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# Alternative formation of amides and β-enaminones from aroyl chlorides using the $TiCl_4$-trialkylamine reagent system

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The $TiCl_4/NR_3$ reagent system has been successfully employed for the synthesis of amides and β-enaminones. The reaction of variously substituted benzoyl chlorides with $TiCl_4/NR_3$ reagent system, by using two different experimental procedures (Method A and Method B), afforded alternatively the corresponding amides and β-enaminones as unique or major products. The two developed protocols were investigated with a series of tertiary amines. The reactions, modulated by the presence of $TiCl_4$, provided the corresponding amides or β-enaminones with satisfactory yields. This paper reports a new method for carbon-carbon bond formation via the reaction of aroyl chlorides with $TiCl_4/NR_3$ reagent system.

## Introduction

Various kinds of Lewis acid are employed in organic synthesis to promote reactions.[1] In particular titanium tetrachloride is a reagent widely used in organic synthesis for accelerating many reactions and transforming different functional groups.[2]

Titanium tetrachloride ($TiCl_4$) used in combination with a tertiary amine ($NR_3$) represents a useful reagent system ($TiCl_4$-$NR_3$) for the formation of carbon-carbon bonds, also with high stereoselectivity, such as in aldol and other condensation reactions.[3]

Titanium enolates can be generated by the action of triethylamine ($Et_3N$) and $TiCl_4$ with aldehydes or ketones through the removal of an acid hydrogen atom and used in conjugate addition reactions to α,β-unsaturated carbonyl compounds.[4]

$TiCl_4/Et_3N$ reagent system is used also to promote the Baiylis-Hilman type reaction in which arylaldehydes react with α,β-unsaturated carbonyl compounds to provide the corresponding chlorinated condensation product.[5]

Complex processes occur when $TiCl_4$ and $Et_3N$ react with esters generating titanium enolates. In these cases, oxidation-reduction reactions involve dimerization of the enolates.[6]

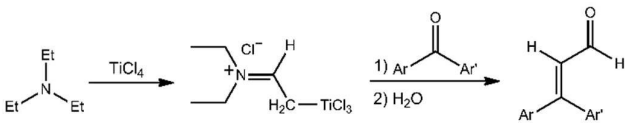
Furthermore, the reaction of $TiCl_4/Et_3N$ reagent system with ketimines and ketoximes allows the formation of heterocycle systems.[7]

Organotitanium compounds are also obtained by the reaction of 1-alkynes with $TiCl_4$-$NR_3$ system. These reagents react with carbonyl compounds to give the corresponding enynones.[8]

In all cases, the reaction is driven by the amine that generates a carbanion by deprotonation. This carbanion by interaction with $TiCl_4$ originates species such as titanium enolates or simple organotitanium compounds.

In the absence of organic substrates containing acidic hydrogens, the tertiary amine reacts with titanium tetrachloride to give an ammonium ion adduct which evolves producing an oxidation product with iminium ion structure and a titanium (III) specie.

The iminium ion intermediate containing acidic hydrogen atoms is converted into an organotitanium compound by the consecutive action of the amine and titanium tetrachloride. Such organotitanium intermediates are not isolated but react in situ with aromatic ketones by giving the corresponding unsaturated aldehydes (Scheme 1).[9]




**Scheme 1** Conversion of diaryl ketones into α,β-unsaturated aldehydes.

Herein we report an interesting study on the reactivity of acyl chlorides, lacking of hydrogen atoms at the carbon atom alpha to the carbonyl group, with organotitanium compounds obtained from the reaction of trialkylamines with $TiCl_4$.

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† Electronic Supplementary Information (ESI) available: $^1H$ NMR, $^{13}C$ NMR and MS (EI) spectra for compounds **2a-8d**. See DOI: 10.1039/x0xx00000x

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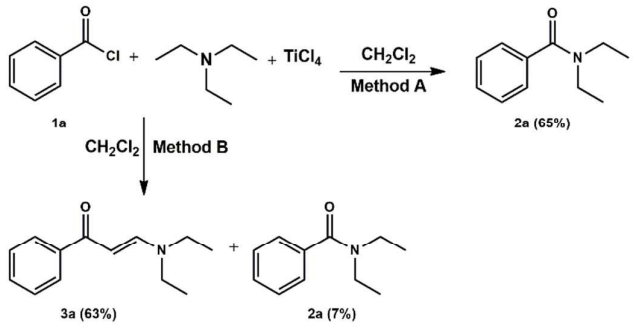
On this base we developed two different experimental procedures that lead to the exclusive or prevalent formation of amides and β-enaminones that are of great importance in organic synthesis.

## Results and discussion

We began the investigation by testing the model reaction between benzoyl chloride and the reagent system consisting of triethylamine ($Et_3N$) and titanium tetrachloride (Scheme 2).

The amount of amine used proved to be critical to the outcomes of the reaction. Two different ways of performing the reaction were established leading to the formation of completely different main products as the result of two diverse reaction pathways (Method A and Method B) (Scheme 2).

The reaction via Method A is characterized by the presence of an excess of amine and the rapid consecutive addition of the reagents. Benzoyl chloride (1 mmol) and $TiCl_4$ (4 mmol) are added to a solution of $Et_3N$ (6mmol) in methylene chloride (15 mL). The reaction mixture is kept under magnetic stirring at room temperature for about 12 h until complete conversion of the benzoyl chloride. *N*,*N*-diethylbenzamide (**2a**) is recovered in 65 % yield after purification of the crude reaction mixture by column chromatography (Scheme 2).



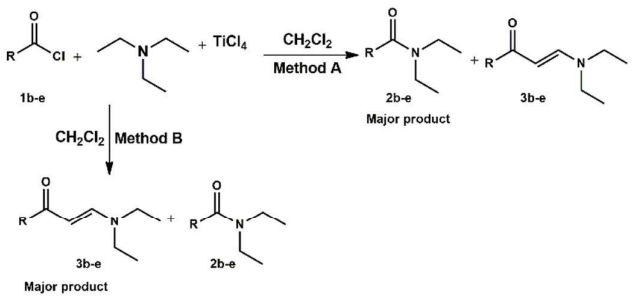

**Method A**: PhCOCl : $Et_3N$ : $TiCl_4$ = 1 : 6 : 4; **Method B**: PhCOCl : $Et_3N$ : $TiCl_4$ = 1 : 4 : 4

**Scheme 2** Conversion of benzoyl chloride into the corresponding *N*,*N*-diethylamide (Method A) or *N*,*N*-diethyl-β-enaminone (Method B).

In the Method B a solution of $Et_3N$ (4 mmol) in methylene chloride (15 mL) is added dropwise, by means of a pressure equalized dropping funnel, over a period of 1 hour to a solution of benzoyl chloride (1 mmol) and $TiCl_4$ (4 mmol) in methylene chloride (20 mL). The reaction is complete within about 12 h. The purification of crude reaction product by column chromatography afforded as main reaction product the corresponding β-enaminone, (*E*)-3-(diethylamino)-1-phenylprop-2-en-1-one (**3a**), in 63 % yield and *N*,*N*-diethylbenzamide (**2a**) in 7 % yield (Scheme 2).

Under the Method B experimental conditions, the reaction occurs in the presence of a low concentration of base.

In the light of these results, in order to confirm the outcome of the reaction via the two methods we decided to apply the adopted procedures (Method A and Method B) to a series of differently substituted benzoyl chlorides (Scheme 3, Table 1).




**Method A**: RCOCl : $Et_3N$ : $TiCl_4$ = 1 : 6 : 4; **Method B**: RCOCl : $Et_3N$ : $TiCl_4$ = 1 : 4 : 4

**Scheme 3** Synthesis of *N*,*N*-diethylamides (Method A) or *N*,*N*-diethyl-β-enaminones (Method B).

*N*,*N*-diethylamides (**2**) are the predominant reaction products by the reaction pathway A while β-enaminones (**3**) are the main ones by the reaction pathway B.

However, with both protocols (Method A and Method B), no particular electronic effects of the substituents on the aromatic ring of the starting substrates are observed.

**Table 1.** Results of the reactions reported in Scheme 3.

| | R | Method | Amide[a] 2 | β-Enaminone[a] 3 |
|---|---|---|---|---|
| b | *p*-$H_3COC_6H_4$ | A | 62 % | 8 % |
| b | *p*-$H_3COC_6H_4$ | B | 8 % | 65 % |
| c | *m*-$ClC_6H_4$ | A | 70 % | |
| c | *m*-$ClC_6H_4$ | B | 7 % | 69 % |
| d | *p*-$ClC_6H_4$ | A | 67 % | 4 % |
| d | *p*-$ClC_6H_4$ | B | 6 % | 60 % |
| e | *p*-$O_2NC_6H_4$ | A | 62 % | 5 % |
| e | *p*-$O_2NC_6H_4$ | B | 7 % | 61 % |

[a] Isolated yield

The reaction of benzoyl chloride with the reagent system consisting of tripropylamine ($Pr_3N$) and $TiCl_4$ (Scheme 4) leads to results consistent with those obtained with triethylamine and $TiCl_4$. In fact, with the method A, *N*,*N*-dipropylbenzamide (**4a**) is obtained in 68% yield as unique reaction product, whereas with method B the amide (**4a**) is recovered only in 4% yield and the β-enaminone (**5a**) is the prevalent product (71% yield) (Scheme 4).

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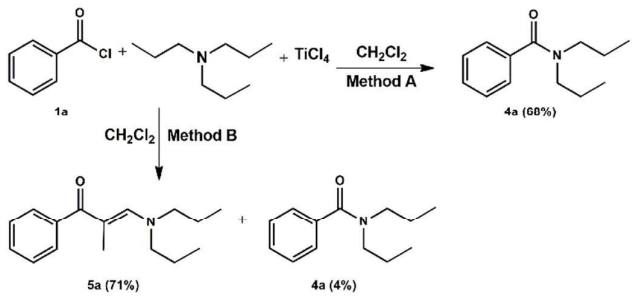


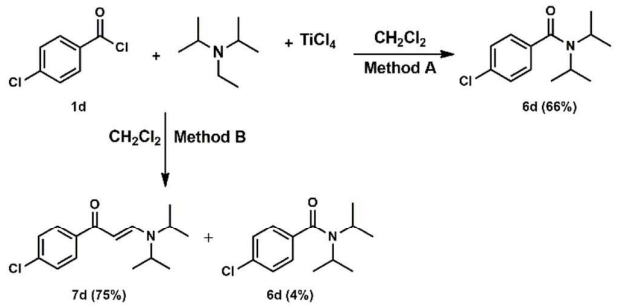

**Method A**: PhCOCl : $Pr_3N$ : $TiCl_4$ = 1 : 6 : 4; **Method B**: PhCOCl : $Pr_3N$ : $TiCl_4$ = 1 : 4 : 4

**Scheme 4** Synthesis of *N*,*N*-dipropylamides (Method A) or *N*,*N*-dipropyl-β-enaminones (Method B).

Additional experiments were performed by using tertiary amines with different alkyl substituents. To this aim, *N*,*N*-diisopropylethylamine (DIPEA) and *N*,*N*-dimethylisopropylamine (DMIPA), chosen as model systems, were treated with *p*-chlorobenzoyl chloride (**1d**) and $TiCl_4$ under the reaction conditions of both Method A and Method B.

It is interesting to note that by using the reagent system consisting of DIPEA and $TiCl_4$ the two isopropyl groups of the amine are kept in the reaction products obtained through both reaction pathways (Scheme 5).

Method A leads to the exclusive formation of *N*,*N*-diisopropyl-*p*-chlorobenzamide (**6d**) (66% yield ) while method B provides the corresponding β-enaminone (*E*)-1-(4-chlorophenyl)-3-(diisopropylamino)prop-2-en-1-one (**7d**) in 75% yield and traces of amide (**6d**) (4% yield) (Scheme 5).

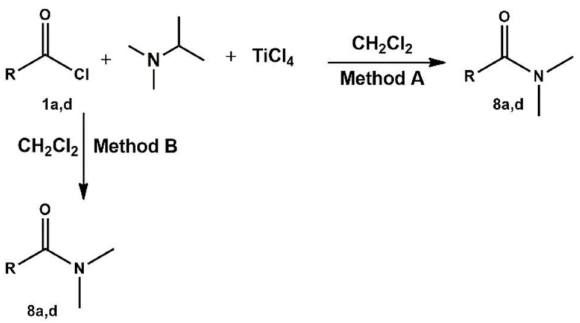



**Method A**: *p*-$ClC_6H_4COCl$ : DIPEA : $TiCl_4$ = 1 : 6 : 4; **Method B**: *p*-$ClC_6H_4COCl$ : DIPEA : $TiCl_4$ = 1 : 4 : 4

**Scheme 5** Synthesis of *N*,*N*-diisopropylamides (Method A) or *N*,*N*-diisopropyl-β-enaminones (Method B).

These results offer evidence that the ethyl group of DIPEA is involved in the formation of the reactive intermediates and is lost during the reaction. On the other hand, the isopropyl groups of DIPEA do not participate in the reaction and are preserved in the reaction products of both reaction pathways.

Instead, the reaction driven by the reagent system DMIPA/$TiCl_4$ under both methods A and B provides a single reaction product consisting of *N*,*N*-dimethyl-*p*-chlorobenzamide (**8d**) in 63% and 70 % yield respectively (Scheme 6, Table 2).




**Method A**: RCOCl : DMIPA : $TiCl_4$ = 1 : 6 : 4; **Method B**: RCOCl : DMIPA : $TiCl_4$ = 1 : 4 : 4

**Scheme 6** Synthesis of *N*,*N*-dimethylamides (Method A, Method B).

The outcome of the reaction of *p*-chlorobenzoyl chloride (**1d**) with the reagent system DMIPA/$TiCl_4$ shows that the formation of the β-enaminone requires that at least one of the alkyl groups of the amine has, in alpha position with respect to nitrogen atom, a primary carbon atom with not sterically hindered hydrogens and also a chain of at least two carbon atoms.

This finding is confirmed by the reaction of the same reagent system DMIPA/$TiCl_4$ with benzoyl chloride (**1a**) (Scheme 6, Table 2). Also in this case, in fact, both method A and B provide exclusively *N*,*N*-dimethylbenzamide (**8a**) with yields close to 65%.

**Table 2.** Results of the reactions reported in Scheme 6.

| | R | Method | Amide[a] 8 | β-Enaminone[a] |
|---|---|---|---|---|
| **a** | $C_6H_5$ | **A** | 65 % | – |
| **a** | $C_6H_5$ | **B** | 63 % | – |
| **d** | *p*-$ClC_6H_5$ | **A** | 63 % | – |
| **d** | *p*-$ClC_6H_5$ | **B** | 70 % | – |

[a] Isolated yield

On the basis of the collected experimental data using differently substituted tertiary amines under the reaction conditions of the two diverse reaction pathways, and of the available literature data[9] on the reactivity of the $TiCl_4/Et_3N$ reagent system, adequate reaction mechanisms for the formation of the amides and β-enaminones were hypothesized.

The key intermediate could be the ammonium ion (Adduct I) (Scheme 7, Scheme 8) that is generated from the reaction between the tertiary amine and titanium tetrachloride.

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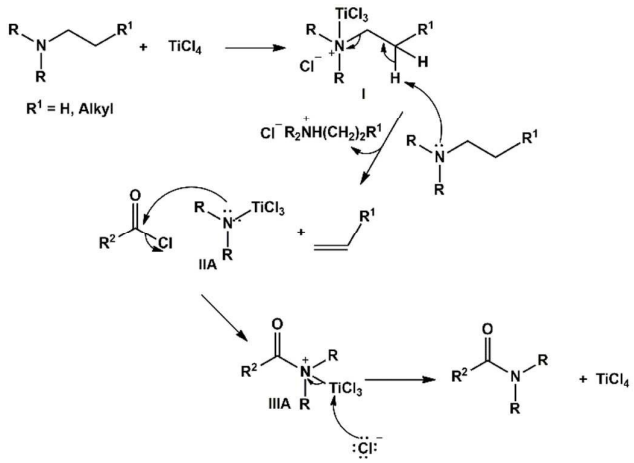
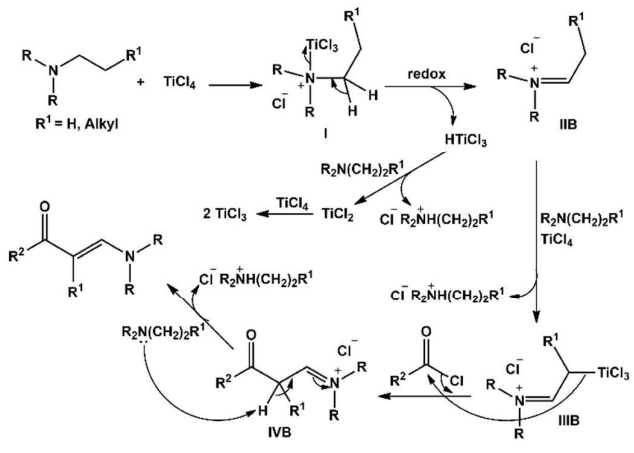



**Scheme 7** Proposed mechanism for amide formation (Method A)

The reaction path, which provides the amide as the predominant product, is favoured when an excess of amine is present in the reaction medium (Method A). Under these conditions, the ammonium ion (Adduct I) reacts with the amine in excess through an elimination process with the loss of an alkene (Hoffmann elimination) and the formation of a nucleophile intermediate (IIA) that reacts with the acyl chloride thus generating the amide (Scheme 7).

When the amine is added slowly (Method B) to the reaction mixture containing $TiCl_4$ and the acyl chloride, the produced ammonium ion (adduct I), in the presence of limited amount of amine, is oxidized generating the iminium ion (IIB) which then reacts with the amine and $TiCl_4$ to give the imminioalkyl titanium ion (IIIB) (Scheme 8). The reaction of acyl chloride with the organotitanium compound (IIIB) generates the adduct IVB, that evolves to β-enaminone, and $TiCl_4$ that is converted in titanium dioxide ($TiO_2$) during the final hydrolytic workup (Scheme 8).




**Scheme 8** Proposed mechanism for β-enaminone formation (Method B)

## Conclusions

In this work, we have devised two methodologies that can constitute alternative procedures for the synthesis of amides and β-enaminones. The reported study represents a new example of reactivity of $TiCl_4$-$NR_3$ reagent system with aroyl chlorides involving carbon-carbon bond formation.

The reactions according to method A and method B, both modulated by the presence of $TiCl_4$, lead to the formation, with satisfactory yields, of amides or β-enaminones that are of great importance in organic synthesis.

Amides in fact are very important functional groups in organic chemistry and the formation of amide bond is one of the most used transformations in organic synthesis.[10] Amides are also biologically interesting compounds because of their presence in molecules such as peptides, pharmaceutical agents, naturally occurring molecules, proteins.[11]

β-enaminones represent useful synthons for the synthesis of various heterocyclic compounds and biologically active molecules.[12] β-enaminones possess the nucleophilicity of an enamine and the electrophilicity of an enone, therefore they are important intermediates in organic synthesis.

Titanium tetrachloride forms with the alkyl tertiary amine an ammonium ion adduct. In the presence of an excess of amine this adduct generates, through an elimination process, the amide (Method A). The formation of the amide with the proposed method A is quite general.

In the absence of further amine the adduct leads to the formation of β-enaminone (Method B). This mechanism operates when the amine is added slowly.

The formation of the β-enaminone with the method B, however, does not occur when the amine has a secondary carbon directly linked to the nitrogen atom. This situation evidently prevents the oxidation process of the amine to the iminium ion by $TiCl_4$. Iminium ion, in fact, constitutes the key intermediate for the formation of the β-enaminone.

The formation of alkyltitanium species seems to be favoured at primary carbon atoms rather than secondary ones. When β-enaminone, for the reasons mentioned above, does not form, the channel leading to the formation of the amide is activated.

## Experimental

### General experimental details

All reagents were purchased commercially without further purification. Solvents were purified according to well-known laboratory methods and freshly distilled prior to use. Reaction were carried out in a tightly sealed screw-capped vial. Reactions were magnetically stirred and monitored by thin layer chromatography using Merck-Kieselgel 60 F254 plates. $^1H$ and $^{13}C$ NMR spectra were recorded on a Bruker Avance 300 instrument at 300 MHz and 75 MHz, respectively. Spectroscopic analysis was performed at 293 K on diluted solutions of each compound by using $CDCl_3$ as the solvent. Chemical shifts (δ) are reported in ppm. Coupling constants (J) are reported in Hertz (Hz). GC–MS analyses were performed with

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a DB-35MS (20 m × 0.18 mm, 35% Phenyl 65% dimethylpolysiloxane) capillary column. The mass detector was operated in the electron impact ionization mode (EI/MS) with an electron energy of 70 eV. The injection port was heated to 250 °C. The oven temperature program was initially set at 70 °C with a hold of 2 min and ramped to 280 °C at 20 °C/min with a hold of 10 min.

**General procedures for the synthesis of amides and β-enaminones.**

*General procedure Method A*

Benzoyl chloride or substituted benzoyl chloride (1 mmol) and $TiCl_4$ (4 mmol) were added in rapid succession to a solution of trialkylamine (6 mmol) in anhydrous dichloromethane (15 mL). The resulting mixture was maintained under an inert atmosphere ($N_2$) and stirred at room temperature for about 12 hours monitoring the reaction progress by TLC (chloroform/methanol 90:10 v/v). After adding dichloromethane (20 mL) the mixture was washed first with aqueous HCl 1N (3×10 mL) and then with a saturated aqueous solution of $NaHCO_3$ (3 × 10 mL) and dried over anhydrous $Na_2SO_4$. The evaporation of the organic solvent under reduced pressure afforded a crude reaction product that was purified by flash column chromatography (chloroform/methanol 95:5 v/v) to provide the corresponding *N*,*N*-dialkylamide (62-70 % yield) and *N*,*N*-dialkyl-β-enaminone (0-8 % yield).

*General procedure Method B*

To a solution of benzoyl chloride or substituted benzoyl chloride (1 mmol) in anhydrous dichloromethane (20 mL), under an inert atmosphere ($N_2$), $TiCl_4$ (4 mmol) was added. To the resulting solution trialkylamine (4 mmol), dissolved in anhydrous dichloromethane (15 mL), was added dropwise over a period of an hour. The mixture was stirred at room temperature for about 12 hours monitoring the reaction progress by TLC (chloroform/methanol 90:10 v/v). Then the mixture was washed with aqueous HCl 1N (3×10 mL) and with a saturated aqueous solution of $NaHCO_3$ (3 × 10 mL) and dried ($Na_2SO_4$). The organic solution was concentrated in vacuo and the crude residue was purified by flash column chromatography (chloroform/methanol 95:5 v/v) to provide the corresponding *N*,*N*-dialkyl-β-enaminone (61-75 % yield) and *N*,*N*-dialkylamide (0-7 % yield).

***N,N*-diethylbenzamide (2a)** Oil (65%); Rf = 0.70; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.45-7.30 (m, 5H, ArH), 3.67-3.43 (m, 2H, $CH_2$), 3.40-3.15 (m, 2H, $CH_2$), 1.25 (t, *J* = 6.0 Hz, 3H, $CH_3$), 1.11 (t, *J* = 6.0 Hz, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 171.14, 137.12, 128.94, 128.23, 126.09, 43.13, 39.12, 14.02, 12.74; GC/MS (EI, 70 eV) m/z (% rel.): 177 [$M^{+\cdot}$] (15), 176 (42), 162 (1), 148 (3), 105 (100), 77 (32), 51 (6). Found: C, 74.62; H, 8.56; N, 7.86. $C_{11}H_{15}NO$ requires C, 74.54.13; H, 8.53; N, 7.90%

**(*E*)-3-(diethylamino)-1-phenylprop-2-en-1-one (3a)** Oil (63%); Rf = 0.62; $^1$H-NMR (300 MHz, $CDCl_3$) δ: 7.93-7.77 (m, 3H, ArH, CHN), 7.56-7.30 (m, 3H, ArH), 5.75 (d, *J* = 12.5 Hz, 1H, COCH), 3.42-3.13 (m, 4H, $CH_2$), 1.43-1.02 (m, 6H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 188.80, 152.46, 140.78, 130.73, 128.07, 127.44, 91.77, 50.52, 42.91, 14.59, 11.39 (prof); GC/MS (EI, 70 eV) m/z (% rel.): 203 [$M^{+\cdot}$] (97), 186 (100), 174 (40), 146 (17), 126 (18), 105 (95), 98 (32), 77 (45). Found: C, 76.56; H, 8.48; N, 6.81. $C_{13}H_{17}NO$ requires C, 76.81; H, 8.43; N, 6.89%.

***N,N*-diethyl-4-methoxybenzamide (2b)** Oil (62%); Rf = 0.71; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.22 (d, *J* = 8.7 Hz, 2H, ArH), 6.77 (d, *J* = 8.7 Hz, 2H, ArH), 3.68 (s, 3H, $OCH_3$), 3.49-3.06 (m, 4H, $CH_2$), 0.90-1.26 (m, 6H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 171.06, 160.15, 129.30, 127.99, 113.48, 55.08, 42.40, 39.81, 13.30; GC/MS (EI, 70 eV) m/z (% rel.): 207 [$M^{+\cdot}$] (12), 206 (28), 135 (100), 107 (5), 92 (10), 77 (11). Found: C, 69.61; H, 8.21; N, 6.65. $C_{12}H_{17}NO_2$ requires C, 69.54; H, 8.27; N, 6.76%.

**(*E*)-3-(diethylamino)-1-(4-methoxyphenyl)prop-2-en-1-one (3b)** Oil (65%); Rf = 0.64; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.87 (d, *J* = 8.9 Hz, 2H, ArH), 7.79 (d, *J* = 12.5 Hz, 1H, CHN), 6.89 (d, *J* = 8.9 Hz, 2H, ArH), 5.74 (d, *J* =12.5 Hz, 1H, COCH), 3.82 (s, 3H, $OCH_3$), 3.30 (q, *J* = 7.2 Hz, 4H, $CH_2$), 1.20 (t, *J* = 7.2 Hz, 6H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 187.57, 161.84, 152.02, 133.30, 129.39, 113.26, 91.15, 55.33, 45.51, 14.67; MS (EI, 70 eV) m/z (% rel.): 233 [$M^{+\cdot}$] (54), 216 (46), 204 (10), 190 (5), 176 (7), 161 (3), 135 (100), 107 (5), 98 (26), 77 (15). Found: C, 72.33; H, 8.29; N, 5.93. $C_{14}H_{19}NO_2$ requires C, 72.07; H, 8.21; N, 6.00%.

**3-chloro-*N,N*-diethylbenzamide (2c)** Oil (70%); Rf = 0.50; $^1$H NMR (300 MHz, $CDCl_3$) δ: 8.01-7.89 (m, 1H, ArH), 7.55-7.50 (m, 1H, ArH), 7.59-7.47 (m, 1H, ArH), 7.41-7.31 (m, 1H, ArH), 7.28-7.20 (m, 1H, ArH), 3.66-3.45 (m, 2H, $CH_2$), 3.35-3.18 (m, 2H, $CH_2$), 1.33-1.18 (m, 3H, $CH_3$), 1.21-0.99 (m, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 169.88, 138.71, 134.49, 129.85, 129.37, 126.55, 124.41, 45.85, 33.44, 14.12, 12.70; GC/MS (EI, 70 eV) m/z (% rel.): 211 [$M^{+\cdot}$] (13), 210 (38), 182 (5), 139 (100), 111 (25), 75 (11). Found: C, 62.47; H, 6.65; N, 6.54. $C_{11}H_{14}ClNO$ requires C, 62.41; H, 6.67; N, 6.62%.

**(*E*)-1-(3-chlorophenyl)-3-(diethylamino)prop-2-en-1-one (3c)** Oil (69%); Rf = 0.34; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.99-7.53 (m, 3H, ArH, CHN), 7.46-7.07 (m, 2H, ArH), 5.67 (d, *J* = 12.5 Hz, 1H, COCH), 3.51-2.99 (m, 4H, $CH_2$), 1.36-0.89 (m, 6H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 186.88, 152.78, 142.49, 134.12, 130.53, 129.35, 127.50, 125.48, 91.16, 50.58, 42.82, 14.64, 11.48; GC/MS (EI, 70 eV) m/z (% rel.): 237 [$M^{+\cdot}$] (87), 222 (39), 220 (92), 208 (41), 190 (15), 180 (16), 165 (8), 154 (6), 139 (100), 126 (36), 111 (52), 98 (56), 75 (23), 56 (38). Found: C, 65.55; H, 6.85; N, 5.84. $C_{13}H_{16}ClNO$ requires C, 65.68; H, 6.78; Cl, 14.91; N, 5.89%.

**4-chloro-*N,N*-diethylbenzamide (2d)** Oil (67%); Rf = 0.63; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.41-7.24 (m, 4H, ArH), 3.63-3.37 (m, 2H, $CH_2$), 3.34-3.11 (m, 2H, $CH_2$), 1.35-0.97 (m, 6H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 170.21, 135.58, 135.11, 128.67, 127.82, 43.22, 39.11, 14.29, 12.82; GC/MS (EI, 70 eV) m/z (% rel.): 211 [$M^{+\cdot}$] (13), 210

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(35), 139 (100), 111 (24), 75 (10). Found: C, 62.46; H, 6.64; N, 6.54. $C_{11}H_{14}ClNO$ requires C, 62.41; H, 6.67; Cl, 16.75; N, 6.62%.

**(*E*)-1-(4-chlorophenyl)-3-(diethylamino)prop-2-en-1-one (3d)** Oil (60%); Rf = 0.47; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.92-7.77 (m, 3H, ArH, CH-N), 7.45-7.32 (m, 2H, ArH), 5.71 (d, *J* = 12.4 Hz, 1H, COCH), 3.51-3.18 (m, 4H, $CH_2$), 1.38-1.13 (m, 6H, $CH_3$); $^{13}$C NMR (300 MHz, $CDCl_3$) δ: 187.17, 152.62, 139.12, 136.79, 128.88, 128.26, 91.28, 50.70, 42.95, 14.62, 11.60; GC/MS (EI, 70 eV) m/z (% rel.): 237 [$M^{+\cdot}$] (73), 220 (78), 208 (29), 180 (13), 139 (100), 111 (35), 98 (40), 75 (14), 56 (19). Found: C, 65.81; H, 6.71; N, 5.96. $C_{13}H_{16}ClNO$ requires C, 65.68; H, 6.78; Cl, 14.91; N, 5.89%.

***N,N*-diethyl-4-nitrobenzamide (2e)** Oil (62%); Rf = 0.43; $^1$H NMR (300 MHz, $CDCl_3$) δ: 8.35-8.12 (m, 2H, ArH), 7.58-7.38 (m, 2H, ArH), 3.64-3.38 (m, 2H, $CH_2$), 3.29-3.05 (m, 2H, $CH_2$), 1.25 (t, *J* = 7.0 Hz, 3H, $CH_3$), 1.11 (t, *J* = 7.0 Hz, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 168.94, 148.02, 143.38, 127.35, 123.87, 43.28, 39.48, 14.19,12.85; GC/MS (EI, 70 eV) m/z (% rel.): 222 [$M^{+\cdot}$] (14), 221 (34), 193 (3), 150 (100), 120 (27), 104 (31), 92 (14), 76 (19). Found: C, 59.38; H, 6.44; N, 12.70. $C_{11}H_{14}N_2O_3$ requires C, 59.45; H, 6.35; N, 12.60%.

**(*E*)-3-(diethylamino)-1-(4-nitrophenyl)prop-2-en-1-one (3e)** Solid (61%); mp = 85.0-86.6 °C; Rf = 0.30; $^1$H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, *J* = 8.8 Hz, 2H, ArH), 7.99 (d, *J* = 8.8 Hz, 2H, ArH), 7.86 (d, *J* = 12.4 Hz, 1H, CHN), 5.72 (d, *J* = 12.4 Hz, 1H, COCH), 3.51-3.21 (m, 4H, $CH_2$), 1.34-1.17 (m, 6H, -$CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 185.82, 153.32, 148.92, 146.23, 128.23, 123.32, 91.44, 50.80, 43.02, 14.64, 11.52; GC/MS (EI, 70 eV) m/z (% rel.): 248 [$M^{+\cdot}$] (75), 231 (100), 219 (43), 173 (16), 150 (49), 98 (49), 76 (21), 56 (34). Found: C, 63.04; H, 6.45; N, 11.19. $C_{13}H_{16}N_2O_3$ requires C, 62.89; H, 6.50; N, 11.28%.

***N,N*-dipropylbenzamide (4a)** Oil (68%); Rf = 0.77; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.48-7.29 (m, 5H, ArH), 3.57-3.35 (m, 2H, $NCH_2$), 3.25-3.07 (m, 2H, $NCH_2$), 1.80-1.61 (m, 2H, $CH_2$), 1.61-1.42 (m, 2H, -$CH_2$), 1.08-0.91 (m, 3H, $CH_3$), 0.83-0.65 (m, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 170.90, 136.42, 128.36, 127.52, 125.61, 49.89, 45.48, 21.05, 19.85, 10.65, 10.18; GC/MS (EI, 70 eV) m/z (% rel.): 205 [$M^{+\cdot}$] (15), 204 (20), 176 (8), 162 (2), 134 (7), 105 (100), 77 (23). Found: C, 75.98; H, 9.35; N, 6.75. $C_{13}H_{19}NO$ requires C, 76.06; H, 9.33; N, 6.82%.

**(*E*)-3-(dipropylamino)-1-phenylbut-2-en-1-one (5a)** Oil (71%); Rf = 0.66; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.62-7.20 (m, 6H, ArH, CHN), 3.28-3.02 (m 4H, $NCH_2$), 2.08 (s, 3H, $CH_3$), 1.69-1.46 (m, 4H, $\underline{CH_2}CH_3$), 1.09-0.70 (m, 6H, $CH_2\underline{CH_3}$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 197.00, 155.43, 142.35, 128.83, 128.25, 127.71, 105.12, 55.05, 22.59, 10.87, 10.83; GC/MS (EI, 70 eV) m/z (% rel.): 245 [$M^{+\cdot}$] (37%), 228 (100), 216 (45), 202 (17), 168 (11), 160 (12), 145 (8), 140 (30), 105 (84), 91 (50), 77 (56). Found: C, 78.18; H, 9.38; N, 5.65. $C_{16}H_{23}NO$ requires C, 78.32; H, 9.45; N, 5.71%.

**4-chloro-*N,N*-diisopropylbenzamide (6d)** Solid (66%); mp= 81.6-83.7 °C; Rf = 0.70; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.42-7.32 (m, 2H, ArH), 7.30-7.21 (m, 2H, ArH), 3.98-3.34 (m, 2H, $NC\underline{H}(CH_3)_2$), 1.61-1.02 (m, 12H, $NCH(C\underline{H_3})_2$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 169.88, 137.30, 134.61, 128.70, 127.13, 51.99, 20.69; GC/MS (EI, 70 eV) m/z (% rel.): 239 [$M^{+\cdot}$] (6), 224 (5), 196 (18), 139 (100), 111 (19). Found: C, 65.22; H, 7.64; N, 5.79. $C_{13}H_{18}ClNO$ requires C, 65.13; H, 7.57; Cl, 14.79; N, 5.84%.

**(*E*)-1-(4-chlorophenyl)-3-(diisopropylamino)prop-2-en-1-one (7d)** Oil (75%); Rf = 0.63; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.97 (d, *J* = 12.5 Hz, 1H, CHN), 7.82 (d, 2H, *J* = 8.7 Hz, ArH), 7.35 (d, 2H, *J* = 8.7 Hz, ArH), 5.83 (d, *J* = 12.5 Hz, 1H, -CO-CH=CH), 4.08-3.90 (m, 1H, $NC\underline{H}CH_3)_2$), 3.73-3.51 (m, 1H, -$NC\underline{H}(CH_3)_2$), 1.30-1.20 (m, 12H, -$NCH(C\underline{H_3})_2$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 186.49, 149.31, 139.19, 136.65, 128.87, 128.23, 91.29, 49.51, 48.19, 23.68, 19.68; GC/MS (EI, 70 eV) m/z (% rel.): 265 [$M^{+\cdot}$] (33), 250 (8), 222 (56), 139 (100), 126 (20), 111 (21), 43 (18). Found: C, 68.04; H, 7.67; N, 5.16. $C_{15}H_{20}ClNO$ requires C, 67.79; H, 7.58; Cl, 13.34; N, 5.27%.

***N,N*-dimethylbenzamide (8a)** Oil (65% yield method A, 63% yield method B); Rf = 0.64; $^1$H-NMR (300 MHz, $CDCl_3$) δ: 7.51-7.30 (m, 5H, ArH), 3.11 (s, 3H, $CH_3$), 2.97 (s, 3H, $CH_3$); $^{13}$C- NMR ( 75 MHz, $CDCl_3$) δ: 171.62, 136.37, 129.45, 128.29, 127.01, 39.23, 35.11; GC/MS (EI, 70 eV) m/z (% rel.): 149 [$M^{+\cdot}$] (21), 148 (64), 105 (100), 77 (53), 51 (12). Found: C, 72.50; H, 7.40; N, 9.34. $C_9H_{11}NO$ requires C, 72.46; H, 7.43; N, 9.39%.

**4-chloro-*N,N*-dimethylbenzamide (8d)** Oil (63% yield method A, 70% yield method B); Rf = 0.53; $^1$H NMR (300 MHz, $CDCl_3$) δ: 7.42-7.24 (m, 4H, ArH), 3.08 (s, 3H, $CH_3$), 2.96 (s, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ: 170.51, 135.57, 134.68, 128.62, 128.59, 39.50, 35.55; GC/MS (EI, 70 eV) m/z (% rel.): 183 [$M^{+\cdot}$] (18), 182 (51), 139 (100), 111 (38), 75 (16). Found: C, 58.97; H, 5.53; N, 7.58. $C_9H_{10}ClNO$ requires C, 58.86; H, 5.49; Cl, 19.31; N, 7.63%.

## Conflicts of interest

There are no conflicts to declare.

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