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$TiCl_4$-activated selective nucleophilic substitutions of *tert*-butyl alcohol and benzyl alcohols with π-donating substituents

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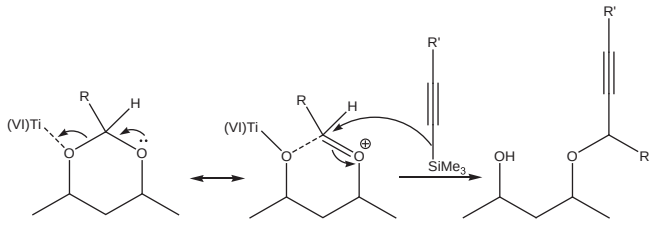
ABSTRACT

$TiCl_4$-activated selective nucleophilic substitution reactions of *tert*-butyl alcohol and benzyl alcohols with π-donating substituents in the presence of primary and secondary alcohols can be carried out with various oxygen, nitrogen and carbon nucleophiles in good yields.

1. Introduction

Ti(IV) as a Lewis acid facilitates a variety of reactions by activating various functional groups, such as aldehydes,[1] carboxylates,[2] acetals,[3] sulfonates,[4] epoxides,[5] and so on. Ti(IV) in the activation of aldehydes, carboxylates, or sulfonates significantly polarizes carbonyl or sulfonyl π bond, resulting in more electrophilic carbonyl carbon or sulfonyl sulfur, which is susceptible to various nucleophiles.[1,2,4] The activation of an epoxide by Ti(IV) releases its angle strain by partially breaking epoxide C–O bond, forming a partially positive charge on the more substituted carbon of the epoxide.[5] As shown in Scheme 1, Ti(IV) in the activation of an acetal facilitates the partial breakage of acetal C–O bond, developing a partially positive charge on acetal carbon, which is stabilized through resonance by the lone pair of electrons of oxygen at the other ether linkage.[3] This activation results in more electrophilic acetal carbon, which is susceptible to various nucleophiles.



Scheme 1.

There was some research that reported Lewis-acid-activated nucleophilic substitutions of alcohols.[6] However, to our knowledge, it was rare that Ti(IV) was used as a Lewis acid in activation of alcohols for their nucleophilic substitutions. It was reported that benzylic, allylic, or tertiary alcohols react smoothly with an excess of HN_3 in the presence of 0.5 equiv of $TiCl_4$, while primary alcohols appear to be inert in the same condition.[7] To our knowledge, so far, no other literature has applied this method involving Ti(IV)-activated nucleophilic substitution of alcohols to organic synthesis. It implies that some more information is needed about this method. For example, whether or not other nucleophiles like oxygen, carbon and nitrogen nucleophiles work well with this method? Also, what type of alcohol structures may facilitate their Ti(IV)-activated nucleophilic substitutions? It is likely that these data will enhance usage rate of this method.

A hydroxyl group of alcohol is not a good-leaving group, so in order for an alcohol to carry out nucleophilic substitution, one needs to convert a hydroxyl group to a good-leaving group. There are several ways to do that. Some of them do that in situ, followed by nucleophilic substitution in the same pot. For example, alcohols are treated with HBr, HI, $SOCl_2$, PBr_3, PCl_5, CCl_4/PPh_3, or H_2SO_4 to get the corresponding alkyl halides or ethers.[8a] This way involves a one-pot reaction, but products from this way are usually limited to alkyl halides and ethers. Some other ways involve isolable intermediates that have their hydroxyl groups converted to good-leaving groups, and subsequent nucleophilic substitution of the

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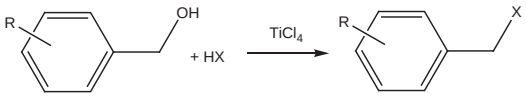
intermediates is usually carried out in another pot.[8a] For example, alcohols are converted to isolable sulfonates, followed by reacting with various kinds of nucleophiles. The advantage of this way is that isolable sulfonates may react with a variety of nucleophiles to generate various types of products, but this way usually involves two pots. In this paper, we tried to explore (1) if $TiCl_4$ can activate alcohols in situ for further nucleophilic substitution with various kinds of nucleophiles, (2) what types of alcohols may facilitate this $TiCl_4$-activated nucleophilic substitution reaction, and (3) if $TiCl_4$ can selectively activate some types of alcohols for their nucleophilic substitution reactions in the presence of other types of alcohols.

2. Results and discussion

We first explored if $TiCl_4$ is able to activate primary, secondary, or tertiary alcohols in situ for their nucleophilic substitution reactions with a primary alcohol as a nucleophile. As shown in Table 1, the primary alcohol **1** was treated with 0.2 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 4 days, but no reaction occurred. This is consistent with the literature[7] that has HN_3 as a nucleophile. We also found that no reaction occurred when the secondary alcohol **2** was treated with 2 equiv of the primary alcohol **1** in the presence of 0.2 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 4 days. However, reaction of the tertiary alcohol **3** with 2 equiv of the primary alcohol **1** in the presence of 0.2 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 2 days generated the nucleophilic substitution product **4** in a good yield. This is consistent with the literature[7] in which HN_3 serves as a nucleophile. It indicates that $TiCl_4$ activates a tertiary alcohol for nucleophilic substitution possibly through a tertiary carbon cation. It is likely that $TiCl_4$ may activate other alcohols, forming less unstable carbon cations, for nucleophilic substitution. Hence, we tested how well $TiCl_4$ activates substituted benzyl alcohols for nucleophilic substitution with oxygen, nitrogen or carbon nucleophiles.



5a, **5b**, **5g**, **5h** → **6a~n**

5a, **6a** : R = H, X = CH_3O;
5b, **6c** : R = *p*-CH_3O, X = *n*-BuNH;
5b, **6e** : R = *p*-CH_3O, X = PhNH;
5g, **6g** : R = *o*-CH_3O, X = CH_3O;
5h, **6i** : R = *p*-Me_2N, X = *n*-BuNH;
5h, **6k**: R = *p*-Me_2N, X = PhNH;
5b, **6m**: R = *p*-CH_3O, X = *p*-HOC_6H_4;
5b, **6b** : R = *p*-CH_3O, X = CH_3O;
5b, **6d** : R = *p*-CH_3O, X = Et_2N;
5b, **6f** : R = *p*-CH_3O, X = $[CH_3C(O)]_2CH$
5h, **6h** : R = *p*-Me_2N, X = CH_3O;
5h, **6j** : R = *p*-Me_2N, X = Et_2N;
5h, **6l**: R = *p*-Me_2N, X = $[CH_3C(O)]_2CH$;
5h, **6n**: R = *p*-Me_2N, X = *p*-HOC_6H_4;

Scheme 2.

We were thinking to make a new C–C bond by this method with a carbon nucleophile. The carbon nucleophile we tried for the nucleophilic substitution was a β-diketone. When benzyl alcohol **5b** with *p*-methoxy substituent reacted with 2 equiv of a β-diketone in the presence of 0.1 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 2 days, the nucleophilic substitution product **6f** was obtained in a good yield. The p*K*a of β-diketone is ca. 9[8a] but we did not add any qualified base in the reaction system, so its conjugate base may not be the nucleophile that makes the reaction work. The β-diketone follows tautomerization equilibrium and 80% of the equilibrium mixture is thermodynamically more stable enol tautomer. It is likely that the enol tautomer serves as a nucleophile for the nucleophilic substitution reaction.

Table 1
$TiCl_4$-activated nucleophilic substitutions of alcohols produced[a] via Scheme 2

Substrate	Nucleophile (HX)	$TiCl_4$	Rxn time	Product	Yield (%)
$Ph(CH_2)_3OH$ (**1**)	$Ph(CH_2)_3OH$	0.2 equiv	4 days	No rxn	—
$(CH_3)_2CHOH$ (**2**)	$Ph(CH_2)_3OH$	0.2 equiv	4 days	No rxn	—
t-BuOH (**3**)	$Ph(CH_2)_3OH$	0.2 equiv	2 days	*t*-$BuO(CH_2)_3Ph$ (**4**)	73
5a	CH_3OH	0.3 equiv	3 days	**6a**	20
5b	CH_3OH	0.1 equiv	9 h	**6b**	82
5b	*n*-$BuNH_2$	0.1 equiv	1.5 days	**6c**	69
5b	Et_2NH	0.1 equiv	1.5 days	**6d**	71
5b	$PhNH_2$	0.1 equiv	1 days	**6e**	75
5b	$[CH_3C(O)]_2CH_2$	0.1 equiv	2 days	**6f**	58
5g	CH_3OH	0.3 equiv	2 days	**6g**	50
5h	CH_3OH	0.1 equiv	1.5 days	**6h**	72
5h	*n*-$BuNH_2$	0.1 equiv	1.5 days	**6i**	61
5h	Et_2NH	0.1 equiv	1.5 days	**6j**	63
5h	$PhNH_2$	0.1 equiv	1 days	**6k**	62
5h	$[CH_3C(O)]_2CH_2$	0.1 equiv	2 days	**6l**	48
5b	PhOH	0.1 equiv	1 days	**6m**	65
5h	PhOH	0.1 equiv	1 days	**6n**	60

[a] The reaction was conducted at a reflux condition in $CDCl_3$.

As shown in Scheme 2 and Table 1, the reaction of benzyl alcohol **5a** with 2 equiv of CH_3OH in the presence of 0.3 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 3 days generated the nucleophilic substitution product **6a** with 20% conversion, and what left was the unreacted benzyl alcohol. The same reaction condition was applied to $TiCl_4$-activated nucleophilic substitution of *p*-nitrobenzyl alcohol with 2 equiv of CH_3OH, but no reaction occurred. Conversely, when benzyl alcohol **5b** with *p*-methoxy substituent reacted with 2 equiv of CH_3OH in the presence of 0.1 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 9 h, the nucleophilic substitution product **6b** was obtained in 82% yield. The yield was significantly improved by π-donating *p*-methoxy substituent. When reacting with 2 equiv of CH_3OH in the presence of 0.3 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 2 days, benzyl alcohol **5g** with *o*-methoxy substituent also generated the substitution product **6g** in a good yield. Different types of amines, including a primary amine, secondary amine and aniline, were used as nucleophiles for nucleophilic substitution reactions of benzyl alcohol **5b** with *p*-methoxy substituent in the presence of 0.1 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 1 or 1.5 days. The nucleophilic substitutions worked very well and the products **6c**–**e** were obtained in good yields.

The *p*-*N*,*N*-dimethylamino substituent is a stronger π-donating group than *p*-methoxy substituent.[8a] Like $TiCl_4$-activated nucleophilic substitution of benzyl alcohol **5b** with *p*-methoxy substituent, benzyl alcohol **5h** with *p*-*N*,*N*-dimethylamino substituent was able to be activated by $TiCl_4$ for the next nucleophilic

substitution reactions with oxygen nucleophile (methanol), nitrogen nucleophiles (primary amine, secondary amine, and aniline), and carbon nucleophile (β-diketone). The nucleophilic substitution products **6h**–**l** were obtained in good yields with newly formed C–O, C–N, and C–C bonds.

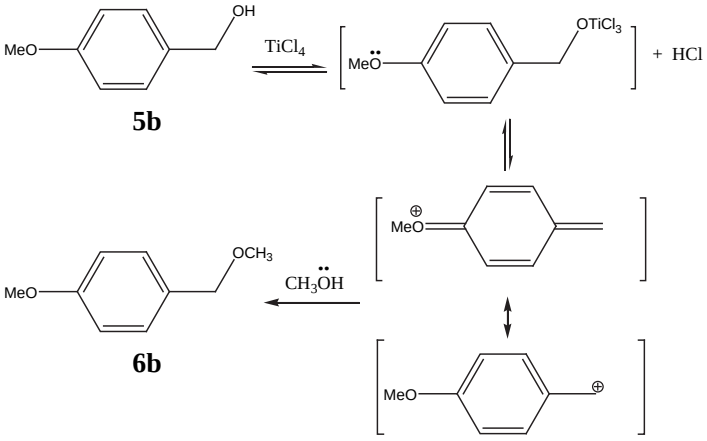
When benzyl alcohol **5b** with *p*-methoxy substituent or benzyl alcohol **5h** with *p*-*N*,*N*-dimethylamino substituent reacted with 2 equiv of phenol in the presence of 0.1 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 1 day, the substitution product **6m** or **6n** was obtained in a good yield. Actually, we planed to use phenol as an oxygen nucleophile in the Ti(IV)-activated nucleophilic substitution, but a new C–C bond was formed between benzyl carbon and C-4 of phenol. It indicates that electrophilic substitution occurs at the *para*-position of phenol with $TiCl_4$-activated benzyl alcohols as electrophiles. We tried to use toluene to replace phenol for the electrophilic substitution reaction with **5b** in the presence of 0.1 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 1 day, but toluene did not react at all because the activator of *p*-methyl is not as strong as *p*-hydroxy. The reaction route of electrophilic substitution was also found when aniline was used as a nucleophile, but it was much slower than the nucleophilic substitution with aniline as a nitrogen nucleophile.

For the above $TiCl_4$-activated nucleophilic substitution reactions of *tert*-butyl alcohol and benzyl alcohols with π-donating substituents, the increasing amount of $TiCl_4$ shortened the reaction time of the nucleophilic substitution reactions and increased the yields. The minimum amount of $TiCl_4$ for the $TiCl_4$-activated nucleophilic substitutions of *tert*-butyl alcohol and benzyl alcohols with π-donating substituents was around 0.1 equiv Residual water in the solvent slowed down the nucleophilic substitution reactions and decreased the yields, so molecular sieves were usually used in the reactions.

To test $TiCl_4$-activated selective nucleophilic substitutions of alcohols, we mixed primary or secondary alcohol with *tert*-butanol or benzyl alcohol with π-donating substituent, and treated the mixture with excess of various oxygen, nitrogen or carbon nucleophile in the presence of 0.1–0.3 equiv of $TiCl_4$ in $CDCl_3$ under a reflux condition for 1–2 days. Selective nucleophilic substitution of *t*-butanol or benzyl alcohol with π-donating substituent was performed in a good yield. The results were similar to those shown in Table 1.

To figure out which one activates benzyl alcohol in the $TiCl_4$-activated nucleophilic substitution reactions of benzyl alcohols with π-donating substituents, $TiCl_4$ or HCl, we compared two reactions, which were run at the same condition. In the first reaction, we treated **5b** (1 mmol) with CH_3OH (2 mmol) and $TiCl_4$ (0.1 mmol) in $CDCl_3$ with activated 4 Å molecular sieves. In the first hour at room temperature, the reaction produced **6b** (5%) and *p*-methoxybenzyl chloride (12%). After 9 h at a reflux condition, the reaction generated **6b** (82%) and *p*-methoxybenzyl chloride (10%). In the second reaction, we treated **5b** (1 mmol) with CH_3OH (2 mmol) and concd HCl (0.4 mmol) in $CDCl_3$ with activated 4 Å molecular sieves. For this reaction, we used activated 4 Å molecular sieves to remove water in the reaction system. In the first hour at room temperature, the reaction produced **6b** (4%) and *p*-methoxybenzyl chloride (14%). After 9 h at a reflux condition, the reaction generated **6b** (52%) and *p*-methoxybenzyl chloride (48%). Because more *p*-methoxybenzyl chloride was generated in the second reaction than in the first reaction, it strongly suggests that $TiCl_4$ is the major species in activating benzyl alcohol in the $TiCl_4$-activated nucleophilic substitution reactions of benzyl alcohols with π-donating substituents. However, HCl that was generated from ligand-exchange of $TiCl_4$ with alcohols also activates alcohols for further nucleophilic substitutions.

The mechanism for the $TiCl_4$-activated nucleophilic substitution reaction of benzyl alcohol **5b** with methanol in $CDCl_3$ with activated 4 Å molecular sieves is proposed in Scheme 3. At first, $TiCl_4$ would do ligand-exchange reaction with **5b**, making hydroxyl group of **5b** be activated by $TiCl_4$. According to the literature,[8b] only some but not all chloro ligands would be exchanged with alcohols in the absence of a base. In addition, because $TiCl_4$ activated a tertiary alcohol **3** for the nucleophilic substitution and generated **4**, it suggests that the reaction went through a carbon cation. Hence, the $TiCl_4$-activated **5b** might be dissociated into a transient of benzyl cation, which would be stabilized by *p*-methoxy group. The nucleophile that had the most concentration in the reaction system would be methanol, and it would react with benzyl cation to form the product **6b**.



Scheme 3.

Other Lewis acids like $SnCl_4$ and $FeCl_3$ were used to replace $TiCl_4$ in the $TiCl_4$-activated nucleophilic substitution reaction of benzyl alcohol **5b** with methanol in $CDCl_3$ with activated 4 Å molecular sieves at room temperature or a reflux condition. No substitution product **6b** was formed at all. These experimental results confirm that $TiCl_4$ as a Lewis acid is a good choice for the selective nucleophilic substitutions of *tert*-butanol and benzyl alcohols with π-donating substituents.

3. Conclusion

In conclusion, $TiCl_4$ may selectively activate *tert*-butanol and benzyl alcohols with π-donating substituents for their nucleophilic substitution reactions with various oxygen, nitrogen, and carbon nucleophiles in the presence of primary and secondary alcohols.

4. Experimental section

4.1. General procedure for $TiCl_4$-activated nucleophilic substitutions of alcohols

To an alcohol (1 mmol) and 4 Å molecular sieves (0.5 g) in $CHCl_3$ (2 mL) at room temperature was added $TiCl_4$ (0.1–0.3 mmol, 10% in $CHCl_3$). The mixture was stirred at room temperature for 1 min. A suitable nucleophile (2 mmol) was added into the mixture, followed by stirring at a reflux condition for 1–3 days. The product was purified by column chromatography with silica gel as stationary phase and hexane/EtOAc as mobile phase.

According to the procedure, the following products were obtained with the yields shown in Table 1. The products are known and their characterization by ^1H and ^{13}C NMR spectroscopic data.

*4.1.1. 1-(3-Phenylpropyl)-1-(1,1-dimethylethyl) ether (**4**)*[9]. ^1H NMR (300 MHz, $CDCl_3$): δ 7.21–7.33 (m, 5H), 3.40 (t, *J*=6.5 Hz, 2H), 2.73 (t,

J=7.6 Hz, 2H), 1.90 (m, 2H), 1.23 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 142.2, 128.4, 128.1, 125.6, 72.4, 60.6, 32.4, 32.1, 27.5.

*4.1.2. Benzyl methyl ether (**6a**)*[10]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.30–7.39 (m, 5H), 4.41 (s, 2H), 3.34 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 138.0, 128.0, 127.3, 127.2, 74.2, 57.6.

*4.1.3. 4-Methoxybenzyl methyl ether (**6b**)*[11]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.27 (d, *J*=8.5 Hz, 2H), 6.90 (d, *J*=8.5 Hz, 2H), 4.40 (s, 2H), 3.80 (s, 3H), 3.37 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 159.1, 130.16, 129.21, 113.63, 74.19, 57.61, 55.06.

*4.1.4. N-(4-Methoxybenzyl)butan-1-amine (**6c**)*[12]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.23 (d, *J*=8.6 Hz, 2H), 6.86 (d, *J*=8.6 Hz, 2H), 3.79 (s, 3H), 3.74 (s, 2H), 2.64 (t, *J*=7 Hz, 2H), 1.5 (m, 2H), 1.35 (m, 2H), 0.9 (t, *J*=7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.7, 131.7, 129.5, 113.8, 55.2, 53.2, 48.8, 31.8, 20.4, 13.9.

*4.1.5. N-Ethyl-N-(4-methoxybenzyl)ethanamine (**6d**)*[12]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.23 (d, *J*=8.6 Hz, 2H), 6.84 (d, *J*=8.6 Hz, 2H), 3.80 (s, 3H), 3.51 (s, 2H), 2.50 (q, *J*=7.2 Hz, 4H), 1.04 (t, *J*=7.2 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.5, 131.6, 130.1, 113.5, 56.7, 55.2, 46.4, 11.6.

*4.1.6. N-(4-Methoxybenzyl)aniline (**6e**)*[13]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.62–7.31 (m, 9H), 4.25 (s, 2H), 3.80 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.9, 148.2, 131.4, 129.2, 128.8, 117.5, 114.0, 112.8, 55.3, 47.8.

*4.1.7. 3-(4-Methoxybenzyl)pentane-2,4-dione (**6f**)*[14] *(keto and enol forms).* ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.79–7.07 (m, 4H), 3.96 (t, *J*=7.5 Hz, 0.6H), 3.77 (s, 3H), 3.58 (s, 0.8H), 3.09 (d, *J*=7.5 Hz, 1.2H), 2.08 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 203.8, 191.9, 158.4, 158.1, 131.6, 129.9, 129.6, 128.3, 114.1, 114.0, 108.6, 70.2, 55.3, 55.2, 33.5, 32.0, 29.7, 23.2.

*4.1.8. 2-Methoxybenzyl methyl ether (**6**)*[15]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.90–7.42 (m, 4H), 4.52 (s, 2H), 3.84 (s, 3H), 3.43 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 157.2, 129.1, 128.7, 126.4, 120.3, 110.2, 69.5, 58.3, 55.3.

*4.1.9. 4-N,N-Dimethylaminobenzyl methyl ether (**6h**)*[16]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.21 (d, *J*=8.3 Hz, 2H), 6.71 (d, *J*=8.3 Hz, 2H), 4.36 (s, 2H), 3.34 (s, 3H), 2.94 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 150.3, 129.3, 125.9, 112.4, 74.6, 57.5, 40.6.

*4.1.10. 4-((Butylamino)methyl)-N,N-dimethylaniline (**6i**)*[12]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.26 (d, J=8.7 Hz, 2H), 6.64 (d, *J*=8.7 Hz, 2H), 3.94 (s, 2H), 2.89 (s, 6H), 2.83 (t, *J*=7.9 Hz, 2H), 1.62 (m, 2H), 1.30 (m, 2H), 0.86 (t, *J*=7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 150.7, 130.8, 118.6, 112.3, 51.2, 46.3, 40.2, 28.3, 19.9, 13.5.

*4.1.11. 4-((Diethylamino)methyl)-N,N-dimethylaniline (**6j**)*[12]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.18 (d, *J*=8.3 Hz, 2H), 6.69 (d, *J*=8.3 Hz, 2H), 3.55 (s, 2H), 2.93 (s, 6H), 2.56 (q, *J*=7.1 Hz, 4H), 1.07 (t, *J*=7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 149.8, 130.1, 129.6, 112.4, 56.5, 46.2, 40.7, 11.3.

*4.1.12. N,N-Dimethyl-4-((phenylamino)methyl)-aniline (**6k**)*[13]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.64–6.75 (m, 7H), 7.04–7.08 (m, 2H), 4.21 (s, 2H), 2.95 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 150.0, 148.4, 129.4, 128.7, 127.0, 117.3, 113.0, 112.8, 47.9, 40.9.

*4.1.13. 3-(4-(Dimethylamino)benzyl)pentane-2,4-dione (**6l**)*[14] *(keto and enol forms).* ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.64–7.04 (m, 4H), 3.97 (t, *J*=7.5 Hz, 0.6H), 3.55 (s, 0.8H), 3.06 (d, *J*=7.5 Hz, 1.2H), 2.91 (s, 6H), 2.09 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 204.2, 191.9, 149.4, 149.3, 129.2, 128.0, 127.4, 125.5, 113.0, 112.9, 108.8, 70.4, 40.8, 40.6, 33.5, 31.8, 29.7, 23.2.

*4.1.14. 4-(4-Methoxybenzyl)phenol (**6m**)*[17]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.24–7.10 (m, 8H), 4.78 (b, OH), 3.85 (s, 2H), 3.79 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 157.9, 153.7, 133.8, 133.7, 129.9, 129.7, 115.2, 113.8, 55.3, 40.1.

*4.1.15. 4-(4-N,N-Dimethylaminobenzyl)phenol (**6n**)*[17]. ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.67–7.14 (m, 8H), 4.74 (b, OH), 3.90 (s, 2H), 2.91 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 154.1, 145.1, 130.8, 129.3, 127.7, 120.8, 115.9, 113.2, 40.7, 35.8.

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Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tet.2010.06.046.

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