cyclooxygenase system.[4] Although the synthesis of α-aryl esters has been a field of active research for years,[5] the development of a catalytic, economically reasonable, and general protocol remains elusive.

Common strategies for the synthesis of α-aryl esters have a number of disadvantages, including the need for special and often toxic reagents, stoichiometric or large excesses of substrates, harsh reaction conditions, or multiple steps.[5,7] While many of these methods are quite effective, their practicality is diminished by the time needed to prepare the required stoichiometric reagents. Moreover, many of these methods do not use an ester but instead a less readily available derivative.

For the few catalytic α-arylations of esters, a Reformatsky reagent,[7a,b] silylketene acetals,[8] aryl-Grignard reagents,[9] α-halocarbonyl compound,[10] silyl enol ether,[11] or tin enolate[12] is required. Musco and Santi reported the palladium-mediated coupling of trimethylsilylketene acetals with aryl triflates or halides in the presence of toxic thallium acetate to provide alkyl 2-arylalkanoates in moderate to good yields.[8a,b] Yamanaka disclosed the palladium-catalyzed synthesis of ethyl aryl acetates using aryl halides and ethoxy(trialkylstannyl)acetylenes to afford ethoxy(ethynylalkylstannyl)acetylenes that, after solvolysis, provided ethylaryl acetates.[8c,d] Kuwajima and Urabe found that tin enolates, generated in situ from silyl enol ethers in the presence of tributyltin fluoride, undergo palladium-catalyzed cross-coupling with aryl bromides to provide α-aryl ketones.[13] Sulikowski extended Kuwajima and Urabe's results to the synthesis of aryl acetates by palladium-catalyzed cross-coupling of aryl bromides and copper(II) enolates.[8e] In this case, yields are good, but the reaction is limited to the synthesis of α-aryl acetates. Clearly a need exists for a general, inexpensive, and practical synthesis of α-aryl esters.

Recently, Hartwig, Satoh, and our own group reported the palladium-catalyzed α-arylation of ketones.[14] Hartwig subsequently reported an improved method based on PCy_3 and $P(t\text{-}Bu)_3$. We have described the use of bulky, electron-rich

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(2) Rieu, J.-P.; Boucherle, A.; Cousse, H.; Mouzin, G. *Tetrahedron* **1986**, *42*, 4095.

(3) Williams, K. M.; Day, R. O.; Breit, S. N. *Adv. Drug Res.* **1993**, *24*, 121−198.

(4) (a) Brooks, P. M.; Day, R. O. *New Engl. J. Med.* **1991**, *324*, 1716−1725. (b) Vane, J. R.; Botting, R. M. *Inflamm. Res.* **1995**, *44*, 1−10.

(5) For a survey of methods that give α-aryl esters see references cited in footnotes 6−12.

(6) Fox, J. M.; Huang, X.; Chieffi, A.; Buchwald, S. L. *J. Am. Chem. Soc.* **2000**, *122*, 1360.

(7) (a) Fauvarque, J. F.; Jutand, A. *J. Organomet. Chem.* **1979**, *177*, 273. (b) Orsini, F.; Pelizzoni, F.; Vallarino, L. M. *J. Organomet. Chem.* **1989**, *367*, 375.

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(9) Amano, T.; Yoshikawa, K.; Sano, T.; Ohuchi, Y.; Manzo, S.; Ishiguro, M.; Fujita, Y. *Synth. Commun.* **1986**, *16*, 499.

(10) (a) Durandetti, M.; Périchon, J.; Nédélec, J.-Y. *J. Org. Chem.* **1997**, *62*, 7914 and references therein. (b) Durandetti, M.; Nédélec, J.-Y.; Périchon, J. *J. Org. Chem.* **1996**, *61*, 1748.

(11) Tamao, K.; Zembayashi, M.; Kumada, M. *Chem. Lett.* **1976**, 1239.

(12) Kosugi, M.; Hagiwara, I.; Sumiya, T.; Migita, T. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 242.

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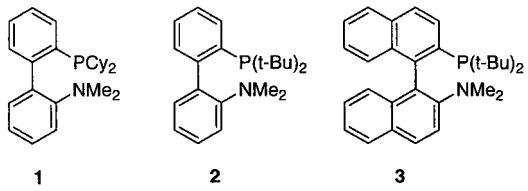
o-biphenyl phosphines which constitute a significant improvement from our initial system.[6] This catalyst system demonstrated a good functional group tolerance and a high selectivity for ketones with two enolizable positions wherein the less substituted position is arylated. In addition, this protocol was extended to the arylation of nitroalkanes, malonate esters, and 1,3-diketones.[6] We have also disclosed an enantioselective variant of our initial system using the Pd/BINAP catalyst.[15]

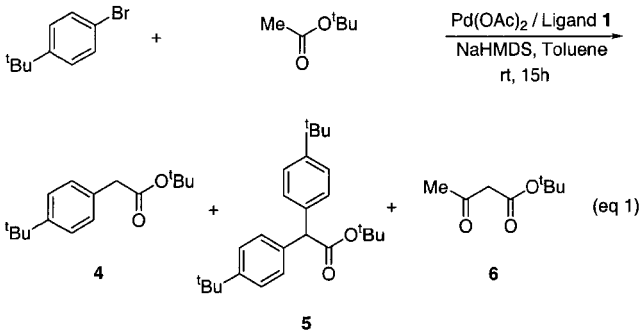


1 **2** **3**

The use of bulky, electron-rich *o*-biphenyl phosphine ligands **1**−**3** for the α-arylation of esters was a desirable extension of other palladium-catalyzed cross-coupling processes.[16] On the basis of our success with other catalyzed cross-coupling reactions, particularly ketone arylation, we chose to explore the palladium-catalyzed arylation of esters.

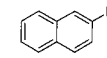
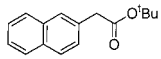
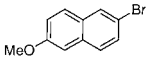
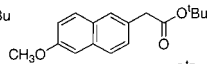
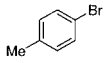
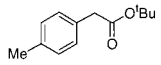
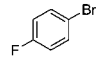
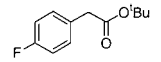
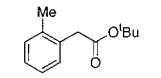
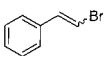
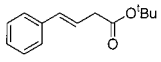
Results

Initial attempts to couple 1-bromo-4-*tert*-butylbenzene with *tert*-butyl acetate using sodium hexamethyldisilazane (NaHMDS) as base and a catalyst derived from **1** and $Pd(OAc)_2$ gave a mixture of mono- and diarylated products (**4** and **5**) along with significant amounts of the Claisen product **6** (eq 1). The mixture of **4** and **5** was obtained in 46% yield.



To search for better conditions, we screened a number of reaction variables including temperature, base, and ligands. We found that lithium hexamethyldisilazane (LiHMDS) was the most effective base for the α-arylation of esters. In contrast to what we had observed with NaHMDS, reactions with LiHMDS gave only traces of diarylated product. We note that this is the first time that we have witnessed a situation in which a reaction protocol using a Li^+ counterion gave superior results to one employing a Na^+ counterion. This result is consistent with previous findings that the selective monoalkylation of dianions derived from *β*-diketones is favored on moving from K^+ to Na^+ counterions (i.e., more covalent M−O bonds).[17] That Li−O bonds are more covalent than Na−O bonds has ample precendent.[18]

Table 1. Palladium-Catalyzed α-Arylation of *tert*-Butyl Acetate Using Ligand **1** and LiHMDS at Room Temperature[a]

Entry	Aryl Bromide	Ester	Product	Time [h]	Yield[b] [%]
1				1	84
2				4	90
3				4	81
4				6	71
5[c]				0.2	78
6				1	66

[a] Reaction conditions: 1.0 equiv of aryl bromide, 2.3 equiv of *tert*-butyl acetate, 2.5 equiv of LiHMDS, 3.0 mol % $Pd(OAc)_2$, and 6.3 mol % ligand **1**. 2 mL of toluene was added per 0.5 mmol of aryl bromide. [b] Isolated yield. [c] The reaction temperature was 80 °C.

With a catalyst combination employing **1** as ligand, LiHMDS as base, and toluene as solvent it was possible to carry out the reaction at room temperature, and doing so, the formation of the diarylation product (e.g., **5**) was suppressed. As shown in Entry 1 of Table 1, the reaction of 2-bromonaphthalene and *tert*-butyl acetate at room temperature for 1 h in toluene with LiHMDS as base, 3 mol % $Pd(OAc)_2$ and ligand **1** gave the desired product in 84% yield.

One limitation of the method is that it was necessary to use 2.3 equiv of ester and 2.5 equiv of LiHMDS to effect complete conversion of the aryl bromide. A significant part of the ester was consumed via Claisen condensation. We assume that, in many instances, the product may exist in deprotonated form prior to the quenching of the reaction mixture.[14e] Attempts to use less base and ester under these conditions were unsuccessful as the reaction did not go to completion. The use of sodium *tert*-butoxide as base under the same conditions gave no conversion of the aryl bromide. We found that either $Pd(OAc)_2$ or $Pd_2(dba)_3$ could be used as the catalyst precursor. The most general catalyst system was comprised of the commercially available ligand **1**, $Pd(OAc)_2$, and LiHMDS in toluene. This

(14) (a) Palucki, M.; Buchwald, S. L. *J. Am. Chem. Soc.* **1997**, *119*, 11108. (b) See reference 6. (c) Hamann, B. C.; Hartwig, J. F. *J. Am. Chem. Soc.* **1997**, *119*, 12382. (d) Shaughnessy, K. H.; Hamann, B. C.; Hartwig, J. F. *J. Org. Chem.* **1998**, *63*, 6546. (e) Kawatsura, M.; Hartwig, J. F. *J. Am. Chem. Soc.* **1999**, *121*, 1473. (f) Satoh, T.; Kawamura, Y.; Miura, M.; Nomura, M. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 1740. (g) Satoh, T.; Inoh, J.-I.; Kawamura, Y.; Kawamura, Y.; Miura, M.; Nomura, M. *Bull. Chem. Soc. Jpn.* **1998**, *71*, 2239.

(15) Åhman, J.; Wolfe, J. P.; Troutman, M. V.; Palucki, M.; Buchwald, S. L. *J. Am. Chem. Soc.* **1998**, *120*, 1918.

(16) For C−N coupling reactions employing these ligands, see: (a) Harris, M. C.; Buchwald, S. L. *J. Org. Chem.* **2000**, *65*, 5327−5333. (b) Zhang, X. X.; Sadighi, J. P.; Mackewitz, T. W.; Buchwald, S. L. *J. Am. Chem. Soc.* **2000**, *122*, 7606−7607. (c) Plante, O. J.; Buchwald, S. L.; Seeberger, P. H. *J. Am. Chem. Soc.* **2000**, *122*, 7148−7149. (d) Old, D. W.; Harris, M. C.; Buchwald, S. L. *Org. Lett.* **2000**, *2*, 1403−1406. (e) Wolfe, J. P.; Tomori, H.; Sadighi, J. P.; Yin, J. J.; Buchwald, S. L. *J. Org. Chem.* **2000**, *65*, 1158−1174. (f) Wolfe, J. P.; Buchwald, S. L. *Angew. Chem., Int. Ed. Engl.* **1999**, *38*, 2413−2416. (g) Old, D. W.; Wolfe, J. P.; Buchwald, S. L. *J. Am. Chem. Soc.* **1998,** *120*, 9722−9723. (h) For C−O coupling reactions, see: Aranyos, A.; Old, D. W.; Kiyomori, A.; Wolfe, J. P.; Sadighi, J. P.; Buchwald, S. L. *J. Am. Chem. Soc.* **1999**, *121*, 4369−4378. (i) For α-arylation see ref 6. For the C−C coupling reaction employing these ligands, see: (j) Wolfe, J. P.; Singer, R. A.; Yang, B. H.; Buchwald, S. L. *J. Am. Chem. Soc.* **1999**, *121*, 9550−9561. (k) Wolfe, J. P.; Buchwald, S. L. *Angew. Chem., Int. Ed. Engl.* **1999**, *38*, 2413−2416. For the synthesis of these ligands, see: (l) Tomori, H.; Fox, J. M.; Buchwald, S. L. *J. Org. Chem.* **2000**, *65*, 5334−5341.

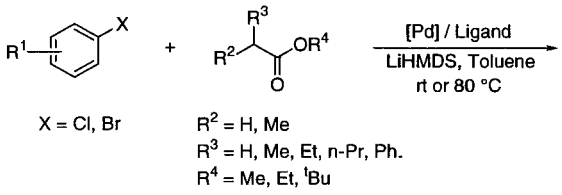
(17) Hampton, K. G.; Harris, T. M.; Hauser, C. R. *J. Org. Chem.* **1963**, *28*, 1946.

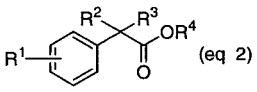
(18) Schlosser, M. In *Organometallics in Synthesis: A Manual*; Schlosser, M., Ed.; Wiley: Chichester, 1994; Chapter 1.

procedure proved to be general for the α-arylation of *tert*-butyl acetate with a variety of aryl bromides (Table 1). In all cases examined, only traces of diarylation products were observed. We note that the use of esters derived from smaller alcohols (e.g., ethyl) led to reduced yields in many instances.

It should be noted that the vinylation of *tert*-butyl acetate is also possible under the same conditions. The reaction of *β*-bromostyrene and *tert*-butyl acetate gave the corresponding *β*,*γ*-unsaturated ester in 66% yield (Table 1, entry 6). It is interesting that even in the presence of excess strong base, isomerization to the α,*β*-unsaturated ester did not predominate.

After our success with the synthesis of α-aryl acetates, we turned our attention to the preparation of α-aryl propionic esters (eq 2). That class of compounds is important as many non-steroidal antiinflammatory and analgesic drugs are based on α-aryl propionic acids and their derivatives.[1,2]





The α-arylation of *tert*-butyl propionate with a variety of aryl bromides was examined and was found to proceed in good yield either at room temperature or at 80 °C (see Table 2). For example, the combination of 2-bromonaphthalene and 2.3 equiv of *tert*-butylpropionate using 3 mol % $Pd(OAc)_2$, 6.3 mol % **1**, and 2.5 equiv of LiHMDS as base gave, after 15 min at 80 °C, the desired product in 92% yield (entry 1). The only significant byproduct (10−20%) observed in this α-arylation process was the Claisen product of the corresponding *tert*-butyl ester. Using this catalyst system, a number of aryl bromides were converted to products in very good to excellent yields.

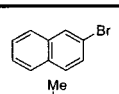
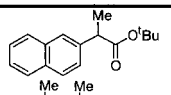
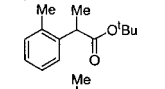
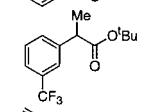
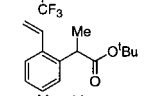
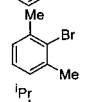
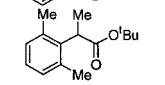
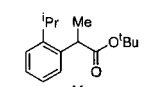
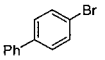
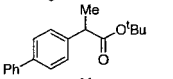
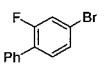
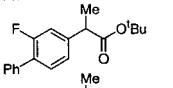
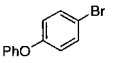
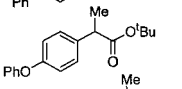
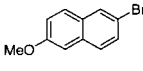
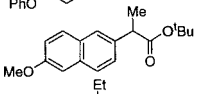
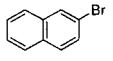
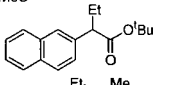
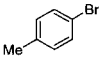
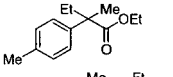
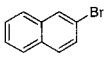
As shown in Table 2, the reaction has a good level of generality and tolerates trifluoromethyl and *o*-vinyl groups as well as 2,6-disubstitution. Also shown is that ethyl esters can be utilized and quaternary centers can be formed, albeit in moderate yields (Table 2, entries 12 and 13).

The reaction described in Table 2, entry 1 was also carried out at room temperature using PPh_3, BINAP, PCy_3, and P(t-Bu)$_3$ as ligands. Only P(t-Bu)$_3$ gives the desired α-aryl ester in any significant amount, but the reactions were much slower and resulted in lower yield than those using **1**. We note, however, that no attempt was made to optimize the process using any of these ligands.

One goal of the ester α-arylation was the development of an efficient method for the preparation of several non-steriodal antiinflammatories (Table 2, entries 8, 9, and 10). Using the simple protocol described, (±)-naproxen *tert*-butyl ester can be prepared in 79% yield (Table 2, entry 10) and (±)-flurbiprofen *tert*-butyl ester in 86% yield (Table 2, entry 8). Reaction of the *tert*-butyl ester of flurbiprofen with TFA in dichloromethane at 40 °C provided the free carboxylic acid in 96% yield. Our method is quite competitive with the other methods of synthesizing flubiprofen described in the literature.[19]

(19) Schlosser, M.; Geneste, H. *Chem. Eur. J.* **1998**, *4*, 1969 and references therein.

Table 2. Palladium-Catalyzed α-Arylation of α-Alkyl Esters[a]

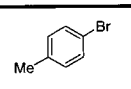
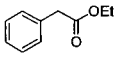
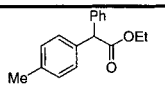
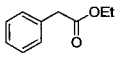
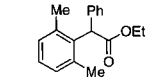
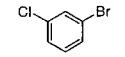
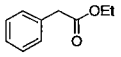
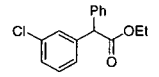
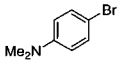
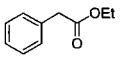
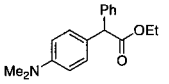
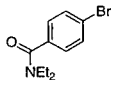
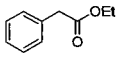
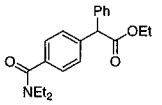
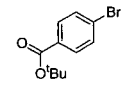
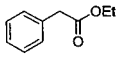
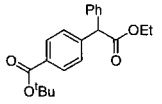
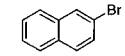
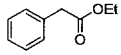
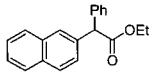
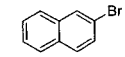
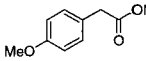
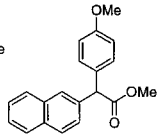
Entry	Aryl Bromide	Ester	Product	Temp. [°C]	Time [h]	Yield[b] [%]
1				rt 80	17 0.25	84 92
2				80	2	82
3				80	1	81
4				80	2	77
5				80	2	68
6				80	2	88
7				80	0.5	86
8				80	0.3	86
9				80	2	71
10				rt 80	15 0.5	79 74
11				80	2	81
12[c]				80	0.5	48
13[c]				40	17	54

[a] Reaction conditions: 1.0 equiv of aryl bromide, 2.3 equiv of ester, 2.5 equiv of LiHMDS, 3.0 mol % $Pd(OAc)_2$, and 6.3 mol % ligand **1**. 2 mL of toluene was added per 0.5 mmol of aryl bromide. [b] Isolated yield. [c] Ligand **3** was used.

We were also interested in extending the scope of the arylation process to include methyl or ethyl esters. Our initial attempts to use ethyl phenylacetate under reaction conditions similar to those described above at room temperature were unsuccessful; unreacted aryl bromide was recovered. However, the same reaction proceeded cleanly in only 10 min when the reaction temperature was increased to 80 °C. As is evident from the results shown in Table 3, the method is quite effective in a number of instances and produces the desired products in very good yields. Moreover, a variety of functional groups (Cl, NMe_2, CO_2NEt_2, and $CO_2{}^tBu$) were tolerated as illustrated (Table 3, entries 3−6 and 8). From these results it is evident that, at least for stabilized ester enolates, ethyl and methyl esters are satisfactory substrates.

The only byproduct in all of the reactions described in Table 3 was that of Claisen condensation of the starting ester. Despite the usefulness of the catalyst system derived from $Pd(OAc)_2$ and ligand **1** for the preparation of many α-aryl esters, not all combinations of substrates were effectively transformed. The coupling product of ethyl phenylacetate with *N*,*N*-dimethyl-4-bromoaniline was obtained in only 49% yield with $Pd(OAc)_2$ (Table 3, entry 4). The combination of 1.5 mol % $Pd_2(dba)_3$ and **2**, however, gave the desired product in 90% yield and was complete in only 10 min at 80 °C.

Table 3. Palladium-Catalyzed α-Arylation of Ethyl Phenyl Acetate Using Ligand **1**[a]

Entry	Aryl Bromide	Ester	Product	Time [h]	Yield[b] [%]
1				0.5	85
2				2	71
3				1	79
4				3 0.2	49 90[c]
5				1	88
6				0.5	75
7				3	88
8				0.5	83

[a] Reaction conditions: 1.0 equiv of aryl bromide, 2.3 equiv of ethyl phenylacetate, 2.5 equiv of LiHMDS, 3.0 mol % $Pd(OAc)_2$, and 6.3 mol % ligand **1**. 2 mL of toluene was used per 0.5 mmol of aryl bromide. The reaction temperature was 80 °C. [b] Isolated yield. [c] 1.5 mol % $Pd_2(dba)_3$ and 6.3 mol % ligand **2** were used.

Because aryl chlorides are relatively inexpensive and therefore attractive for industrial applications, attempts were made to apply our method for aryl bromides to the α-arylation of ethyl phenylacetate with aryl chlorides. We found that di-*tert*-butylphosphine ligand **2** is much more effective for this purpose than is **1**. To demonstrate the efficacy of the ligand **2**/$Pd_2(dba)_3$ catalyst system, we have prepared the compounds shown in Table 4 from aryl chlorides. While activated esters such as ethyl phenylacetate give very good results (Table 4, entries 1 and 2), *tert*-butyl propionate gave only moderate yields of the desired product. As before, Claisen condensation of *tert*-butyl propionate was the predominant side reaction.

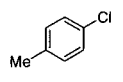
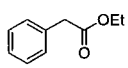
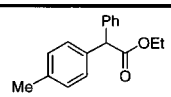
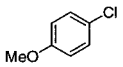
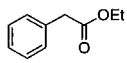
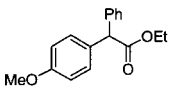
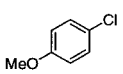
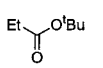
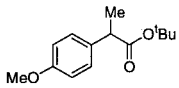
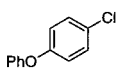
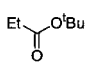
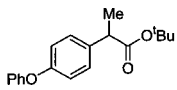
While the yields given in Table 4 are moderate, to the best of our knowledge, they represent the first examples of the palladium-catalyzed α-arylation of an ester using an aryl chloride.

Ligands **1**−**3** possess a fine balance of steric and electronic properties that allow for significantly accelerated oxidative addition while facilitating, or at least not inhibiting, the other steps in the catalytic cycle. Although mechanistic investigations have not been carried out, we expect that the key steps are similar to the proposed mechanism of the palladium-catalyzed α-arylation of ketones.[15]

Conclusion

We have thus extended the palladium-catalyzed α-arylation method to the α-arylation of esters. The lack of a straightforward way to prepare α-aryl esters can be solved, in many instances, using bulky electron-rich *o*-biphenyl phosphines **1**−**3**.

Table 4. α-Arylation of Esters Using Aryl Chlorides and Ligand **2** at 80 °C[a]

Entry	Aryl Chloride	Ester	Product	Time [h]	Yield[b] [%]
1				2	82
2				1	87
3				5	56
4				3	54

[a] Reaction conditions: 1.0 equiv of aryl chloride, 2.3 equiv of ester, 2.5 equiv of LiHMDS, 1.5 mol % $Pd_2(dba)_3$, and 6.3 mol % ligand **2**. 2 mL of toluene was added per 0.5 mmol of aryl chloride. The reaction temperature was 80 °C. [b] Isolated yield.

The described method has the advantage of simplicity and employs a one-pot procedure to obtain α-aryl esters in high yields from commercially available starting materials. Of special importance is that the use of LiHMDS as the base is a key factor in obtaining monoarylated product in a selective manner. In addition to the efficacy of our catalyst system, these conditions exhibited good functional group compatibility. The reactions proceed at room temperature to 80 °C with 3 mol % palladium catalyst in good to excellent yields and with high selectivity for monoarylation.

Experimental Section

General Considerations. All reactions were carried out in glassware that was flame-dried under vacuum and cooled under argon. Flash chromatography was performed on Silicycle ultrapure silica gel (230−400 mesh). Elemental analyses were performed by Atlantic Microlabs, Inc, Norcross, GA. Toluene was distilled from molten sodium under an atmosphere of nitrogen. Alternatively, toluene was purchased from J. T. Baker in CYCLE-TAINER solvent delivery kegs, and vigorously purged with argon for 2 h. Toluene was further purified by passing it through two packed columns of neutral alumina and copper(II) oxide under argon pressure. Esters and aryl halides were purchased from commercial sources and used without purification. Palladium acetate, tris(dibenzylideneacetone)dipalladium(0), and sodium hexamethyldisilazane (NaHMDS) were purchased from Strem Chemical, Inc. Lithium hexamethyldisilazane (LiHMDS) and sodium *tert*-butoxide were purchased from Aldrich Chemical Co., and the bases were stored under nitrogen in a Vacuum Atmospheres glovebox. All materials were weighed in the air, except for LiHMDS and NaHMDS, which were weighed and added to the reaction flask in a glovebox. IR spectra reported in this paper were obtained by placing neat samples directly on the DiComp probe of an ASI REACTIR in situ IR instrument. Alternatively, IR spectra in this paper for several compounds were recorded on a Perkin-Elmer FT-IR 1600. Yields in tables refer to isolated yields of compounds estimated to be 95% pure as determined by ^{1}H NMR, GC, and, in most cases, combustion analysis. Compounds that are described more than once in the same table were completely characterized once. Other samples of these compounds were characterized by comparing their ^{1}H NMR spectra to those of the fully characterized product, and their purity was confirmed by GC analysis.

General Procedure. An oven-dried, resealable Schlenk tube containing a stirbar was capped with a rubber septum, flame-dried under vacuum, and then backfilled with argon and cooled to room temperature. The tube was then charged with $Pd(OAc)_2$ (3.4 mg, 15 μmol) and **1** (12.4 mg, 31.5 μmol). The tube was sealed and brought into a nitrogen-filled glovebox where lithium bis(trimethylsilyl)amide (209 mg, 1.25

mmol) was added. The Schlenk tube was removed from the box and the mixture was dissolved in toluene (2 mL) and stirred for 10 min at room temperature. The ester (1.15 mmol) was added dropwise to this solution at −10 °C under argon, and the mixture was stirred for an additional 10 min to complete the formation of the enolate. The aryl bromide (0.5 mmol) was added at −10 °C and then the reaction mixture was allowed to warm to room temperature and stirred for the time specified. In some cases the temperature was increased to 80 °C. After cooling, if necessary, the reaction mixture was filtered through a plug of 5 g of silica gel using 150 mL of toluene as eluent and then concentrated under reduced pressure, and the residue was chromatographed on silica gel.

***tert*-Butyl (naphthalen-2-yl)acetate (Table 1, entry 1):** The general procedure was followed. The reaction was carried out at room temperature for 1 h. The yield was 102 mg (84%). Mp 45−46 °C; ^{1}H NMR (C_6D_6, 300 MHz) δ 7.60−7.57 (m, 4H), 7.40−7.36 (m, 1H), 7.27−7.20 (m, 2H), 3.51 (s, 2H), 1.34 (s, 9H); ^{13}C NMR (C_6D_6, 75 MHz) δ 170.6, 134.4, 133.3, 133.2, 128.7, 128.6, 128.4, 128.3, 128.1, 126.6, 126.2, 80.7, 43.5, 28.5 ppm; IR (neat, cm^{-1}) ν 3054, 2978, 2930, 1719, 1633, 1598, 1455, 1385, 1390, 1365, 1295, 1256, 1145. Anal. Calcd for $C_{16}H_{18}O_2$: C, 79.31; H, 7.49. Found: C, 79.51; H, 7.39.

***tert*-Butyl (6-methoxynaphthalen-2-yl)acetate (Table 1, entry 2):** The general procedure was followed. The reaction was carried out at room temperature for 4 h. The yield was 122 mg (90%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.58−7.51 (m, 2H), 7.46−7.41 (m, 2H), 7.17 (m, 1H), 6.89 (m, 1H), 3.52 (s, 2H), 3.36 (s, 3H), 1.34 (s, 9H); ^{13}C NMR (C_6D_6, 75 MHz) δ 170.9, 158.4, 134.5, 130.8, 129.9, 129.9, 128.6, 128.5, 127.6, 119.7, 106.3, 80.6, 55.2, 43.4, 28.5 ppm; IR (neat, cm^{-1}) ν 3056, 2977, 2908, 1720, 1631, 1610, 1476, 1385, 1365, 1331, 1262, 1212, 1158, 1020; HRMS for $C_{17}H_{20}O_3$ 272.1407, found 272.1413.

***tert*-Butyl (4-methylphenyl)acetate (Table 1, entry 3):**[20] The general procedure was followed. The reaction was carried out at room temperature for 4 h. The yield was 83 mg (81%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.15 (d, 2H, J = 8.10 Hz), 6.95 (d, 2H, J = 8.10 Hz), 3.37 (s, 2H), 2.07 (s, 3H), 1.32 (s, 3H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 170.9, 136.7, 132.7, 129.8, 129.7, 80.3, 42.9, 28.3, 21.3 ppm; IR (neat, cm^{-1}) ν 3007, 2974, 2923, 1725, 1505, 1446, 1362, 1294, 1252, 1134.

***tert*-Butyl (4-fluorophenyl)acetate (Table 1, entry 4):** The general procedure was followed. The reaction was carried out at room temperature for 6 h. The yield was 74 mg (71%). ^{1}H NMR (C_6D_6, 300 MHz) δ 6.96−6.91 (m, 2H), 6.78−6.71 (m, 2H), 3.20 (s, 2H), 1.30 (s, 3H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 170.4, 164.2, 161.0, 131.4 (d, J = 7.92 Hz), 115.7 (d, J = 21.21 Hz), 80.7, 42.3, 28.4 ppm; ^{19}F NMR (C_6D_6, 282 MHz) δ −116.6; IR (neat, cm^{-1}) ν 3045, 2979, 2933, 1732, 1607, 1510, 1392, 1368, 1257, 1225, 1144; HRMS for $C_{12}H_{15}FO_2$ [M + Na]$^+$ 233.0948, found 233.0957.

***tert*-Butyl (2-methylphenyl)acetate (Table 1, entry 5):** The general procedure was followed. The reaction was carried out at 80 °C for 10 min. The yield was 79 mg (78%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.15−7.12 (m, 2H), 7.05−6.98 (m, 2H), 3.37 (s, 2H), 2.16 (s, 3H), 1.30 (3, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 170.6, 137.3, 134.4, 130.8, 130.8, 127.7, 126.6, 80.4, 41.3, 28.5, 20.2 ppm; IR (neat, cm^{-1}) ν 3065, 2977, 2930, 1732, 1495, 1456, 1392, 1367, 1335, 1256, 1144; HRMS for $C_{13}H_{18}O_2$ [M + Na]$^+$ 229.1199, found 229.1209.

4-Phenylbut-3-enoic acid *tert*-butyl ester (Table 1, entry 6): The general procedure was followed. The reaction was carried out at room temperature for 1 h. The yield was 72 mg (66%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.20−7.18 (m, 3H), 7.11−6.98 (m, 2H), 6.37−6.20 (m, 2H), 2.97 (d, 2H, J = 6.30 Hz), 1.36 (s, 9H); ^{13}C NMR (C_6D_6, 75 MHz) δ 170.6, 137.9, 133.6, 129.1, 127.9, 127.0, 123.3, 80.6, 40.2, 28.6 ppm; IR (neat, cm^{-1}) ν 3062, 3028, 2983, 2926, 1721, 1602, 1493, 1441, 1390, 1361, 1293, 1259, 1145. Anal. Calcd for $C_{14}H_{18}O_2$: C, 77.03; H, 8.31. Found: C, 76.98; H, 8.43.

***tert*-Butyl α-(naphthalen-2-yl) propionate (Table 2, entry 1):** The general procedure was followed. The reaction was carried out at room temperature for 17 h. The yield was 108 mg (84%). Mp 81−82 °C; ^{1}H NMR (C_6D_6, 300 MHz) δ 7.68 (m, 1H), 7.62−7.57 (m, 3H), 7.48−7.44 (m, 1H), 7.27−7.19 (m, 2H), 3.69 (q, 1H, J = 6.90 Hz), 1.49 (d, 3H, J = 6.90 Hz), 1.29 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.8, 139.7, 134.5, 133.4, 128.9, 128.5, 128.3, 126.8, 126.6, 126.4, 126.2, 80.4, 47.3, 28.3, 19.3 ppm; IR (neat, cm^{-1}) ν 3048, 2966, 2919, 1719, 1596, 1449, 1390, 1367, 1320, 1255, 1208, 1149. Anal. Calcd for $C_{17}H_{20}O_2$: C, 79.65; H, 7.86. Found: C, 79.41; H, 7.94.

***tert*-Butyl α-(2-methylphenyl)propionate (Table 2, entry 2):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 90 mg (82%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.40 (m, 1H), 7.11−6.98 (m, 3H), 3.77 (q, 1H, J = 7.20 Hz), 2.20 (s, 1H), 1.39 (d, 3H, J = 7.20 Hz), 1.28 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 174.0, 140.7, 136.1, 131.0, 127.3, 127.0, 127.0, 80.2, 43.0, 28.4, 20.2, 18.6 ppm; IR (neat, cm^{-1}) ν 3074, 2971, 2937, 1721, 1487, 1453, 1390, 1358, 1333, 1254, 1214, 1151, 1088, 1054. Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.32; H, 9.15. Found: C, 76.49; H, 9.20.

***tert*-Butyl α-(3-trifluoromethylphenyl)propionate (Table 2, entry 3):** The general procedure was followed. The reaction was carried out at 80 °C for 1 h. The yield was 111 mg (81%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.60 (s, 1H), 7.25−7.19 (m, 2H), 6.93−6.88 (m, 1H), 3.36 (q, 1H, J = 7.20 Hz), 1.24 (s, 9H), 1.24 (d, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.9, 143.0, 131.5−131.1 (m), 129.6, 127.1, 125.2 (q, J = 3.8 Hz), 124.3 (q, J = 3.8 Hz), 123.5, 80.9, 46.9, 28.3, 19.1 ppm; ^{19}F NMR (C_6D_6, 282 MHz) δ −62.7; IR (neat, cm^{-1}) ν 2978, 2919, 2849, 1725, 1449, 1455, 1360, 1331, 1255, 1214, 1143, 1073. Anal. Calcd for $C_{14}H_{17}F_3O_2$: C, 61.30; H, 6.25. Found: C, 61.13; H, 6.22.

***tert*-Butyl α-(2-vinylphenyl)propionate (Table 2, entry 4):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 90 mg (77%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.39−7.36 (m, 2H), 7.11−6.99 (m, 3H), 5.50 (dd, 1H, J = 17.39, 1.50 Hz), 5.16 (dd, 1H, J = 11.09, 1.50 Hz), 3.92 (q, 1H, J = 7.20 Hz), 1.39 (d, 3H, J = 7.20 Hz), 1.27 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.8, 139.7, 137.4, 135.5, 128.7, 127.6, 127.4, 127.2, 116.9, 80.4, 43.0, 28.4, 18.9 ppm; IR (neat, cm^{-1}) ν 3060, 2966, 2931, 2872, 1725, 1625, 1484, 1455, 1390, 1331, 1320, 1250, 1220, 1155. Anal. Calcd for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.39; H, 8.59.

***tert*-Butyl α-(2,6-dimethylphenyl)propionate (Table 2, entry 5):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 80 mg (68%). ^{1}H NMR (C_6D_6, 300 MHz) δ 6.98−6.88 (m, 3H), 3.93 (q, 1H, J = 7.20 Hz), 2.22 (s, 6H), 1.40 (d, 3H, J = 7.20 Hz), 1.29 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 174.1, 139.7, 136.5, 129.6, 127.0, 80.1, 42.1, 28.3, 20.9, 15.9 ppm; IR (neat, cm^{-1}) ν 3005, 2971, 2938, 2878, 1723, 1681, 1580, 1462, 1360, 1243, 1162. Anal. Calcd for $C_{15}H_{22}O_2$: C, 76.88; H, 9.46. Found: C, 76.71; H, 9.64.

***tert*-Butyl α-(2-isopropylphenyl)propionate (Table 2, entry 6):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 109 mg (88%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.44−7.41 (m, 1H), 7.19−7.14 (m, 1H), 7.12−7.03 (m, 2H), 3.92 (q, 1H, J = 6.90 Hz), 3.17 (sep, 1H, J = 6.90 Hz), 1.41 (d, 3H, J = 6.60 Hz), 1.28 (s, 9H), 1.24 (d, 3H, J = 6.60 Hz), 1.13 (d, 3H, J = 6.90 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 174.2, 146.3, 139.5, 127.7, 127.3, 126.7, 126.0, 80.1, 41.7, 29.3, 28.2, 24.7, 24.1, 19.6 ppm; IR (neat, cm^{-1}) ν 3060, 2966, 2872, 1725, 1490, 1449, 1390, 1361, 1325, 1249, 1214, 1149. Anal. Calcd for $C_{16}H_{24}O_2$: C, 77.38; H, 9.74. Found: C, 77.36; H, 9.82.

***tert*-Butyl α-(4-biphenyl)propionate (Table 2, entry 7):** The general procedure was followed. The reaction was carried out at 80 °C for 30 min. The yield was 122 mg (86%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.44−7.40 (m, 4H), 7.34−7.30 (m, 2H), 7.22−7.08 (m, 3H), 3.58 (q, 1H, J = 7.20 Hz), 1.44 (d, 3H, J = 7.20 Hz), 1.32 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.7, 141.6, 141.2, 140.6, 129.4, 128.6, 128.0, 127.7, 127.7, 80.4, 47.0, 28.4, 19.6 ppm; IR (neat, cm^{-1}) ν 3049, 3025, 2978, 2931, 2872, 1725, 1601, 1519, 1484, 1455, 1384, 1361, 1337, 1255, 1214, 1149, 1072. Anal. Calcd for $C_{19}H_{22}O_2$: C, 80.82; H, 7.85. Found: C, 81.12; H, 8.04.

***tert*-Butyl α-(2-fluoro-4-biphenyl)propionate (Table 2, entry 8):** The general procedure was followed. The reaction was carried out at 80 °C for 20 min. The yield was 128 mg (86%). Mp = 59−60 °C; ^{1}H NMR (C_6D_6, 300 MHz) δ 7.47−7.44 (m, 2H), 7.20 (m, 1H), 7.16 (m, 1H), 7.15 (m, 2H), 7.12−7.07 (m, 1H), 7.04−7.00 (m, 1H), 3.45 (q, 1H, J = 7.20 Hz), 1.35 (d, 3H, J = 7.20 Hz), 1.30 (s, 9H) ppm; ^{13}C

(20) Amin, H. B.; Taylor, R. *J. Chem. Soc., Perkin Trans. 2* **1978**, 1095−1098.

NMR (C_6D_6, 75 MHz) δ 173.1, 162.2, 158.9, 143.6 (d, J = 7.70 Hz), 136.3 (d, J = 1.36 Hz), 131.4 (d, J = 4 Hz), 129.7 (d, J = 2.94 Hz), 129.0, 128.2, 124.1 (d, J = 3.24 Hz), 116.0 (d, J = 23.47 Hz), 80.8, 46.7, 28.4, 19.3 ppm; ^{19}F NMR (C_6D_6, 282 MHz) δ −118.14 (t, J = 9.03 Hz); IR (neat, cm^{-1}) ν 3059, 3033, 2978, 2934, 2876, 1728, 1624, 1582, 1562, 1484, 1455, 1418, 1368, 1334, 1255, 1147, 1075. Anal. Calcd for $C_{19}H_{21}FO_2$: C, 75.97; H, 7.05. Found: C, 76.11; H, 7.12.

***tert*-Butyl α-(4-diphenoxy)propionate (Table 2, entry 9):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 107 mg (71%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.17−7.13 (m, 3H), 7.05−6.97 (m, 2H), 6.93−6.88 (m, 4H), 6.86−6.80 (m, 1H), 3.48 (q, 1H, J = 7.20 Hz), 1.38 (d, 3H, J = 7.20 Hz), 1.31 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.7, 158.1, 157.0, 136.9, 130.4, 129.5, 123.7, 119.6, 119.6, 80.4, 46.6, 28.4, 19.6 ppm; IR (neat, cm^{-1}) ν 3070, 3038, 2977, 2932, 2874, 1727, 1590, 1506, 1489, 1456, 1367, 1334, 1240, 1148, 1072. Anal. Calcd for $C_{19}H_{22}O_3$: C, 76.48; H, 7.43. Found: C, 76.36; H, 7.47.

***tert*-Butyl α-(6-methoxynaphthalen-2-yl)propionate (Table 2, entry 10):** The general procedure was followed. The reaction was carried out at room temperature for 15 h. The yield was 113 mg (79%). Mp = 72−73 °C; ^{1}H NMR (C_6D_6, 300 MHz) δ 7.60 (m, 1H), 7.56−7.53 (m, 1H), 7.49−7.42 (m, 2H), 7.14−7.10 (m, 1H), 6.86 (m, 1H), 3.67 (q, 1H, J = 7.20 Hz), 3.33 (s, 3H), 1.48 (d, 3H, J = 7.20 Hz), 1.27 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 174.0, 158.5, 137.3, 134.6, 130.0, 129.9, 127.8, 126.9, 126.8, 119.7, 106.2, 80.3, 55.1, 47.2, 28.3, 19.4 ppm; IR (neat, cm^{-1}) ν 2979, 2939, 1721, 1607, 1505, 1488, 1451, 1389, 1368, 1266, 1158, 1027. Anal. Calcd for $C_{18}H_{22}O_3$: C, 75.50; H, 7.74. Found: C, 75.30; H, 7.90.

***tert*-Butyl α-(naphthalen-2-yl)butyrate (Table 2, entry 11):** The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 109 mg (81%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.74 (m, 1H), 7.63−7.56 (m, 3H), 7.54−7.50 (m, 1H), 7.28−7.19 (m, 2H), 3.53 (t, 1H, J = 7.80 Hz), 2.29−2.15 (m, 1H), 1.88−1.74 (m, 1H), 1.30 (s, 9H), 0.88 (t, 3H, J = 7.50 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.3, 138.2, 134.4, 133.5, 128.9, 128.5, 128.3, 127.5, 126.7, 126.6, 126.2, 80.5, 55.3, 28.3, 27.7, 12.8 ppm; IR (neat, cm^{-1}) ν 3042, 2970, 2921, 2873, 1722, 1625, 1595, 1449, 1449, 1389, 1364, 1341, 1256, 1153. Anal. Calcd for $C_{18}H_{22}O_2$: C, 79.96; H, 8.20. Found: C, 80.21; H, 8.17.

Ethyl α-methyl-α-(4-methylphenyl)butyrate (Table 2, entry 12): The general procedure was followed. The reaction was carried out at 80 °C for 30 min. Ligand **3** was used. The yield was 53 mg (48%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.30−7.25 (m, 2H), 7.00−6.98 (m, 2H), 3.93 (q, 2H, J = 7.20 Hz), 2.24−2.10 (m, 1H), 2.03 (s, 3H), 2.01−1.89 (m, 1H), 1.52 (s, 3H), 0.89−0.77 (m, 6H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 176.1, 142.0, 136.4, 129.7, 126.7, 60.9, 50.9, 32.8, 22.9, 21.4, 14.6, 9.9 ppm; IR (neat, cm^{-1}) ν 2975, 2937, 2880, 1728, 1514, 1460, 1381, 1306, 1235, 1144, 1101, 1049. Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.32; H, 9.15. Found: C, 76.32; H, 9.32.

***tert*-Butyl α-methyl-α-(4-naphthalen-2-yl)butyrate (Table 2, entry 13):** The general procedure was followed. The reaction was carried out at 40 °C for 17 h. Ligand **3** was used. The yield was 69 mg (54%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.80 (m, 1H), 7.66−7.57 (m, 3H), 7.52−7.48 (m, 1H), 7.28−7.20 (m, 2H), 3.94 (q, 2H, J = 7.20 Hz), 2.32−2.20 (m, 1H), 2.10−1.98 (m, 1H), 1.62 (s, 3H), 0.86−0.81 (m, 6H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 175.9, 142.3, 134.3, 133.1, 128.8, 128.7, 128.1, 126.6, 126.4, 125.6, 125.4, 61.1, 51.4, 32.6, 22.8, 14.6, 9.9 ppm; IR (neat, cm^{-1}) ν 3048, 2978, 2931, 2884, 1725, 1595, 1502, 1455, 1378, 1302, 1231, 1137, 1126, 1090, 1026. Anal. Calcd for $C_{17}H_{20}O_2$: C, 79.65; H, 7.86. Found: C, 79.60; H, 8.08.

Ethyl α-phenyl-α-(4-methylphenyl)acetate (Table 3, entry 1): The general procedure was followed. The reaction was carried out at 80 °C for 30 min. The yield was 108 mg (85%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.42−7.41 (m, 2H), 7.33−7.30 (m, 2H), 7.16−7.09 (m, 3H), 7.05−7.00 (m, 1H), 6.96−6.93 (m, 1H), 5.03 (s, 1H), 3.93 (q, 2H, J = 7.20 Hz), 2.05 (s, 3H), 0.88 (t, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.5, 140.1, 137.1, 136.9, 129.8, 129.3, 129.2, 129.1, 127.6, 61.3, 57.6, 21.4, 14.5 ppm; IR (neat, cm^{-1}) ν 3027, 2980, 2923, 1737, 1600, 1513, 1494, 1453, 1367, 1366, 1185, 1150, 1028. Anal. Calcd for $C_{17}H_{19}O_2$: C, 80.28; H, 7.13. Found: C, 80.68; H, 7.26.

Ethyl α-phenyl-α-(2,6-dimethylphenyl)acetate (Table 3, entry 2): The general procedure was followed. The reaction was carried out at 80 °C for 2 h. The yield was 95 mg (71%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.28−7.24 (m, 2H), 7.14−7.11 (m, 2H), 7.10−7.06 (m, 2H), 7.07−7.00 (m, 2H), 6.96−6.94 (m, 1H), 5.45 (s, 1H), 3.94 (m, 2H), 2.18 (s, 6H), 0.85 (t, 3H, J = 6.90 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.8, 138.3, 137.9, 136.5, 129.8, 129.4, 128.8, 127.9, 127.2, 61.2, 51.8, 21.5, 14.5 ppm; IR (neat, cm^{-1}) ν 3048, 2966, 2919, 1731, 1595, 1490, 1466, 1443, 1366, 1366, 1178, 1026. Anal. Calcd for $C_{18}H_{20}O_2$: C, 80.56; H, 7.51. Found: C, 80.65; H, 7.61.

Ethyl α-phenyl-α-(3-chlorophenyl)acetate (Table 3, entry 3): The general procedure was followed. The reaction was carried out at 80 °C for 1 h. The yield was 108 mg (79%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.46 (t, 1H, J = 1.80 Hz), 7.28−7.25 (m, 2H), 7.13−6.97 (m, 5H), 6.76 (t, 1H, J = 7.79 Hz), 4.83 (s, 1H), 3.87 (t, 2H, J = 6.89 Hz), 0.83 (t, 3H, J = 6.89 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 171.8, 141.8, 139.1, 135.1, 130.4, 129.5, 129.3, 129.2, 128.0, 127.5, 61.6, 57.4, 14.5 ppm; IR (neat, cm^{-1}) ν 3063, 3028, 2981, 2937, 1735, 1594, 1573, 1496, 1475, 1454, 1367, 1311, 1192, 1152, 1027. Anal. Calcd for $C_{16}H_{15}ClO_2$: C, 69.95; H, 5.50. Found: C, 70.05; H, 5.52.

Ethyl α-phenyl-α-(4-*N*,*N*-dimethylaminophenyl)acetate (Table 3, entry 4): The general procedure was followed. The reaction was carried out at 80 °C for 10 min. $Pd_2(dba)_3$ (1.5 mol %) and **2** (6.3 mol %) were used. The yield was 127 mg (90%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.49−7.45 (m, 2H), 7.39−7.33 (m, 2H), 7.17−7.11 (m, 2H), 7.07−7.02 (m, 1H), 6.57−6.52 (m, 2H), 5.07 (s, 1H), 3.97 (q, 2H, J = 7.20 Hz), 2.47 (s, 6H), 0.91 (t, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.2, 150.4, 140.9, 130.1, 129.4, 129.0, 127.6, 127.5, 113.4, 61.1, 57.1, 40.6, 14.5 ppm; IR (neat, cm^{-1}) ν 3027, 2980, 2901, 2802, 1732, 1613, 1520, 1495, 1453, 1348, 1309, 1226, 1189, 1149, 1028. Anal. Calcd for $C_{18}H_{21}NO_2$: C, 76.30; H, 7.47. Found: C, 76.21; H, 7.47.

Ethyl α-phenyl-α-(4-*N*,*N*-diethylcarbamoylphenyl)acetate (Table 3, entry 5): The general procedure was followed. The reaction was carried out at 80 °C for 1 h. The yield was 149 mg (88%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.33−7.23 (m, 6H), 7.11−6.95 (m, 4H), 4.95 (s, 1H), 3.88 (q, 2H, J = 6.90 Hz), 3.23 (bs, 2H), 2.77 (bs, 2H), 0.96 (br, 3H), 0.84 (t, 3H, J = 6.90 Hz), 0.62 (br, 3H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.2, 170.5, 140.6, 139.5, 137.5, 129.3, 129.2, 127.9, 127.6, 61.6, 57.7, 14.6 ppm; IR (neat, cm^{-1}) ν 2976, 2935, 1732, 1631, 1472, 1455, 1428, 1381, 1366, 1309, 1287, 1190, 1152, 1096, 1022. Anal. Calcd for $C_{21}H_{25}NO_3$: C, 74.31; H, 7.42. Found: C, 74.05; H, 7.51.

4-(Ethoxycarbonylphenylmethyl)benzoic acid *tert*-butyl ester (Table 3, entry 6): The general procedure was followed. The reaction was carried out at 80 °C for 30 min. The yield was 128 mg (75%). ^{1}H NMR (C_6D_6, 300 MHz) δ 8.07−8.03 (m, 2H), 7.33−7.26 (m, 4H), 7.13−6.99 (m, 3H), 4.95 (s, 1H), 3.91 (q, 2H, J = 7.20 Hz), 1.44 (s, 9H), 0.86 (t, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 171.9, 165.6, 144.2, 139.3, 131.9, 130.5, 129.3, 129.3, 129.2, 127.9, 80.4, 61.6, 57.8, 28.6, 14.6 ppm; IR (neat, cm^{-1}) ν 3062, 2978, 2933, 1735, 1712, 1610, 1520, 1495, 1454, 1367, 1293, 1256, 1191, 1162, 1117, 1020. Anal. Calcd for $C_{21}H_{24}O_4$: C, 74.09; H, 7.11. Found: C, 73.92; H, 7.21.

Ethyl α-phenyl-α-(naphthalen-2-yl)acetate (Table 3, entry 7): The general procedure was followed. The reaction was carried out at 80 °C for 3 h. The yield was 128 mg (88%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.74 (m, 1H), 7.49−7.41 (m, 4H), 7.35−7.32 (m, 2H), 7.18−6.92 (m, 5H), 5.10 (s, 1H), 3.88 (q, 2H, J = 7.20 Hz), 0.84 (t, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.5, 139.8, 137.3, 134.3, 133.5, 129.5, 129.2, 129.0, 128.3, 128.1, 127.8, 127.6, 126.7, 126.5, 61.5, 58.1, 14.6 ppm; IR (neat, cm^{-1}) ν 3049, 2972, 1734, 1597, 1507, 1490, 1452, 1366, 1306, 1153, 1029. Anal. Calcd for $C_{20}H_{18}O_2$: C, 82.73; H, 6.25. Found: C, 82.62; H, 6.34.

Methyl α-methoxyphenyl-α-(naphthalen-2-yl)acetate (Table 3, entry 8): The general procedure was followed. The reaction was carried out at 80 °C for 30 min. The yield was 127 mg (83%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.83 (m, 1H), 7.60−7.49 (m, 4H), 7.34−7.28 (m, 2H), 7.23−7.18 (m, 2H), 6.77−6.72 (m, 2H), 5.16 (s, 1H), 3.35 (s, 3H), 3.25 (s, 3H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 173.2, 159.7, 137.6, 134.3, 133.4, 131.6, 130.6, 129.0, 128.7, 128.3, 128.0, 127.6, 126.7, 126.5, 57.1, 55.2, 52.2 ppm; IR (neat, cm^{-1}) ν 3055, 3000, 2950, 2835,

1736, 1609, 1582, 1510, 1462, 1434, 1369, 1303, 1251, 1156, 1033, 1007. Anal. Calcd for $C_{20}H_{18}O_3$: C, 78.41; H, 5.92. Found: C, 78.31; H, 6.04.

Ethyl α-phenyl-α-(methoxyphenyl)acetate (Table 4, entry 2): The general procedure was followed. The reaction was carried out at 80 °C for 1 h. The yield was 129 mg (87%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.41−7.37 (m, 2H), 7.32−7.27 (m, 2H), 7.12−7.10 (m, 2H), 7.05−7.00 (m, 1H), 6.75−6.70 (m, 2H), 5.00 (s, 1H), 3.94 (q, 2H, J = 7.20 Hz), 3.26 (s, 3H), 0.89 (t, 3H, J = 7.20 Hz) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 172.8, 159.6, 140.4, 131.9, 130.5, 129.3, 129.1, 127.7, 114.7, 61.4, 57.2, 55.2, 14.6 ppm; IR (neat, cm^{-1}) ν 3061, 3018, 2985, 2920, 2832, 1730, 1610, 1582, 1506, 1495, 1457, 1452, 1364, 1299, 1250, 1174, 1146, 1027. Anal. Calcd for $C_{17}H_{18}O_3$: C, 75.53; H, 6.84. Found: C, 75.65; H, 6.84.

***tert*-Butyl α-(methoxyphenyl)propionate (Table 4, entry 3):** The general procedure was followed. The reaction was carried out at 80 °C for 5 h. The yield was 66 mg (56%). ^{1}H NMR (C_6D_6, 300 MHz) δ 7.23−7.18 (m, 2H), 6.77−6.72 (m, 2H), 3.53 (s, 1H, J = 7.20 Hz), 3.27 (s, 3H), 1.42 (d, 3H, J = 7.20 Hz), 1.31 (s, 9H) ppm; ^{13}C NMR (C_6D_6, 75 MHz) δ 174.0, 159.4, 134.2, 129.1, 114.6, 80.2, 55.2, 46.5, 28.4, 19.6 ppm; IR (neat, cm^{-1}) ν 2976, 2934, 2836, 1727, 1612, 1584, 1513, 1457, 1392, 1367, 1248, 1149, 1036. Anal. Calcd for $C_{14}H_{20}O_3$: C, 71.16; H, 8.53. Found: C, 71.13; H, 8.57.

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