# Competition of the $R_3P$/DAAD and RNC/DAAD Zwitterions in Their Production and Reaction with Aromatic Carboxylic Acids: A Novel Binucleophilic System for Three-Component Synthesis of 2-Aminofurans

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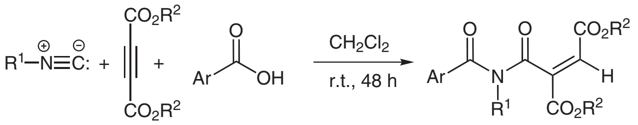
**Abstract:** We recently reported a new class of triphenylphosphine and isocyanide based multicomponent reactions ($Ph_3P$/DAAD and IMCRs/DAAD) mediated by $R_3P$/DAAD and RNC/DAAD zwitterionic intermediates in the presence of CH, OH, and NH acids. Herein, the reactions of Huisgen 1:1 zwitterionic intermediates, generated from dialkyl acetylenedicarboxylates (DAAD), trivalent phosphorus reagents, and isocyanides, with aromatic carboxylic acids as initial proton source are investigated. This novel binucleophilic ($R_3P$–RNC/DAAD) system afforded 2-aminofuran derivatives.

**Key words:** isocyanide, trialkyl phosphine, trialkyl phosphite, dialkyl acetylenedicarboxylate, aromatic carboxylic acid, multicomponent reaction, aminofuran

In 1962, Johnson and Tebby established the reaction of triphenylphosphine with dimethyl acetylenedicarboxylate.[1] This early finding forms the basis for the synthesis of a large class of new backbones which are thus accessible. The chemistry is based upon the initial formation of a zwitterionic adduct of the phosphine with the acetylene compounds.[2] In the other hand, in 1969, Winterfeldt et al. described the reaction of isocyanides and acetylenic compounds.[3] Recently, we have explored the reactivity of zwitterions derived from electron-deficient acetylenes and nucleophiles, such as triphenylphosphine ($Ph_3P$/DAAD), and isocyanides (RNC/DAAD); these studies have lead to a number of interesting carbon–carbon and carbon–heteroatom bond forming reactions and heterocyclic syntheses.[4]

In our recent investigations, the treatment of benzoic acid and its derivatives with dialkyl acetylenedicarboxylate and alkyl isocyanide (RNC/DAAD), in anhydrous dichloromethane at room temperature lead to the formation of linear imide derivatives (Scheme 1).[5]



**Scheme 1**

It was of interest to compare and investigate the reactivity of the $Ph_3P$/DAAD and RNC/DAAD zwitterions towards carboxylic acids. The present studies were initiated by triphenylphosphine and *tert*-butyl isocyanide as nucleophiles, dimethyl acetylenedicarboxylate as the activated acetylene, and benzoic acid as an initial proton source. In a pilot experiment, a solution of phosphine or phosphite, isocyanide, and aromatic carboxylic acid in anhydrous dichloromethane was treated with an equimolar quantity of dialkyl acetylenedicarboxylate at room temperature. To our surprise, in a one-pot reaction between triphenylphosphine, *tert*-butyl isocyanide, and dimethyl acetylenedicarboxylate in the presence of benzoic acid, the product was dimethyl 2-(*tert*-butylamino)-5-phenylfuran-3,4-dicarboxylate; triphenylphosphine oxide was also isolated from the reaction mixture (Scheme 2).[6]

To realize our goal and test the generality of this procedure in the synthesis of 2-aminofurans, we examined this reaction following different pathways. In all cases, under the various conditions, the product of these reactions was the 2-aminofuran, similar to our previous results.

Subsequently, a detailed study of the reaction of other tertiary phosphine and tertiary phosphite reagents, isocyanides, and electron-deficient acetylenes with aromatic carboxylic acids was undertaken and the results are presented in this paper.

In comparing the generation of $Ph_3P$/DAAD and RNC/DAAD zwitterions, our investigations were initiated with triphenylphosphine as the aromatic trivalent phosphine, isocyanides on treatment with dialkyl acetylenedicarboxylate in the presence of a stoichiometric amount of a benzoic acid derivative, to trap the in situ generated zwitterion, in dichloromethane afforded a product characterized as the dialkyl 2-(alkylamino)-5-arylfuran-3,4-dicarboxylate **4** in 69–88% yield (Table 1).

The structures of compounds **4a**–**g** were deduced from their elemental analysis, IR, and high-field $^1H$ and $^{13}C$ NMR spectra. The mass spectrum of **4a** displayed the molecular ion ($M^+$) peak at $m/z = 376$, which is consistent with the structure of dimethyl 2-(*tert*-butylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate structure. The IR spectrum of **4a** exhibited absorption bands due to the carbonyl group of esters and ketones at 1724 and 1669 $cm^{-1}$,

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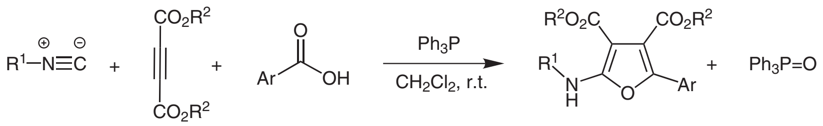
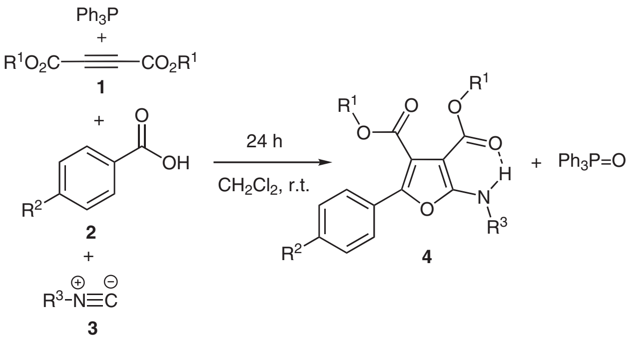


Scheme 2

**Table 1** Reactions of $Ph_3P$–RNC/DAAD Zwitterions with Aromatic Carboxylic Acids



| 4 | $R^1$ | $R^2$ | $R^3$ | Yield (%) of **4** |
|---|---|---|---|---|
| **4a** | Me | $NO_2$ | *t*-Bu | 74 |
| **4b** | Me | H | *t*-Bu | 69 |
| **4c** | Me | H | Cy | 70 |
| **4d** | Me | $NO_2$ | Cy | 84 |
| **4e** | Et | $NO_2$ | Cy | 88 |
| **4f** | Et | H | Cy | 86 |
| **4g** | Et | $NO_2$ | *t*-Bu | 72 |

and an NH group at 3445 $cm^{-1}$, the absorption bands of the nitro moiety appeared at 1591 and 1326 $cm^{-1}$.

The $^1H$ NMR spectrum of **4a** exhibited four single sharp lines readily recognized as arising from the *tert*-butyl group ($\delta = 1.52$), methoxy ($\delta = 3.79$ and 3.96) and NH group ($\delta = 6.97$) protons. The phenyl moiety gave rise to characteristic signals in the aromatic region of the spectrum. The $^1H$ decoupled $^{13}C$ NMR spectrum of **4a** showed 14 distinct resonances in agreement with the structure of dimethyl 2-(*tert*-butylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate. The structure of compound **4a** was confirmed by single crystal X-ray analysis (Figure 1).

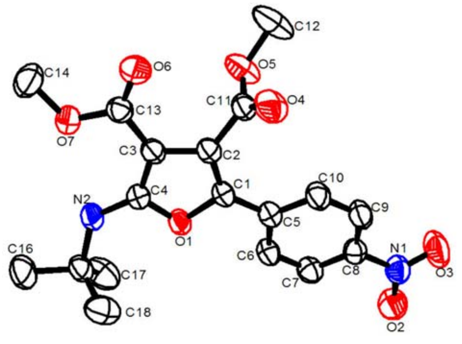
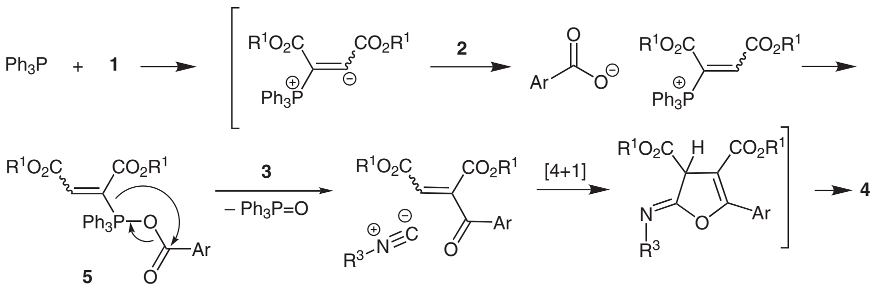


**Figure 1** ORTEP plot of **4a** showing the atom numbering scheme

Although the mechanistic details of the reaction are not clearly known, the rationalization presented earlier may also be invoked here. It is conceivable that the initially formed zwitterion from triphenylphosphine and dialkyl acetylenedicarboxylate is protonated by the carboxylic acid to furnish the vinylphosphoranyl arenecarboxylate intermediate **5**. The latter then eliminates triphenylphosphine oxide, the final product **4** is produced by a [4+1] attachment of isocyanide and then aromatization by [1,3] *H*-migration (Scheme 3).

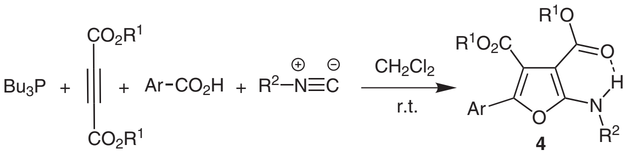
In view of the interesting results obtained with triphenylphosphine, the studies were extended using tributylphosphine. As expected, the reaction of dimethyl acetylenedicarboxylate with tributylphosphine and *tert*-butyl isocyanide in the presence of stoichiometric amount of 4-nitrobenzoic acid in anhydrous dichloromethane at room temperature afforded dimethyl 2-(*tert*-butylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate (**4a**) as an orange crystalline solid in 85% yield, likewise aminofurans **4b**–**g** were formed in 83–93% yield (Table 2).

Based on the interesting chemistry and different nucleophilicity of phosphites in comparison with phosphines, we also used the $(RO)_3P$–RNC/DAAD system. The studies were extended using phosphites and isocyanides in a binucleophilic system as the initial nucleophile in multicom-



Scheme 3

**Table 2** Reaction of the $Bu_3P$–RNC/DAAD Zwitterions with Benzoic Acid Derivatives



| **4** | $R^1$ | $R^2$ | Ar | Yield (%) of **4** |
|---|---|---|---|---|
| **4a** | Me | *t*-Bu | $4\text{-}O_2NC_6H_4$ | 85 |
| **4b** | Me | *t*-Bu | Ph | 76 |
| **4c** | Me | Cy | Ph | 83 |
| **4d** | Me | Cy | $4\text{-}O_2NC_6H_4$ | 91 |
| **4e** | Et | Cy | $4\text{-}O_2NC_6H_4$ | 91 |
| **4f** | Et | Cy | Ph | 88 |
| **4g** | Et | *t*-Bu | $4\text{-}O_2NC_6H_4$ | 93 |

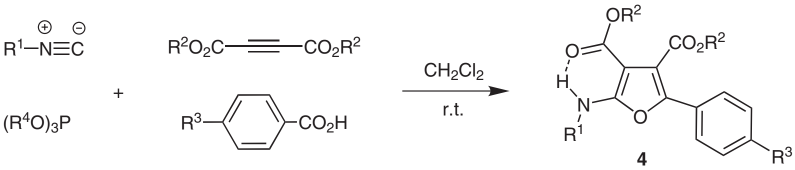
ponent conditions. The reaction was also found to work well with other trivalent phosphorus reagents such as phosphines; the results are summarized in Table 3. Interestingly, the reaction between trialkyl or triaryl phosphites and isocyanides, which on treatment with dialkyl acetylenedicarboxylate in the presence of benzoic acid derivatives afforded dialkyl 2-(alkylamino)-5-arylfuran-3,4-dicarboxylate **4** shows that the nucleophilicity of phosphites is more than that of the isocyanides and the first zwitterionic adduct results from the reaction of the phosphite and the acetylenic compound.

It is conceivable that the products **4** are important structural fragments in organic synthesis. Substituted furans play an important role in organic chemistry, not only as key structural units in many natural products and important pharmaceuticals,[7] but also as useful building blocks in synthetic chemistry.[8] While many synthetic routes exist for the synthesis of furans, convergent annulation strategies without transition-metal catalysis are uncommon.[9,10]

In this context it is interesting to note that only a few reports involving one-pot multicomponent reactions with two different nucleophilic addition are available in the literature.[11–13]

In summary, we have shown that $R_3P$/DAAD and RNC/DAAD zwitterions from the reaction of dialkyl acetylenedicarboxylate, phosphines or phosphites, and isocyanides on reaction with aromatic carboxylic acids as the initial proton source afforded 2-aminofuran derivatives, which showed that the first zwitterion formed was from trivalent phosphorus and dialkyl acetylenedicarboxylates.

**Table 3** Reaction of $(RO)_3P$–DAAD Zwitterions with Benzoic Acid Derivatives in the Presence of Isocyanides



| **4** | $R^1$ | $R^2$ | $R^3$ | $(R^4O)_3P$ | Yield (%) of **4** |
|---|---|---|---|---|---|
| **4a** | *t*-Bu | Me | $NO_2$ | $(MeO)_3P$ | 74 |
| | | | | $(EtO)_3P$ | 76 |
| | | | | $(PhO)_3P$ | 80 |
| **4b** | *t*-Bu | Me | H | $(MeO)_3P$ | 80 |
| | | | | $(EtO)_3P$ | 83 |
| | | | | $(PhO)_3P$ | 80 |
| **4c** | Cy | Me | H | $(MeO)_3P$ | 78 |
| | | | | $(EtO)_3P$ | 80 |
| | | | | $(PhO)_3P$ | 87 |
| **4d** | Cy | Me | $NO_2$ | $(MeO)_3P$ | 84 |
| | | | | $(EtO)_3P$ | 85 |
| | | | | $(PhO)_3P$ | 89 |
| **4e** | Cy | Et | $NO_2$ | $(MeO)_3P$ | 88 |
| | | | | $(EtO)_3P$ | 85 |
| | | | | $(PhO)_3P$ | 91 |
| **4f** | Cy | Et | H | $(MeO)_3P$ | 74 |
| | | | | $(EtO)_3P$ | 76 |
| | | | | $(PhO)_3P$ | 82 |
| **4g** | *t*-Bu | Et | $NO_2$ | $(MeO)_3P$ | 84 |
| | | | | $(EtO)_3P$ | 89 |
| | | | | $(PhO)_3P$ | 91 |

Dimethyl and diethyl acetylenedicarboxylates and *tert*-butyl and cyclohexyl isocyanides were obtained from Merck (Germany) and Fluka (Switzerland) and were used without further purification. Melting points were measured on an Electrothermal 9100 apparatus. Elemental analyses for C, H and N were performed using a Heraeus CHN–O–Rapid analyzer. Mass spectra were recorded on a FINNIGAN-MATT 8430 mass spectrometer operating at an ionization potential of 20 eV. $^{1}H$ and $^{13}C$ NMR spectra were measured ($CDCl_3$) with a Bruker DRX-500 AVANCE spectrometer at 500.13 and 125.8 MHz, respectively. IR spectra were recorded on a Shimadzu IR-460 spectrophotometer. Chromatography columns were prepared from Merck silica gel 230–240 mesh.

### Dimethyl 2-(*tert*-Butylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate (4a); Typical Procedure Using Triphenylphosphine

To a magnetically stirred soln of 4-nitrobenzoic acid (0.17 g, 1 mmol) and DMAD (0.14 g, 1 mmol) in anhyd $CH_2Cl_2$ (5 mL) was added dropwise a soln mixture of $Ph_3P$ (0.26 g, 1 mmol) and *tert*-butyl isocyanide (0.83 g, 1 mmol) in anhyd $CH_2Cl_2$ (3 mL) at r.t. over 20 min; the mixture was stirred for 24 h. The solvent was removed under reduced pressure and the residue was separated by column chromatography (silica gel, Merck 230–240 mesh, hexane–EtOAc) to give **4a** as orange crystals; yield: 0.28 g (74%); mp 177–179 °C.

IR (KBr): 3445 (NH), 1724 ($CO_2Me$), 1669 ($CO_2Me$), 1504 and 1468 (Ar), 1591 and 1326 ($NO_2$), 1261, 1213, 1184 and 1103 (C–O) $cm^{-1}$.

$^{1}H$ NMR (500.1 MHz, $CDCl_3$): $\delta = 1.52$ [s, 9 H, $C(CH_3)_3$], 3.79 (s, 3 H, OMe), 3.96 (s, 3 H, OMe), 6.97 (s, 1 H, NH), 7.61 (d, $J = 8.9$ Hz, 2 H, 2 $CH_{aryl}$), 8.22 (d, $J = 8.9$ Hz, 2 H, 2 $CH_{aryl}$).

$^{13}C$ NMR (125.7 MHz, $CDCl_3$): $\delta = 29.81$ [$C(CH_3)_3$], 51.43 [$C(CH_3)_3$], 53.03 (OMe), 53.13 (OMe), 89.65 ($C3_{furan}$), 117.51 ($C4_{furan}$), 123.95 (2 $CH_{aryl}$), 124.40 (2 $CH_{aryl}$), 134.99 ($C_{ipso}$), 138.36 ($C_{ipso}$-$NO_2$), 146.00 ($C5_{furan}$), 161.94 ($C2_{furan}$), 164.58 ($CO_2Me$), 165.50 ($CO_2Me$).

MS: $m/z$ (%) = 377 ($M^+ + 1$, 10), 376 ($M^+$, 30), 320 (100), 288 (78), 256 (19), 151 (71), 104 (35), 76 (21), 57 (81), 41 (66).

Anal. Calcd for $C_{18}H_{20}N_2O_7$ (376.36): C, 57.44; H, 5.36; N, 7.44. Found: C, 58.00; H, 5.51; N, 7.52.

*Crystal data for* **4a**: $C_{18}H_{20}N_2O_7$ (652092); MW = 376.36, triclinic, space group $P$–1, $a = 9.2280(13)$ Å, $b = 10.1177(14)$ Å, $c = 10.9028(15)$ Å, $\alpha = 91.030(2)$, $\beta = 113.853(2)$, $\gamma = 92.379(2)°$, $V = 929.5(2)$ Å$^3$, $Z = 2$, $Dc = 1.345$ mg/m$^3$, $F(000) = 396$, crystal dimension 0.11 × 0.15 × 0.21 mm, radiation, Mo$K\alpha$ ($\lambda = 0.71073$ Å), $2.04 \le 2\theta \le 25.20$, intensity data were collected at 295 K with a *Bruker APEX* area-detector diffractometer, and employing $\omega/2\theta$ scanning technique, in the range of $-11 \le h \le 8$, $-12 \le k \le 12$, $-13 \le l \le 13$; the structure was solved by a direct method, all non-hydrogen atoms were positioned and anisotropic thermal parameters refined from 2415 observed reflections with $R(\text{int}) = 0.0156$ by a full-matrix least-squares technique converged to $R = 0.0475$ and $Rw = 0.1227$ [$I > 2\sigma(I)$].

### Dimethyl 2-(*tert*-Butylamino)-5-phenylfuran-3,4-dicarboxylate (4b)

Colorless crystals; mp 75–77 °C.

IR (KBr): 3380 (NH), 1745 ($CO_2Me$), 1687 ($CO_2Me$), 1514 and 1437 (Ph), 1259, 1212, 1093 and 1071 (C–O) $cm^{-1}$.

$^{1}H$ NMR (500.1 MHz, $CDCl_3$): $\delta = 1.49$ [s, 9 H, $C(CH_3)_3$], 3.77 (s, 3 H, OMe), 3.91 (s, 3 H, OMe), 6.81 (s, 1 H, NH), 7.26 (t, $J = 7.0$ Hz, 1 H, $CH_{Ph}$), 7.37 (t, $J = 7.6$ Hz, 2 H, 2 $CH_{Ph}$), 7.52 (t, $J = 7.5$ Hz, 2 H, 2 $CH_{Ph}$).

$^{13}C$ NMR (125.7 MHz, $CDCl_3$): $\delta = 29.90$ [$C(CH_3)_3$], 51.13 [$C(CH_3)_3$], 52.62 (OMe), 53.54 (OMe), 88.52 ($C3_{furan}$), 113.16 ($C4_{furan}$), 124.55 (2 $CH_{Ph}$), 128.74 (2 $CH_{Ph}$), 129.60 ($CH_{Ph}$), 134.91 ($C_{ipso}$), 141.31 ($C5_{furan}$), 161.61 ($C2_{furan}$), 165.03 ($CO_2Me$), 166.10 ($CO_2Me$).

MS: $m/z$ (%) = 349 ($M^+ + H_2O$, 3), 332 ($M^+ + 1$, 4), 304 (5), 275 (7), 150 (18), 105 (100), 91 (5), 77 (34), 43 (12), 41 (28).

Anal. Calcd for $C_{18}H_{21}NO_5$ (331.37): C, 65.24; H, 6.39; N, 4.23. Found: C, 65.50; H, 6.42; N, 4.30.

### Dimethyl 2-(Cyclohexylamino)-5-phenylfuran-3,4-dicarboxylate (4c)

Viscous pale yellow oil.

IR (KBr): 3325 (NH), 1708 ($CO_2Me$), 1678 ($CO_2Me$), 1555 and 1480 (Ph), 1250, 1259, 1197, 1100 and 1050 (C–O) $cm^{-1}$.

$^{1}H$ NMR (500.1 MHz, $CDCl_3$): $\delta = 1.14$-2.34 (m, 10 H, 5 $CH_2$ of *c*-Hex), 3.72 (m, 1 H, NCH), 3.76 (s, 3 H, OMe), 3.82 (s, 3 H, OMe), 7.15 (t, $J = 7.4$ Hz, 1 H, NH), 7.44 (t, $J = 7.8$ Hz, 1 H, $CH_{Ph}$), 7.53 (t, $J = 7.4$ Hz, 2 H, 2 $CH_{Ph}$), 7.64 (d, $J = 7.1$ Hz, 2 H, 2 $CH_{Ph}$).

$^{13}C$ NMR (125.7 MHz, $CDCl_3$): $\delta = 25.16$–29.28 (5 $CH_2$ of *c*-Hex), 52.34 (CHN ), 52.98 (OMe), 60.39 (OMe), 93.00 ($C3_{furan}$), 113.00 ($C4_{furan}$), 128.42 (2 *o*-$CH_{Ph}$), 128.57 (2 *m*-$CH_{Ph}$), 132.56 (*p*-$CH_{Ph}$), 135.27 ($C_{ipso}$), 142.44 ($C5_{furan}$), 163.13 ($C2_{furan}$), 164.57 ($CO_2Me$), 165.73 ($CO_2Me$).

MS: $m/z$ (%) = 374 ($M^+ + H_2O$, 1), 348 (2), 314 (3), 232 (5), 150 (3), 122 (12), 105 (39), 77 (18), 58 (34), 43 (100), 41 (9).

Anal. Calcd for $C_{20}H_{23}NO_5$ (357.40): C, 67.21; H, 6.49; N, 3.92. Found: C, 67.50; H, 6.50; N, 4.10.

### Dimethyl 2-(Cyclohexylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate (4d)

Orange crystals; mp 140–142 °C.

IR (KBr) : 3340 (NH), 1724 ($CO_2Me$), 1671 ($CO_2Me$), 1504 and 1469 (Ar), 1588 and 1327 ($NO_2$), 1256, 1224, 1103 and 1072 (C–O) $cm^{-1}$.

$^{1}H$ NMR (500.1 MHz, $CDCl_3$): $\delta = 1.10$–2.06 (m, 10 H, 5 $CH_2$ of *c*-Hex), 3.77 (m, 1 H, H of *c*-Hex), 3.78 (s, 3 H, OMe), 3.94 (s, 3 H, OMe), 6.72 (d, $J = 8.0$ Hz, 1 H, NH), 7.59 (d, $J = 8.9$ Hz, 2 H, 2 $CH_{aryl}$), 8.19 (d, $J = 8.9$ Hz, 2 H, 2 $CH_{aryl}$).

$^{13}C$ NMR (125.7 MHz, $CDCl_3$): $\delta = 24.45$–33.35 (5 $CH_2$ of *c*-Hex), 51.31 (CHN), 51.69 (OMe), 52.90 (OMe), 88.81 ($C3_{furan}$), 117.83 ($C4_{furan}$), 123.97 (2 $CH_{aryl}$), 124.24 (2 $CH_{aryl}$), 134.96 ($C_{ipso}$), 137.94 ($C_{ipso}$-$NO_2$), 145.97 ($C5_{furan}$), 161.57 ($C2_{furan}$), 164.38 ($CO_2Me$), 165.32 ($CO_2Me$).

MS: $m/z$ (%) = 402 ($M^+$, 2), 349 (7), 150 (23), 105 (53), 77 (26), 57 (32), 43 (100), 41 (40).

Anal. Calcd for $C_{20}H_{22}N_2O_7$ (402.40): C, 59.70; H, 5.51; N, 6.96. Found: C, 60.00; H, 5.60; N, 7.00.

### Diethyl 2-(Cyclohexylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate (4e)

Orange crystals; mp 137–139 °C.

IR (KBr): 3415 (NH), 1715 ($CO_2Et$), 1669 ($CO_2Et$), 1501 and 1470 (Ar), 1588 and 1327 ($NO_2$), 1225, 1183, 1103 and 1067 (C–O) $cm^{-1}$.

$^{1}H$ NMR (500.1 MHz, $CDCl_3$): $\delta = 1.31$ (t, $J = 7.1$ Hz, 3 H, $OCH_2CH_3$), 1.37 (t, $J = 7.1$ Hz, 3 H, $OCH_2CH_3$) 1.41–2.05 (m, 10 H, 5 $CH_2$ of *c*-Hex), 3.75 (m, 1 H, CHN), 4.24 (q, $J = 7.1$ Hz, 2 H, $OCH_2CH_3$), 4.41 (t, $J = 7.1$ Hz, 2 H, $OCH_2CH_3$), 6.77 (d, $J = 7.9$ Hz, 1 H, NH), 7.60 (d, $J = 9.0$ Hz, 2 H, 2 $CH_{aryl}$), 8.20 (d, $J = 9.0$ Hz, 2 H, 2 $CH_{aryl}$).

$^{13}C$ NMR (125.7 MHz, $CDCl_3$): $\delta = 14.05$ ($OCH_2CH_3$), 14.38 ($OCH_2CH_3$), 24.47–33.39 (5 $CH_2$ of *c*-Hex), 51.66 (CHN), 59.99 ($OCH_2CH_3$), 62.11 ($OCH_2CH_3$), 89.60 ($C3_{furan}$), 118.36 ($C4_{furan}$), 123.84 (2 $CH_{aryl}$), 124.29 (2 $CH_{aryl}$), 135.15 ($C_{ipso}$), 137.63 ($C_{ipso}$-

$NO_2$), 145.89 (C5$_{\text{furan}}$), 161.67 (C2$_{\text{furan}}$), 164.16 (*C*O$_2$Et), 164.94 (*C*O$_2$Et).

MS: *m*/*z* (%) = 432 ($M^+$ + 2, 7), 431 ($M^+$ + 1, 29), 430 ($M^+$, 98), 401 (5), 348 (25), 302 (27), 274 (46), 219 (28), 150 (87), 104 (38), 92 (10), 55 (100), 43 (15), 41 (64).

Anal. Calcd for $C_{22}H_{26}N_2O_7$ (430.45): C, 61.39; H, 6.09; N, 6.51. Found: C, 61.40; H, 6.10.; N, 6.70.

**Diethyl 2-(Cyclohexylamino)-5-phenylfuran-3,4-dicarboxylate (4f)**
Viscous pale yellow oil.

IR (KBr): 3340 (NH), 1730 ($CO_2Et$), 1670 ($CO_2Et$), 1588 and 1501 (Ph), 1333, 1257, 1191, and 1025 (C–O) cm$^{-1}$.

$^1$H NMR (500.1 MHz, $CDCl_3$): δ = 1.16–1.96 (m, 10 H, 5 $CH_2$ of *c*-Hex), 1.26 (t, *J* = 7.1 Hz, 3 H, $OCH_2CH_3$), 1.30 (t, *J* = 7.0 Hz, 3 H, $OCH_2CH_3$), 3.12 (m, 1 H, CHN ), 4.20 (q, *J* = 7.1 Hz, 2 H, $OCH_2CH_3$), 3.82 (q, *J* = 7.0 Hz, 2 H, $OCH_2CH_3$), 6.62 (d, *J* = 7.4 Hz, 1 H, NH), 7.42 (t, *J* = 7.7 Hz, 1 H, CH$_{\text{Ph}}$), 7.52 (t, *J* = 7.6 Hz, 2 H, 2 CH$_{\text{Ph}}$), 7.64 (d, *J* = 7.3 Hz, 2 H, 2 CH$_{\text{Ph}}$).

$^{13}$C NMR (125.7 MHz, $CDCl_3$): δ = 13.91 ($OCH_2CH_3$), 14.02 ($OCH_2CH_3$), 24.90–30.52 (5 $CH_2$ of *c*-Hex), 60.31 (CHN), 61.38 ($OCH_2CH_3$), 62.14 ($OCH_2CH_3$), 96.02 (C3$_{\text{furan}}$), 114.00 (C4$_{\text{furan}}$), 128.41 (2 CH$_{\text{Ph}}$), 128.51 (2 CH$_{\text{aryl}}$), 132.48 (CH$_{\text{Ph}}$), 135.43 ($C_{ipso}$), 142.63 (C5$_{\text{furan}}$), 162.61 (C2$_{\text{furan}}$), 164.18 (*C*O$_2$Et), 165.69 (*C*O$_2$Et).

MS: *m*/*z* (%) = 402 ($M^+ + H_2O$, 3), 385 ($M^+$, 2), 356 (2), 355 (3), 328 (12), 246 (17), 143 (13), 105 (100), 77 (30), 55 (10), 43 (7), 41 (7).

Anal. Calcd for $C_{22}H_{27}NO_5$ (385.46): C, 68.55; H, 7.06; N, 3.63. Found: C, 69.00; H, 7.05; N, 3.75.

**Diethyl 2-(*tert*-Butylamino)-5-(4-nitrophenyl)furan-3,4-dicarboxylate (4g)**
Orange viscous liquid.

IR (KBr): 3325 (NH), 1725 ($CO_2Et$), 1669 ($CO_2Et$), 1513 and 1459 (Ar), 1589 and 1332 ($NO_2$), 1259, 1206, 1091 and 1035 (C–O) cm$^{-1}$.

$^1$H NMR (500.1 MHz, $CDCl_3$): δ = 1.31 (t, *J* = 7.1 Hz, 3 H, $OCH_2CH_3$), 1.40 (t, *J* = 7.2 Hz, 3 H, $OCH_2CH_3$), 1.56 [s, 9 H, $C(CH_3)_3$], 4.25 (t, *J* = 7.1 Hz, 2 H, $OCH_2CH_3$), 4.42 (t, *J* = 7.2 Hz, 2 H, $OCH_2CH_3$), 7.01 (s, 1 H, NH), 7.61 (d, *J* = 8.9 Hz, 2 H, 2 CH$_{\text{aryl}}$), 8.22 (d, *J* = 8.9 Hz, 2 H, 2 CH$_{\text{aryl}}$).

$^{13}$C NMR (125.7 MHz, $CDCl_3$): δ = 14.03 ($OCH_2CH_3$), 14.38 ($OCH_2CH_3$), 29.82 [$C(CH_3)_3$], 53.10 [$C(CH_3)_3$], 60.06 ($OCH_2CH_3$), 62.17 ($OCH_2CH_3$), 89.87 (C3$_{\text{furan}}$), 117.95 (C4$_{\text{furan}}$), 123.79 (2 CH$_{\text{aryl}}$), 124.37 (2 CH$_{\text{aryl}}$), 134.99 ($C_{ipso}$), 138.05 ($C_{ipso}$-$NO_2$), 145.90 (C5$_{\text{furan}}$), 161.97 (C2$_{\text{furan}}$), 164.28 (*C*O$_2$Et), 165.05 (*C*O$_2$Et).

MS: *m*/*z* (%) = 406 ($M^+$ + 2, 11), 405 ($M^+$ + 1, 32), 404 ($M^+$, 36), 374 (12), 348 (100), 302 (22), 274 (59), 150 (79), 104 (29), 76 (14), 57 (80), 41 (58).

Anal. Calcd for $C_{20}H_{24}N_2O_7$ (404.42): C, 59.40; H, 5.98; N, 6.93. Found: C, 59.02; H, 6.01; N, 7.00.

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