J. Braz. Chem. Soc., Vol. 20, No. 7, 1365-1369, 2009.
Printed in Brazil - ©2009 Sociedade Brasileira de Química
0103 - 5053 $6.00+0.00

Article

An Easy Synthesis of 3,5-Disubstituted 1,2,4-Oxadiazoles from Carboxylic Acids and Arylamidoximes Mediated by Ethyl Chloroformate

Ricardo A. W. Neves Filho, Natércia M. M. Bezerra,[#] José M. Guedes and Rajendra M. Srivastava*

Departamento de Química Fundamental, Universidade Federal de Pernambuco, Cidade Universitária, 50740-540 Recife-PE, Brazil

Uma síntese limpa, fácil e eficiente de vários 1,2,4-oxadiazóis 3,5-dissubstituídos partindo de um anidrido misto (gerado a partir de um ácido carboxílico e cloroformiato de etila) e amidoxima é descrita.

An efficient, clean and easy high-yielding synthesis of 3,5-disubstituted 1,2,4-oxadiazoles starting from mixed anhydrides (generated from carboxylic acids and ethyl chloroformate) and arylamidoximes is described.

Keywords: carboxylic acids, arylamidoximes, 1,2,4-oxadiazoles, ^{1}H and ^{13}C NMR spectra

Introduction

1,2,4-Oxadiazoles are well-known nitrogen compounds and sizeable work has been done in this area since their first preparation in 1884.[1] A recent review covering the research papers published from 1996 through 2007 describes the interesting synthetic developments of 1,2,4- and 1,3,4-oxadiazoles.[2] This review also quotes the already established biological attributes to this class of compounds. Although much attention has been given for pharmacological evaluations of 1,2,4-oxadiazoles, recent publications showed also their applicability in the field of luminescent liquid crystals, materials for optical devices, and charge-transporters for organic light-emitting diodes (OLEDs).[3] Because of the vast importance of this class of compounds,[3] which is constantly growing,[4] we decided to develop their simpler and less time-consuming synthesis.

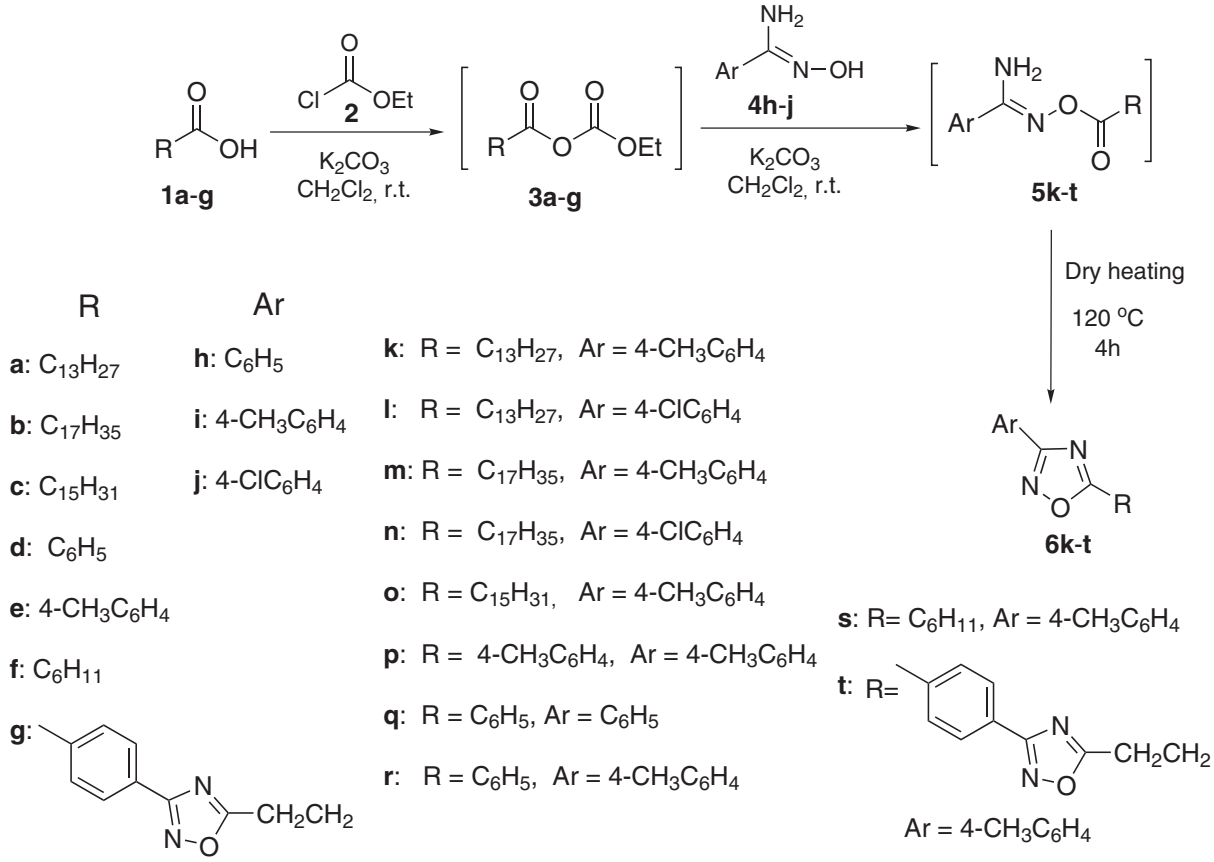
The most prevalent method for synthesizing 1,2,4-oxadiazoles involves *O*-acylation of amidoximes followed by cyclodehydratation. Acyl chlorides, anhydrides, esteres, and trichloroalkanes are commonly used as acylating agents.[5] Carboxylic acids in the presence of coupling reagents like DCC, DIC or EDC are also employed to achieve the same goal.[5,6] These procedures need much work to purify the desired 1,2,4-oxadiazoles. Besides undesired side products are also formed which require, additional time and efforts for their separation.

One-pot methodologies for organic synthesis have attracted chemists' and pharmacists' interest from industries and academia, because these procedures allow reaching the target compounds without isolation of synthetic intermediates.[7] In addition, one-pot reactions also reduce the use of solvents, reagents and adsorbents commonly employed for purifying the intermediates, being considered green protocols.[7] Therefore, we have focused our attention in developing a clean one-pot protocol which allows the synthesis of 1,2,4-oxadiazoles in good yields with less work-up and avoids side product formation. Herein, we would like to report, for the first time, the synthesis of some 2,5-disubstituted 1,2,4-oxadiazoles from carboxylic acids and arylamidoximes in the presence of ethyl chloroformate as a coupling agent (Scheme 1 and Table 1).

Results and Discussion

Although ethyl chloroformate **2** has been used in the presence of a base as carbonyl activator reagent for the one-pot synthesis of esters and amides,[8] it has not been utilized in the synthesis of 1,2,4-oxadiazoles. Therefore, first we carried out various reactions involving benzoic acid **1d** and benzamidoxime **4h** by using different organic solvents and bases to standardize the reaction conditions. The best result was found when we used CH_2Cl_2 as solvent and K_2CO_3

*e-mail: rms_indu@yahoo.com
[#]Taken in part from the MSc Dissertation (2007) of Natércia M. M. Bezerra, Universidade Federal de Pernambuco, Recife-PE, Brazil



Scheme 1.

or Et_3N as bases. We chose to use potassium carbonate because it is cheap as well as easy to remove after the reaction. Thus, a suitable carboxylic acid **1a**-**g** was stirred in the presence of K_2CO_3 in CH_2Cl_2 for 30 min to achieve the formation of carboxylic acid potassium salt which reacts with ethyl chloroformate **2** to generate *in situ* the mixed anhydrides **3a**-**g**. Then, an appropriate amidoxime **4h**-**j** was added to the same solution followed by stirring for an additional 2 h. The reaction between **3a**-**g** and **4h**-**j** forms *O*-acylamidoximes **5k**-**t** with the liberation of CO_2 and EtOH. Although the intermediates **5k**-**t** can be isolated and characterized, we avoided their isolation in many cases. In fact, these were cyclodehydrated individually to afford 1,2,4-oxadiazoles (Table 1).

In order to verify the structure of the intermediates **5k**-**t**, we have isolated two known products **5p** and **5q** whose physical and chemical properties agreed with the literature.[10] Once the structures of the above-cited intermediates have been established, we proceeded to obtain the final products in excellent yields (75-93%). This general protocol has worked well with aromatic, aliphatic and carbocyclic carboxylic acids (entries 1-10, Table 1). Compounds **5k**-**o**,**t** are new ones and their structures have been confirmed by, IR, ^1H and ^{13}C NMR spectra and elemental analyses. The known compounds **5p**-**r**,**s** were characterized by comparing their reported melting points and spectral data.[9]

Conclusions

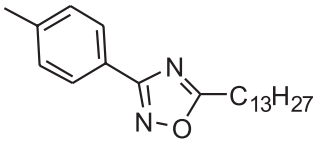
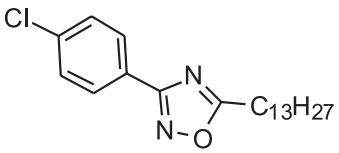
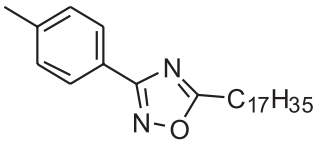
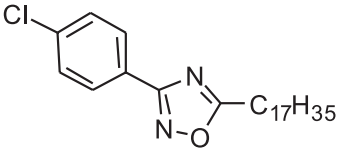
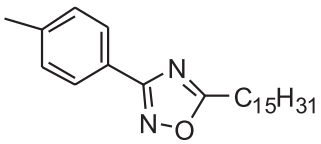
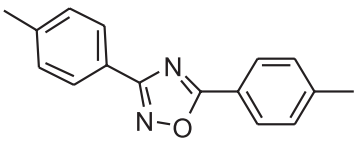
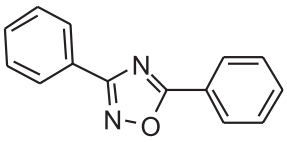
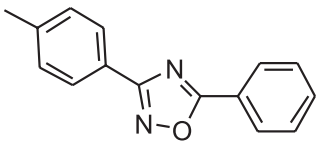
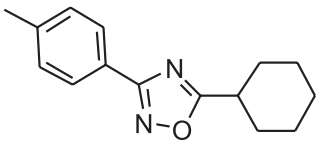
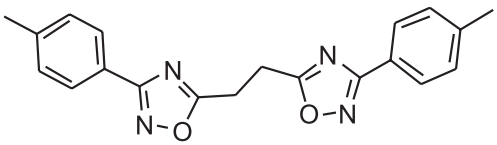
In summary, we have developed an alternate new method to synthesize 1,2,4-oxadiazoles from carboxylic acids and arylamidoximes using ethyl chloroformate as a coupling agent. The desired 3,5-disubstituted oxadiazoles **6k**-**t** have been obtained in excellent yields after simple work-up. This protocol is applicable for synthesizing 1,2,4-oxadiazoles containing aryl or alkyl groups attached at their C-5 side-chain. Further, this procedure is also suitable for the obtaining bis-1,2,4-oxadiazoles.

Experimental

General experimental procedures

All reagents were obtained from commercial sources and used without further purification. Infrared spectra were recorded on a Perkin-Elmer model 283 spectrometer in KBr discs. ^1H and ^{13}C NMR spectra of $CDCl_3$ solutions were obtained in a Varian 300-MHz instrument using

Table 1. Synthesis of 3,5-disubstituted 1,2,4-oxadiazoles **6k**-**t**

Entry	Compound	Yield / (%)	mp / (°C)	mp [Lit.][9] / (°C)
1		86	45	-
2		80	51	-
3		83	56	-
4		79	53	-
5		90	57	57.1
6		75	133-134	134
7		86	108-109	110
8		93	105-106	105-106
9		91	55	-
10		84	169-170	171-172

tetramethylsilane (TMS) as the internal standard. Elemental analysis was performed with a Carlo Erba instrument model E-1110. Carboxylic acids **1a**-**f** were obtained from commercial sources while **1g** and arylamidoximes **4h**-**j** were prepared following the procedures reported earlier.[9,11]

Typical experimental procedure

A suitable carboxylic acid **1a**-**f** (1.6 mmol) was dissolved in dry CH_2Cl_2 (8.0 mL) and placed in a round bottom flask followed by the addition of K_2CO_3 (0.33g, 2.4 mmol) under stirring and kept as such for 30 min at room temperature. Later, ethyl chloroformate **2** (0.2 mL, 2.4 mmol) was added to the same flask and stirred for an additional 30 min. Finally, the addition of an appropriate amidoxime **4h**-**j** (1.6 mmol) with continuous agitation for 2 h completed the reaction. Filtration and solvent evaporation under reduced pressure furnished the crude product which upon heating in an oil bath at 120 °C for 4 h gave the desired compounds which were crystallized from EtOH.

*3-(4-Tolyl)-5-tridecanyl-1,2,4-oxadiazole (**6k**)*

Yield: 86%; colorless crystals; mp 45 °C; R_f 0.61 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2922, 2926, 2846, 1576. ^{1}H NMR (300 MHz,$CDCl_3$); δ 0.87 (t, *J* 7.5 Hz, 3H), 1.25-1.48 (bs, 22H), 1.86 (quintet, *J* 7.5 Hz, 2H), 2.93 (t, *J* 7.5 Hz, 2H), 2.41 (s, 3H), 7.23 (d, *J* 8.4 Hz, 2H), 7.96 (d, *J* 8.4 Hz, 2H).^{13}C NMR (75 MHz,$CDCl_3$); δ 14.13, 21.56, 22.68, 26.67, 29.03, 29.34, 29.54, 29.62, 31.90, 124.07, 127.27, 129.51, 141.34, 168.51, 179.91. Anal. Calc. for $C_{22}H_{36}N_2O$ C, 76.69; H, 10.53; N, 8.13. Found: C, 76.43; H, 10.98; N, 8.21.

*3-(4-Chlorophenyl)-5-tridecanyl-1,2,4-oxadiazole (**6l**)*

Yield: 80%; colorlerss crystals; mp 51 °C; R_f 0.62 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049; 2920; 2925; 2843; 1572; ^{1}H NMR (300 MHz, $CDCl_3$); δ 0.88 (t, *J* 7.2 Hz, 3H), 1.25-1.49 (bs, 22H), 1.86 (quintet, *J* 7.8 Hz, 2H), 2.93 (t, *J* 7.5 Hz, 2H), 7.45 (d, *J* 8.4 Hz, 2H), 8.01 (d, *J* 8.7 Hz, 2H).^{13}C NMR (75 MHz,$CDCl_3$); δ 14.1, 22.7, 26.6, 29.0, 29.1, 29.3, 29.5, 29.6, 29.65, 29.68, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{21}H_{33}ClN_2O$ C, 69.11; H, 9.11; N, 7.68. Found: C, 69.21; H, 9.54; N, 7.58.

*5-Heptadecanyl-3-p-tolyl-1,2,4-oxadiazole (**6m**)*

Yield: 83%; colorless crystals; mp 56 °C; R_f 0.60 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2921, 2846, 1576. ^{1}H NMR (300 MHz,$CDCl_3$) δ 0.87 (t, *J* 5.4 Hz, 3H), 1.25-1.50 (bs, 28H), 1.86 (quintet, *J* 6.9 Hz, 2H), 2.41 (s, 3H), 2.93 (t, *J* 6.9 Hz, 2H), 7.23 (d, *J* 8.1 Hz, 2H), 7.96 (d, *J* 8.1 Hz, 2H).^{13}C NMR (75 MHz, $CDCl_3$); δ 14.1, 22.7, 26.7, 29.0, 29.3, 29.5, 29.6, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{26}H_{42}N_2O$ C, 78.34; H, 10.62; N, 7.03. Found: C, 78.68; H, 10.58, N, 7.21%.

*3-(4-Chlorophenyl)-5-heptadecanyl-1,2,4-oxadiazole (**6n**)*

Yield: 79%; colorless crystals; mp 53 °C; R_f 0.53. ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3048, 2925, 2925, 2847, 1574. ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.88 (t, *J* 6.6 Hz, 3H), 1.25-1.50 (bs, 28H), 1.86 (quintet, *J* 8.1 Hz, 2H), 2.94 (t, *J* 8.1 Hz, 2H), 7.45 (d, *J* 8.7 Hz, 2H), 8.01 (d, *J* 8.7 Hz, 2H).^{13}C NMR (75 MHz,$CDCl_3$); δ 14.1, 22.7, 26.6, 29.0, 29.1, 29.3, 29.5, 29.6, 29.64, 29.67, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{25}H_{39}ClN_2O$ C, 71.66; H, 9.38; N, 6.69. Found: C, 72.01; H, 9.47; N, 6.98%.

*5-Pentadecanyl-3-p-tolyl-1,2,4-oxadiazole (**6o**)*

Yield: 90%; colorless crystals; mp 57 °C (lit,[9] mp 57.1 °C); R_f 0.51 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3063, 2954, 2917, 2848, 1588. ^{1}H NMR (300 MHz, $CDCl_3$); δ 0.88 (t, *J* 6.9 Hz, 3H), 1.25-1.44 (bs, 24H), 1.86 (quintet, *J* 7.8 Hz, 2H), 2.41 (s, 3H), 2.93 (t, *J* 7.8 Hz, 2H), 7.23 (d, *J* 8.1 Hz, 2H), 7.95 (d, *J* 8.1 Hz, 2H).

*3,5-Di-p-tolyl-1,2,4-oxadiazole (**6p**)*

Yield: 75%; colorless crystals; mp 133 °C (lit,[9] mp 134 °C); R_f 0.72 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3023, 2920, 2850, 1594. ^{1}H NMR (300 MHz, $CDCl_3$); δ 2.39 and 2.40 (2s, 6H), 7.27 (d, *J* 7.6 Hz, 2H,), 7.28 (d, *J* 7.8 Hz, 2H), 8.05 (d, *J* 7.8 Hz, 2H,), 8.06 (d, *J* 7.6 Hz, 2H).

*3,5-Diphenyl-1,2,4-oxadiazole (**6q**)*

Yield: 86%; colorless crystals; mp 108-109 °C (lit.[9] mp 110 °C); R_f 0.70 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3022, 2920, 2839, 1594. ^{1}H NMR (300 MHz, $CDCl_3$); δ 7.51-7.62 (m, 6H), 8.14-8.25 (m, 4H).

*3-Phenyl-3-p-tolyl-1,2,4-oxadiazole (**6r**)*

Yield: 93%; colorless crystals; mp 105-106 °C (lit,[9] mp 105-106 °C); R_f 0.52 ($CHCl_3$/C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2955, 2915, 1560. ^{1}H NMR (300 MHz, $CDCl_3$); δ 2.44 (s, 3H), 7.32 (d, *J* 9.6 Hz, 2H), 7.55-7.60 (m, 3H), 8.07 (d, *J* 8.7 Hz, 2H), 8.22 (d, *J* 9.6 Hz, 2H).

*5-Cyclohexyl-4-p-tolyl-1,2,4-oxadiazole (**6s**)*

Yield: 91%; colorless crystals; mp 55 °C; R_f 0.80 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3035, 2918, 2852, 1589. ^{1}H NMR (300 MHz, $CDCl_3$); δ 1.25-2.15 (m, 10H) , 2.41 (s,

3H), 3.00 (tt, $J_{ax\text{-}ax}$ 11.1 Hz, $J_{ax\text{-}eq}$ 3.6 Hz, 1H), 7.27 (d, *J* 8.4 Hz, 2H), 7.96 (d, *J* 8.4 Hz, 2H). ^{13}C NMR (75 MHz, $CDCl_3$); δ 21.5, 25.3, 25.5, 30.2, 36.3, 124.2, 127.3, 129.4, 141.2, 168.0, 182.7. Anal. Calc. for $C_{15}H_{18}N_2O$ C, 74.35; H, 7.49; N, 11.56. Found: C, 74.48; H, 7.33; N, 11.62.

*1,2-Bis-(3-p-tolyl-1,2,4-oxadiazol-5-yl)ethane (**6t**)*

Yield: 84%; colorless crystals; mp 169-170 °C (lit.[9] mp 171-172 °C); R_f 0.73 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3032, 2926, 2854, 1590. ^{1}H NMR (300 MHz, $CDCl_3$); δ 2.41 (s, 6H), 3.57 (s, 4H), 7.28 (d, *J* 8.4 Hz, 4H), 7.95 (d, *J* 8.4 Hz, 4H).

Acknowledgments

The authors are grateful to the Brazilian National Research Council (CNPq) for financial support. One of us N.M.M.B. is thankful to Coordination for the Improvement of Higher Education Staff (CAPES) for a MSc fellowship.

Supplementary Information

Detailed experimental procedures and full set of ^{1}H and ^{13}C NMR spectra are available free of charge at http://jbcs.sbq.org.br, as a PDF file.

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Received: October 20, 2008
Web Release Date: July 23, 2009

J. Braz. Chem. Soc., Vol. 20, No. 7, S1-S10, 2009.
Printed in Brazil - ©2009 Sociedade Brasileira de Química
0103 - 5053 $6.00+0.00

An Easy Synthesis of 3,5-Disubstituted 1,2,4-oxadiazoles from Carboxylic Acids and Arylamidoximes Mediated by Ethyl Chloroformate

Ricardo A. W. Neves Filho, Natércia M. M. Bezerra,[#] José M. Guedes and Rajendra M. Srivastava*

Departamento de Química Fundamental, Universidade Federal de Pernambuco, Cidade Universitária, 50740-540 Recife-PE, Brazil

Experimental

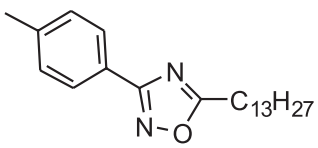
General experimental procedures

All reagents were obtained from commercial sources and used without further purification. Infrared spectra were recorded on a Perkin-Elmer model 283 spectrometer in KBr discs. ^{1}H and ^{13}C NMR spectra of $CDCl_3$ solutions were obtained in a Varian 300-MHz instrument using tetramethylsilane (TMS) as the internal standard. Elemental analysis was performed with a Carlo Erba instrument model E-1110. Carboxylic acids **1a**-**f** were obtained from commercial sources while **1g** and arylamidoximes **4h**-**j** were prepared following the procedure reported earlier.[1,2]

Typical experimental procedure

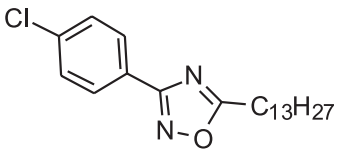
A suitable carboxylic acid **1a**-**f** (1.6 mmol) was dissolved in dry CH_2Cl_2 (8.0 mL) and placed in a round bottom flask followed by the addition of K_2CO_3 (0.332g, 2.4 mmol) under stirring and kept as such for 30 min at room temperature. Later ethyl chloroformate **2** (0.2 mL, 2.4 mmol) was added to the same flask and stirred for an additional 30 min. Finally, the addition of an appropriate amidoxime **4h**-**j** (1.6 mmol) with continuous agitation for 2h completed the reaction. Filtration and solvent evaporation under reduced pressure furnished the crude product which upon heating in an oil bath at 120 °C for 4h gave the desired compounds which were crystallized from EtOH.

*3-(4-Tolyl)-5-tridecanyl-1,2,4-oxadiazole (**6k**)*



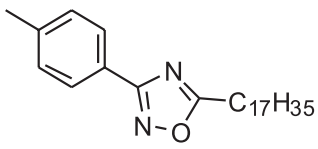
Yield: 86%; colorless crystals; mp 45 °C; R_f 0.61 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2922, 2926, 2846, 1576. ^{1}H NMR (300 MHz, $CDCl_3$); δ 0.87 (t, *J* 7.5 Hz, 3H), 1.25-1.48 (bs, 22H), 1.86 (quintet, *J* 7.5 Hz, 2H), 2.93 (t, *J* 7.5 Hz, 2H), 2.41 (s, 3H), 7.23 (d, *J* 8.4 Hz, 2H), 7.96 (d, *J* 8.4 Hz, 2H).^{13}C NMR (75 MHz, $CDCl_3$); δ 14.13, 21.56, 22.68, 26.67, 29.03, 29.34, 29.54, 29.62, 31.90, 124.07, 127.27, 129.51, 141.34, 168.51, 179.91. Anal. Calc. for $C_{22}H_{36}N_2O$ C, 76.69; H, 10.53; N, 8.13. Found: C, 76.43; H, 10.98; N, 8.21.

*3-(4-Chlorophenyl)-5- tridecanyl-1,2,4-oxadiazole (**6l**)*



Yield: 80%; colorless crystals; mp 51 °C; R_f 0.62 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049; 2920; 2925; 2843; 1572; ^{1}H NMR (300 MHz,$CDCl_3$); δ 0.88 (t, *J* 7.2 Hz, 3H), 1.25-1.49 (bs, 22H), 1.86 (quintet, *J* 7.8 Hz, 2H), 2.93 (t, *J* 7.5 Hz, 2H), 7.45 (d, *J* 8.4 Hz, 2H), 8.01 (d, *J* 8.7 Hz, 2H).^{13}C NMR (75 MHz, $CDCl_3$); δ 14.1, 22.7, 26.6, 29.0, 29.1, 29.3, 29.5, 29.6, 29.65, 29.68, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{21}H_{33}ClN_2O$ C, 69.11; H, 9.11; N, 7.68. Found: C, 69.21; H, 9.54; N, 7.58.

*5-Heptadecanyl-3-p-tolyl-1,2,4-oxadiazole (**6m**)*

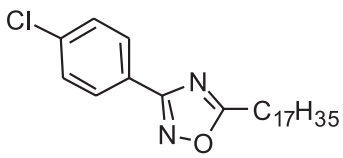


Yield: 83%; colorless crystals; mp 56 °C; R_f 0.60 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2921, 2846, 1576. ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.87 (t, *J* 5.4 Hz, 3H), 1.25-1.50 (bs, 28H), 1.86 (quintet, *J* 6.9 Hz, 2H), 2.41 (s,

*e-mail: rms_indu@yahoo.com
[#]Taken in part from the M. Sc. Dissertation (2007) of Natércia M. M. Bezerra, Universidade Federal de Pernambuco, Recife, PE, Brazil

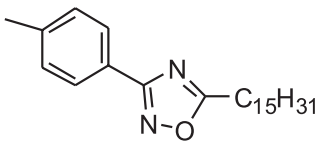
3H), 2.93 (t, *J* 6.9 Hz, 2H), 7.23 (d, *J* 8.1 Hz, 2H), 7.96 (d, *J* 8.1 Hz, 2H).[13]C NMR (75 MHz, $CDCl_3$); δ 14.1, 22.7, 26.7, 29.0, 29.3, 29.5, 29.6, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{26}H_{42}N_2O$ C, 78.34; H, 10.62; N, 7.03; Found: C, 78.68; H, 10.58, N, 7.21%.

*3-(4-Chlorophenyl)-5-heptadecanyl-1,2,4-oxadiazole (**6n**)*



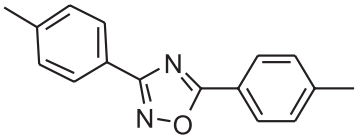
Yield: 79%; colorless crystals; mp 53 °C; R_f 0.53. ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3048, 2925, 2925, 2847, 1574. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.01 (d, *J* 8.7 Hz, 2H), 7.45 (d, *J* 8.7 Hz, 2H), 2.94 (t, *J* 8.1 Hz, 2H), 1.86 (quintet, *J* 8.1 Hz, 2H), 1.25 (m, 28H), 0.88 (t, *J* 6.6 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$); δ 14.1, 22.7, 26.6, 29.0, 29.1, 29.3, 29.5, 29.6, 29.64, 29.67, 31.9, 125.4, 128.7, 129.1, 137.2, 167.4, 180.3. Anal. Calc. for $C_{25}H_{39}ClN_2O$ C, 71.66; H, 9.38; N, 6.69. Found: C, 72.01; H, 9.47; N, 6.98%.

*5-Pentadecanyl-3-p-tolyl-1,2,4-oxadiazole (**6o**)*



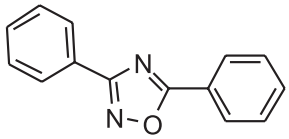
Yield: 90%; colorless crystals; mp 57 °C (lit,[2] mp 57.1 °C); R_f 0.51 ($CHCl_3$:C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3063, 2954, 2917, 2848, 1588. ^{1}H NMR (300 MHz, $CDCl_3$); δ 0.88 (t, *J* 6.9 Hz, 3H), 1.25-1.44 (bs, 24H), 1.86 (quintet, *J* 7.8 Hz, 2H), 2.41 (s, 3H), 2.93 (t, *J* 7.8 Hz, 2H), 7.23 (d, *J* 8.1 Hz, 2H), 7.95 (d, *J* 8.1 Hz, 2H).

*3,5-Di-p-tolyl-1,2,4-oxadiazole (**6p**)*



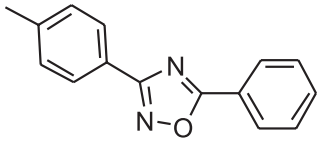
Yield: 75%; colorless crystals; mp 133 °C (lit,[2] mp 134 °C); R_f 0.72 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3023, 2920, 2850, 1594. ^{1}H NMR (300 MHz, $CDCl_3$); δ 2.39 and 2.40 (2s, 6H), 7.27 (d, *J* 7.6 Hz, 2H,), 7.28 (d, *J* 7.8 Hz, 2H,), 8.05 (d, *J* 7.8 Hz, 2H,), 8.06 (d, *J* 7.6 Hz, 2H,).

*3,5-Diphenyl-1,2,4-oxadiazole (**6q**)*



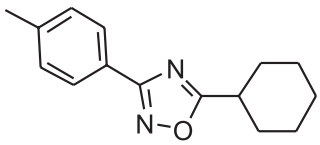
Yield: 86%; colorless crystals; mp 108-109 °C (lit.[2] mp 110 °C); R_f 0.70 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3022, 2920, 2839, 1594. ^{1}H NMR (300 MHz, $CDCl_3$); δ 7.51-7.62 (m, 6H), 8.14-8.25 (m, 4H).

*3-Phenyl-3-p-tolyl-1,2,4-oxadiazole (**6r**)*



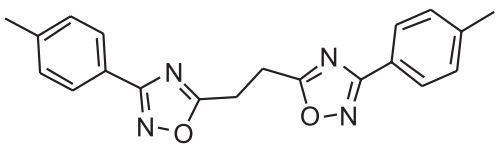
Yield: 93%; colorless crystals; mp 105-106 °C (lit,[2] mp 105-106 °C); R_f 0.52 ($CHCl_3$/C_6H_{12}, 1:1). IR (KBr) ν_{max}/cm^{-1}: 3049, 2955, 2915, 1560. ^{1}H NMR (300 MHz, $CDCl_3$); δ 2.44 (s, 3H), 7.32 (d, *J* 9.6 Hz, 2H), 7.55-7.60 (m, 3H), 8.07 (d, *J* 8.7 Hz, 2H), 8.22 (d, *J* 9.6 Hz, 2H).

*5-Cyclohexyl-4-p-tolyl-1,2,4-oxadiazole (**6s**)*



Yield: 91%; colorless crystals; mp 55 °C; R_f 0.80 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3035, 2918, 2852, 1589. ^{1}H NMR (300 MHz, $CDCl_3$); δ 1.25-2.15 (m, 10H) , 2.41 (s, 3H), 3.00 (tt, $J_{ax\text{-}ax}$ 11.1 Hz, $J_{ax\text{-}eq}$ 3.6 Hz, 1H), 7.27 (d, *J* 8.4 Hz, 2H), 7.96 (d, *J* 8.4 Hz, 2H). ^{13}C NMR (75 MHz, $CDCl_3$); δ 21.5, 25.3, 25.5, 30.2, 36.3, 124.2, 127.3, 129.4, 141.2, 168.0, 182.7. Anal. Calc. for $C_{15}H_{18}N_2O$ C, 74.35; H, 7.49; N, 11.56; Found: C, 74.48; H, 7.33; N, 11.62.

*1,2-bis(3-p-tolyl-1,2,4-oxadiazol-5-yl)ethane (**6t**)*



Yield: 84%; colorless crystals; mp 169-170 °C (lit.[2] mp 171-172 °C); R_f 0.73 ($CHCl_3$). IR (KBr) ν_{max}/cm^{-1}: 3032, 2926, 2854, 1590. ^{1}H NMR (300 MHz, $CDCl_3$); δ

2.41 (s, 6H), 3.57 (s, 4H), 7.28 (d, *J* 8.4 Hz, 4H), 7.95 (d, *J* 8.4 Hz, 4H).

References

1. Srivastava, R. M.; Brinn, I. M.; Machuca-Herrera, J. O.; Faria, H. B.; Carpenter, D. G. B.; Venkatesh, C. G.; de Morais, L. P. F.; *J. Mol. Struct.* **1997**, *406*, 159.
2. For compounds **6o-r** see: Bezerra, N. M. M.; Oliveira, S. P.; Srivastava, R. M.; da Silva, J. R.; *Il Farmaco* **2005**, *60,* 955. Leite, L. F. C.; Srivastava, R. M.; Cavalcanti, A. P.; *Bull. Soc. Chim. Belges* **1989**, *98*, 203. Goetz, N.; *Synthesis* **1976**, *4*, 268. Chiou, S.; *J. Heterocycl. Chem.* **1989**, *26*, 125. For compound **6t** see: Srivastava, R. M.; da Silva, A. J. C. N.; de Oliveira, M. L.; *J. Braz. Chem. Soc.* **1993**, *4*, 84.

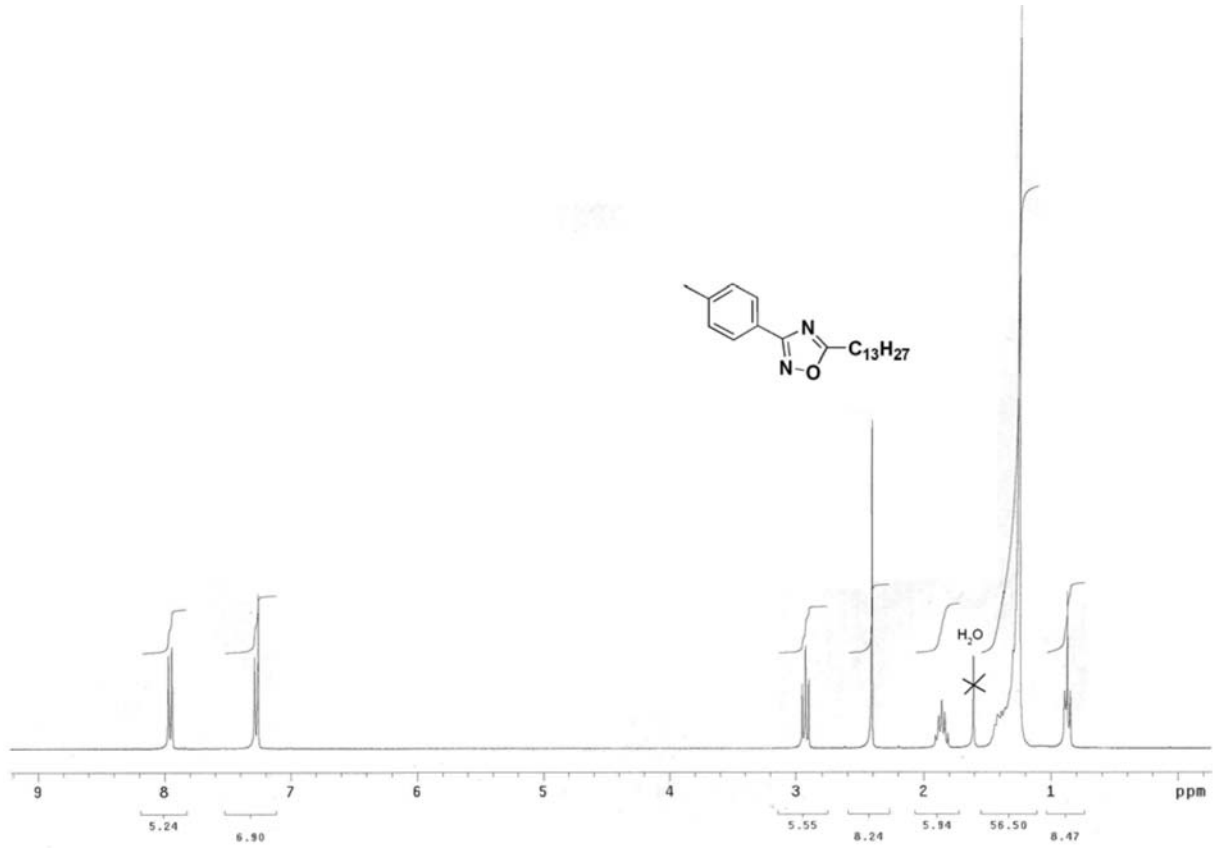


Figure S1. ^{1}H NMR (300 MHz) spectrum of compound **6k** in $CDCl_3$.

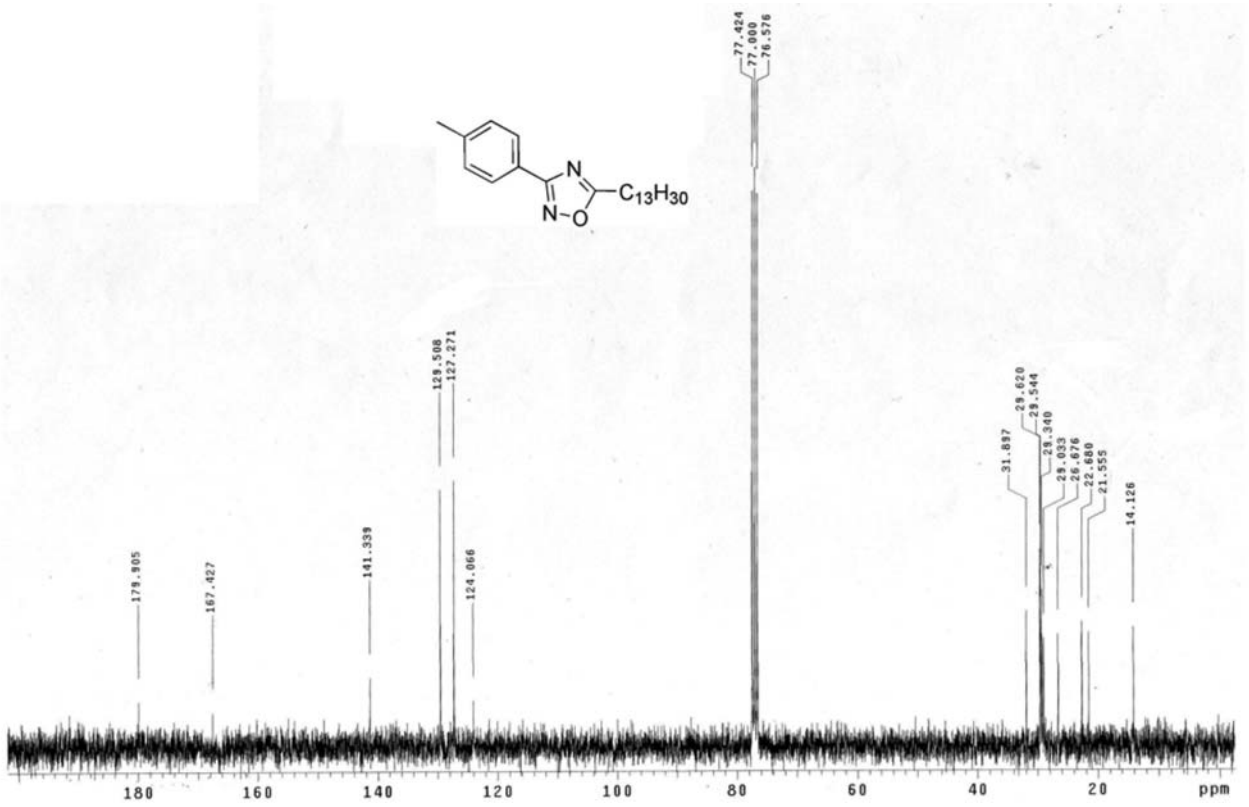


Figure S2. ^{13}C NMR (75 MHz) spectrum of compound **6k** in $CDCl_3$.

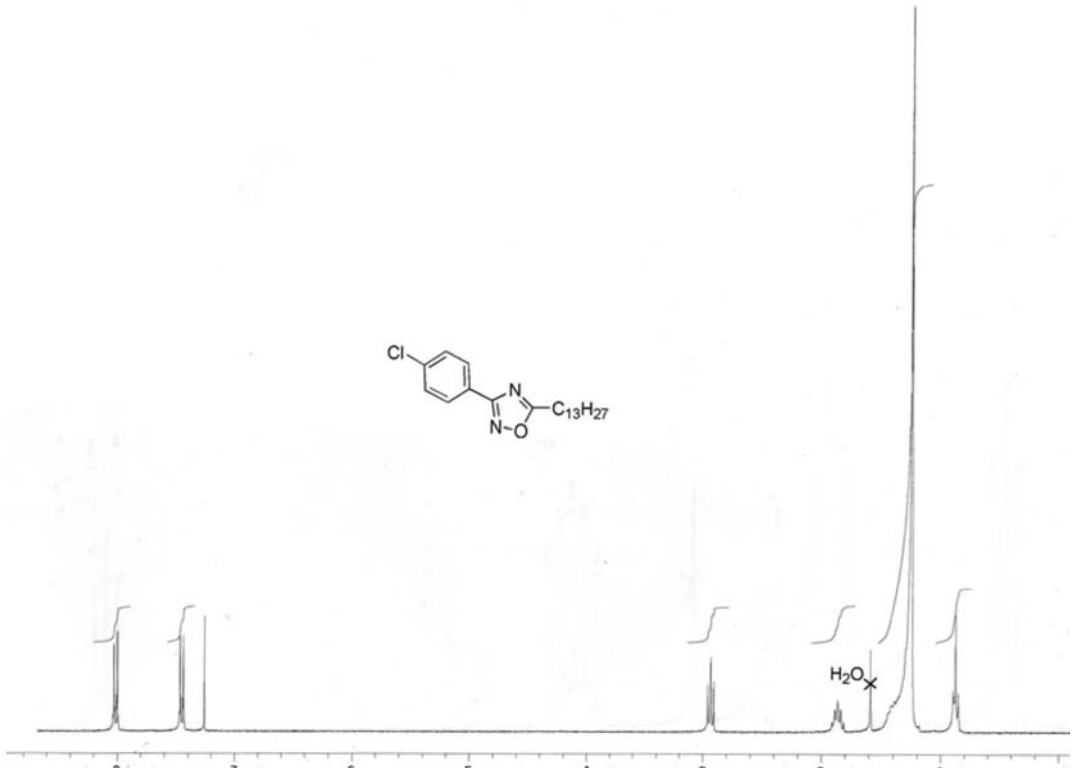


Figure S3. ^{1}H NMR (300 MHz) spectrum of compound **6l** in $CDCl_3$.

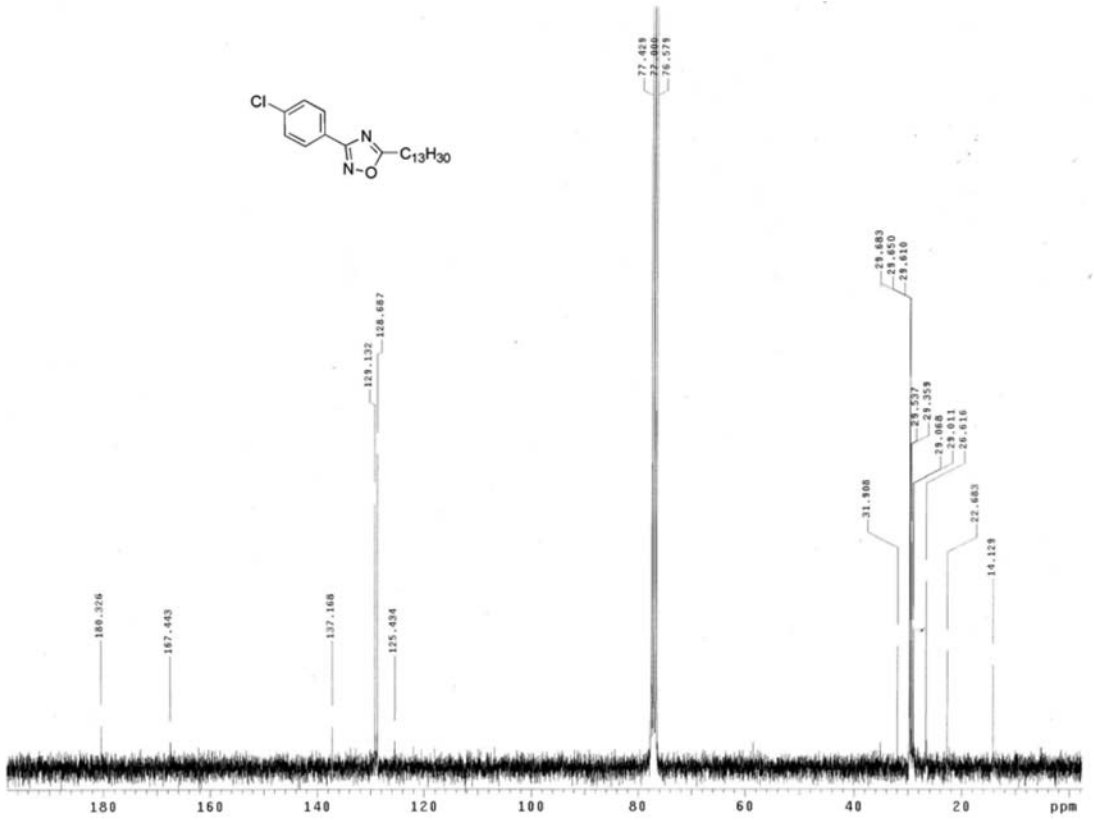


Figure S4. [13]C NMR (75 MHz) spectrum of compound **6l** in $CDCl_3$.

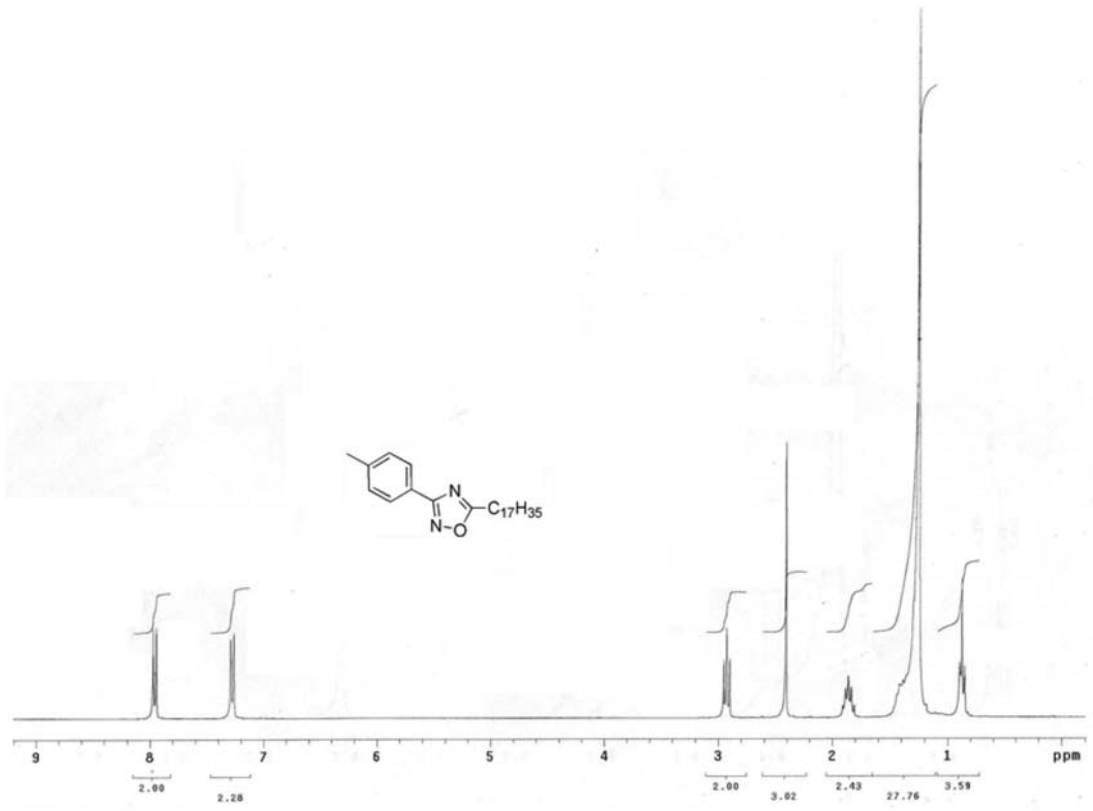


Figure S5. [1]H NMR (300 MHz) spectrum of compound **6m** in $CDCl_3$.

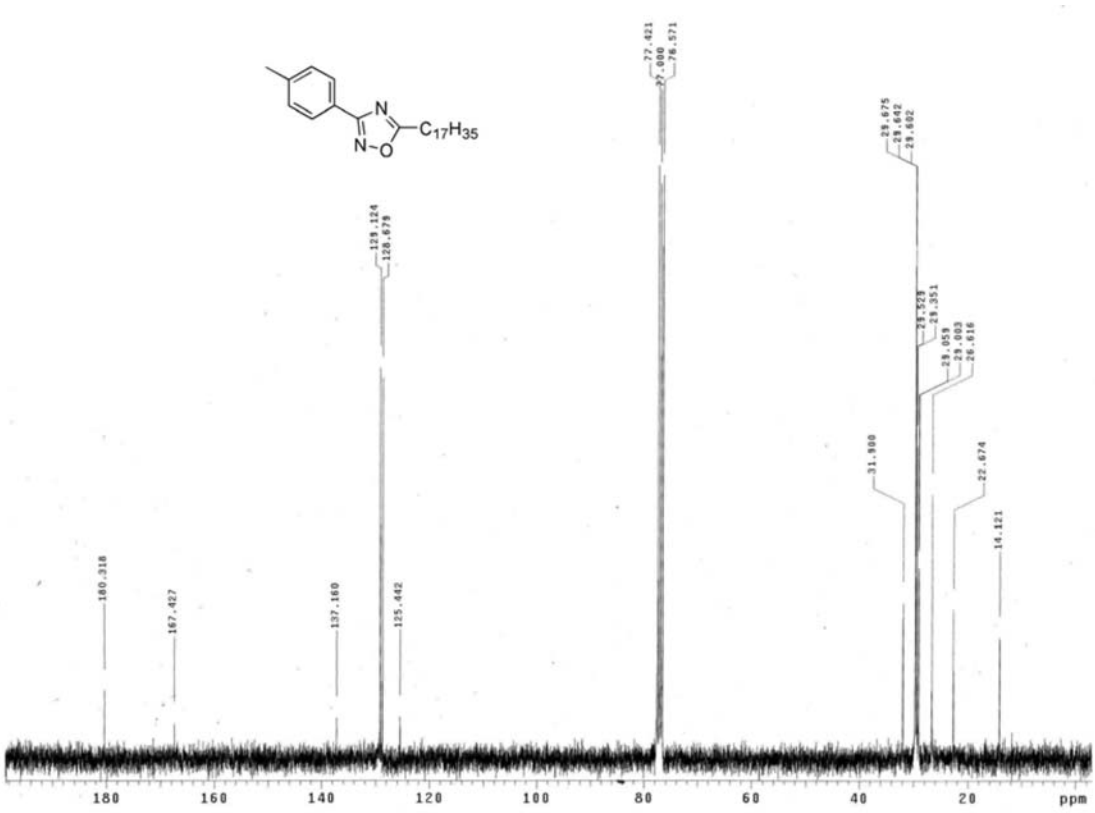


Figure S6. ^{13}C NMR (75 MHz) spectrum of compound **6m** in $CDCl_3$.

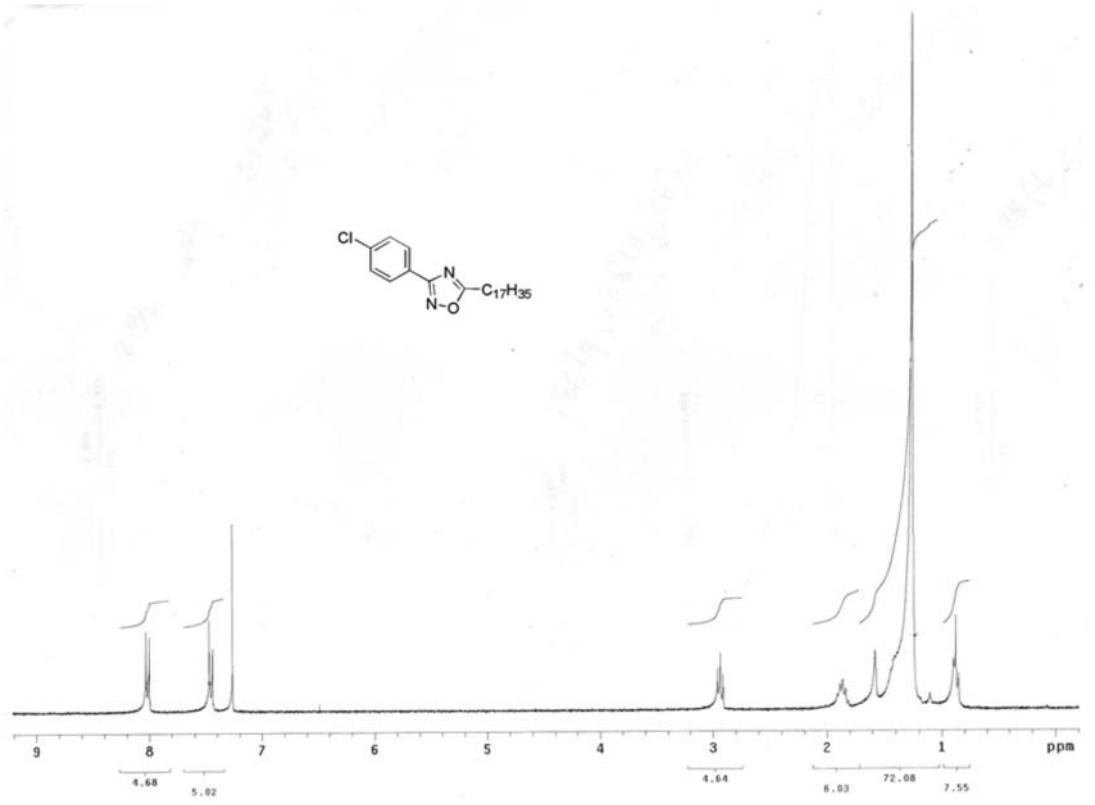


Figure S7. ^{1}H NMR (100 MHz) spectrum of compound **6n** in $CDCl_3$.

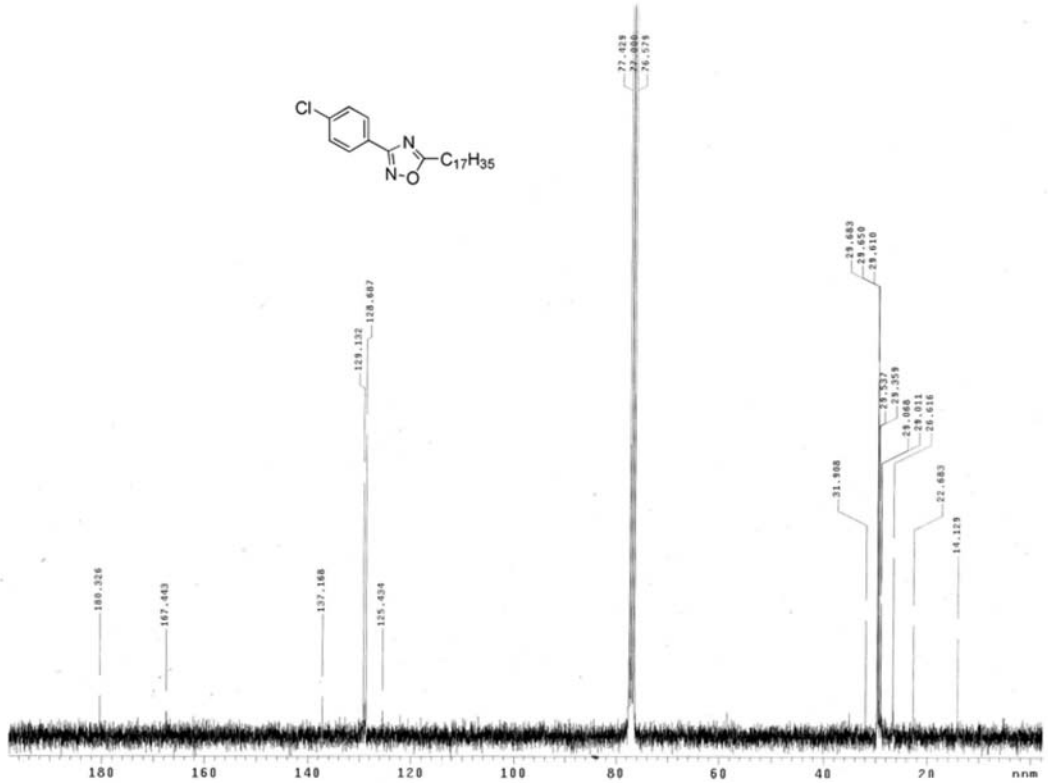


Figure S8. ^{13}C NMR (75 MHz) spectrum of compound **6n** in $CDCl_3$.

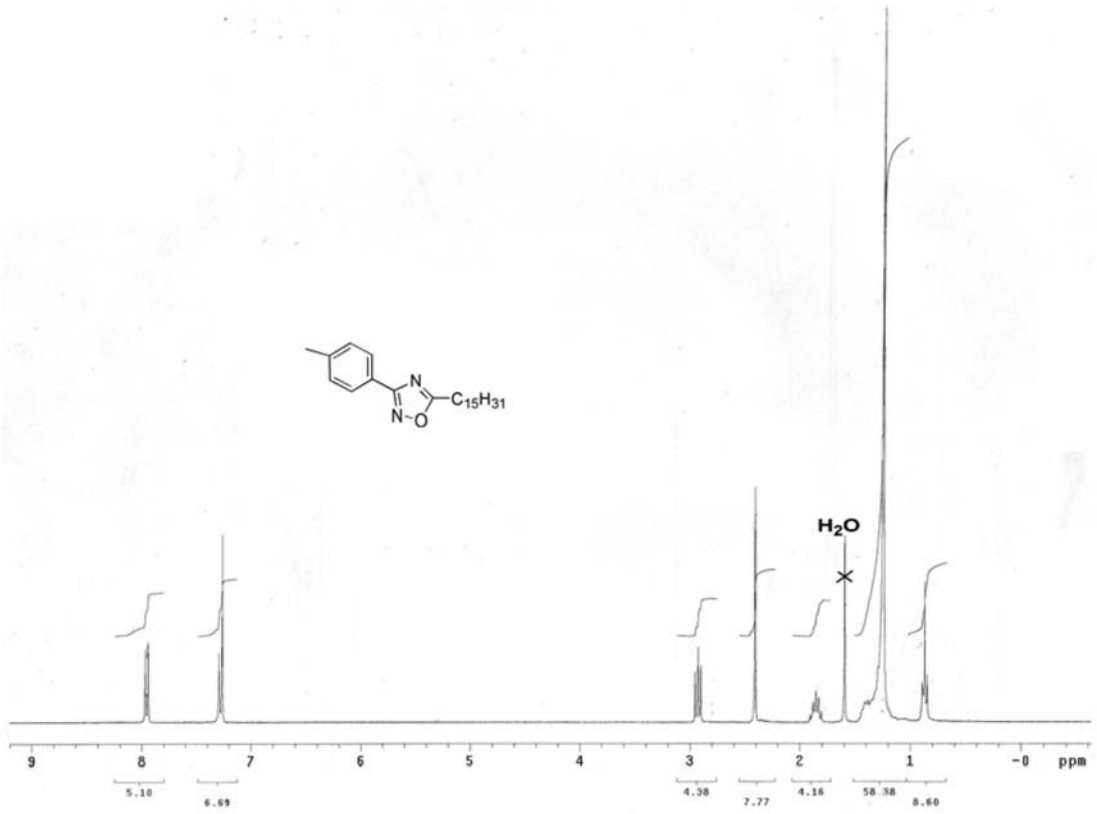


Figure S9. ^{1}H NMR (300 MHz) spectrum of compound **6o** in $CDCl_3$.

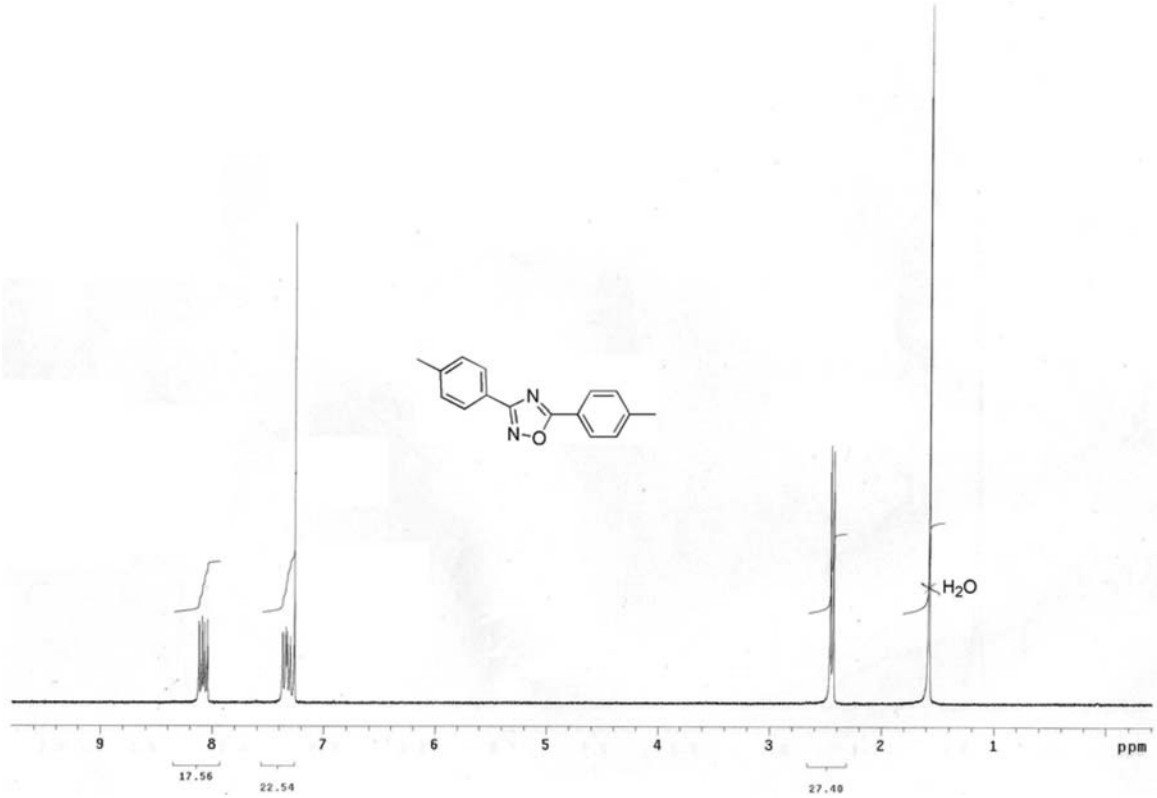


Figure S10. ^{1}H NMR (300 MHz) spectrum of compound **6p** in $CDCl_3$.

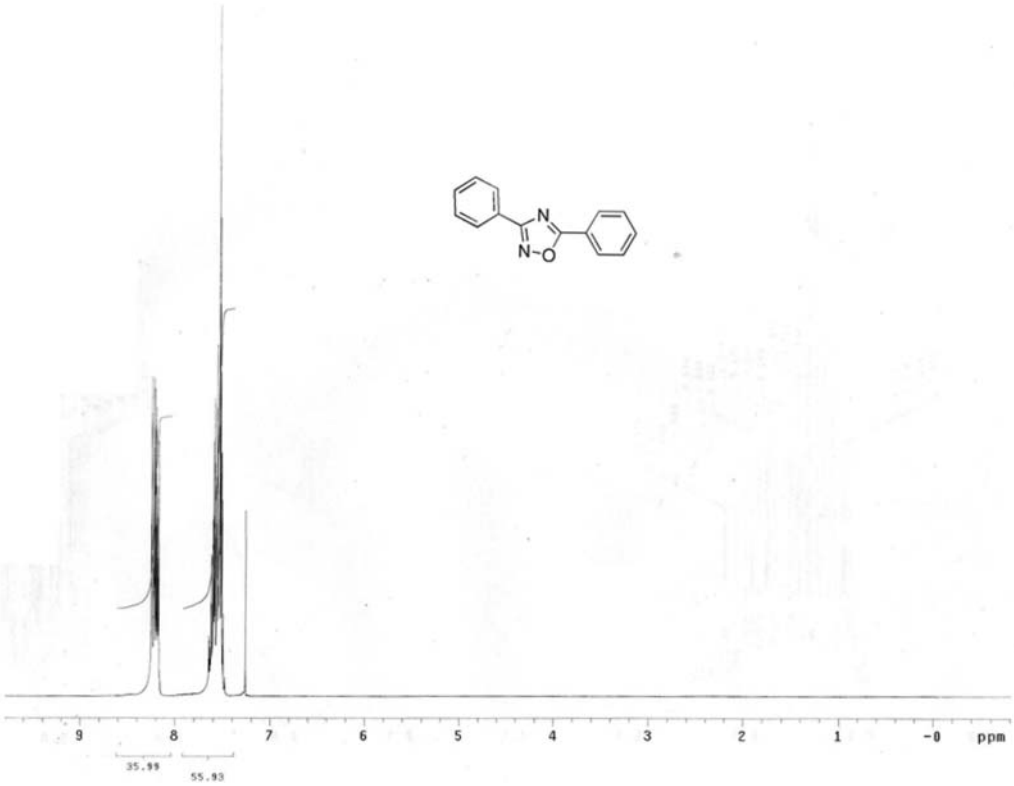


Figure S11. ^{1}H NMR (300 MHz) spectrum of compound **6q** in $CDCl_3$.

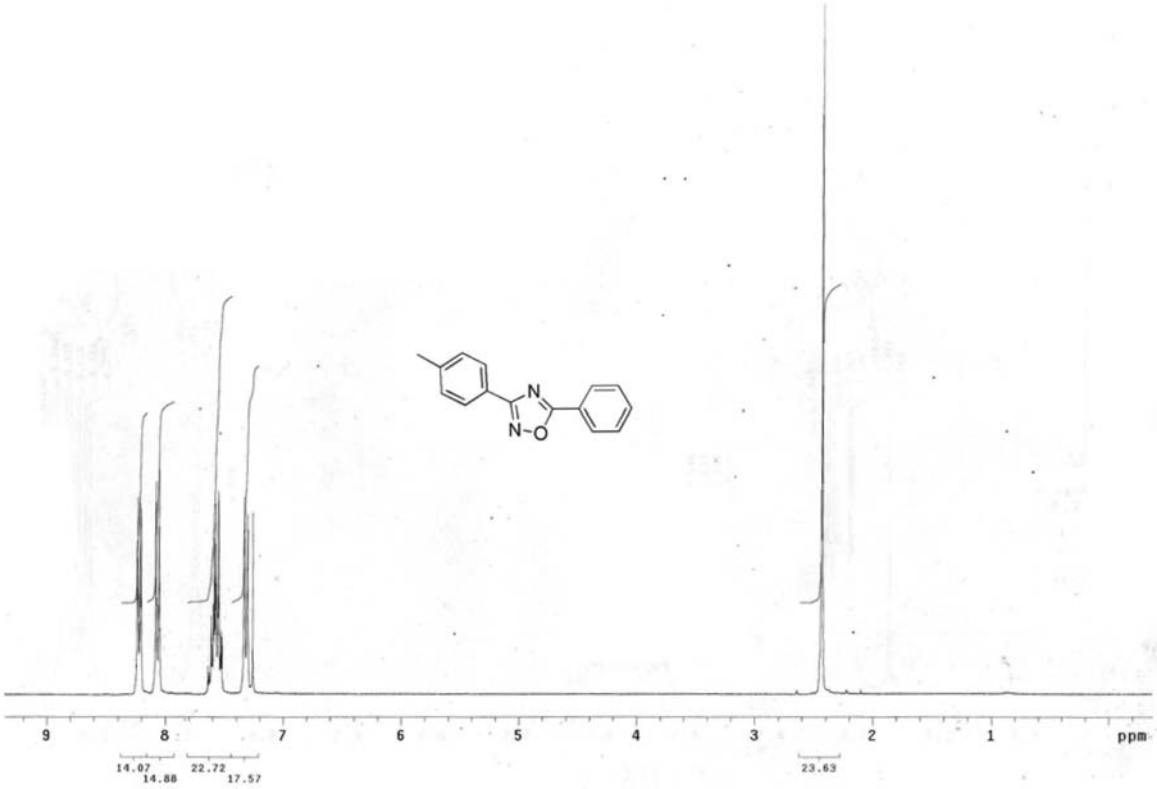


Figure S12. ^{1}H NMR (300 MHz) spectrum of compound **6r** in $CDCl_3$.

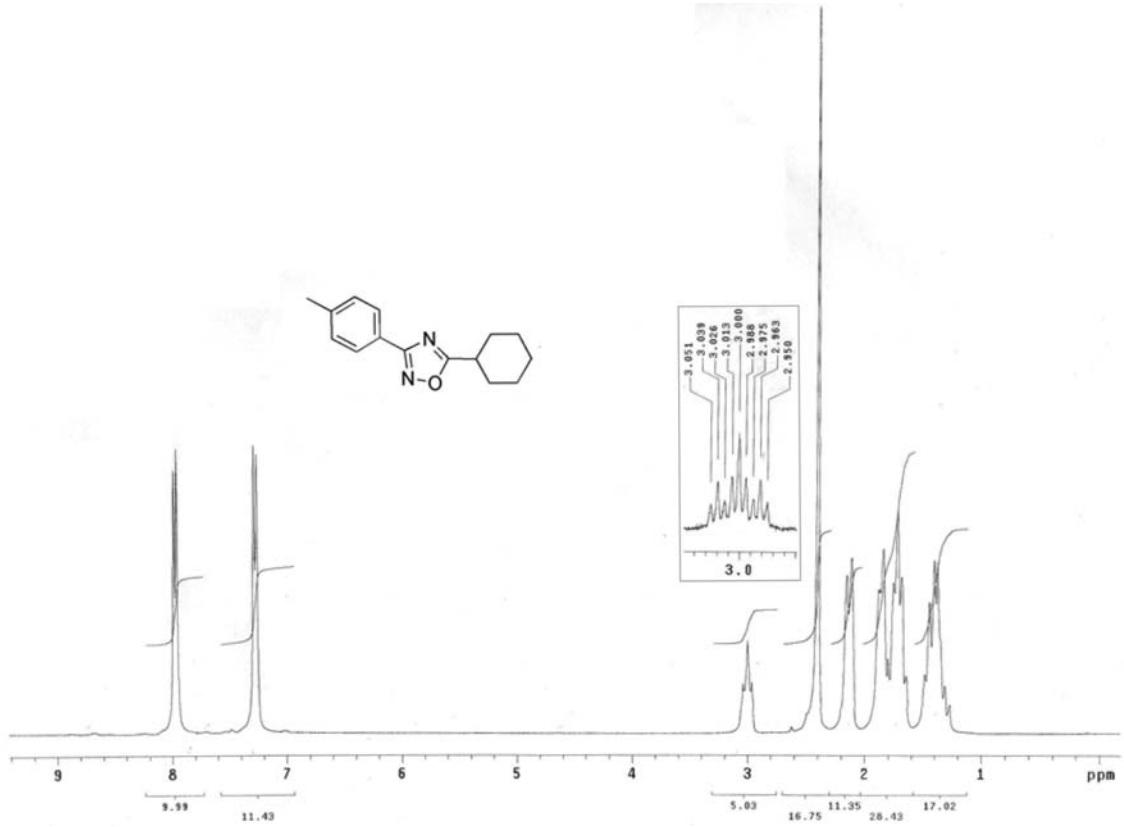


Figure S13. ^{1}H NMR (300 MHz) spectrum of compound **6s** in $CDCl_3$.

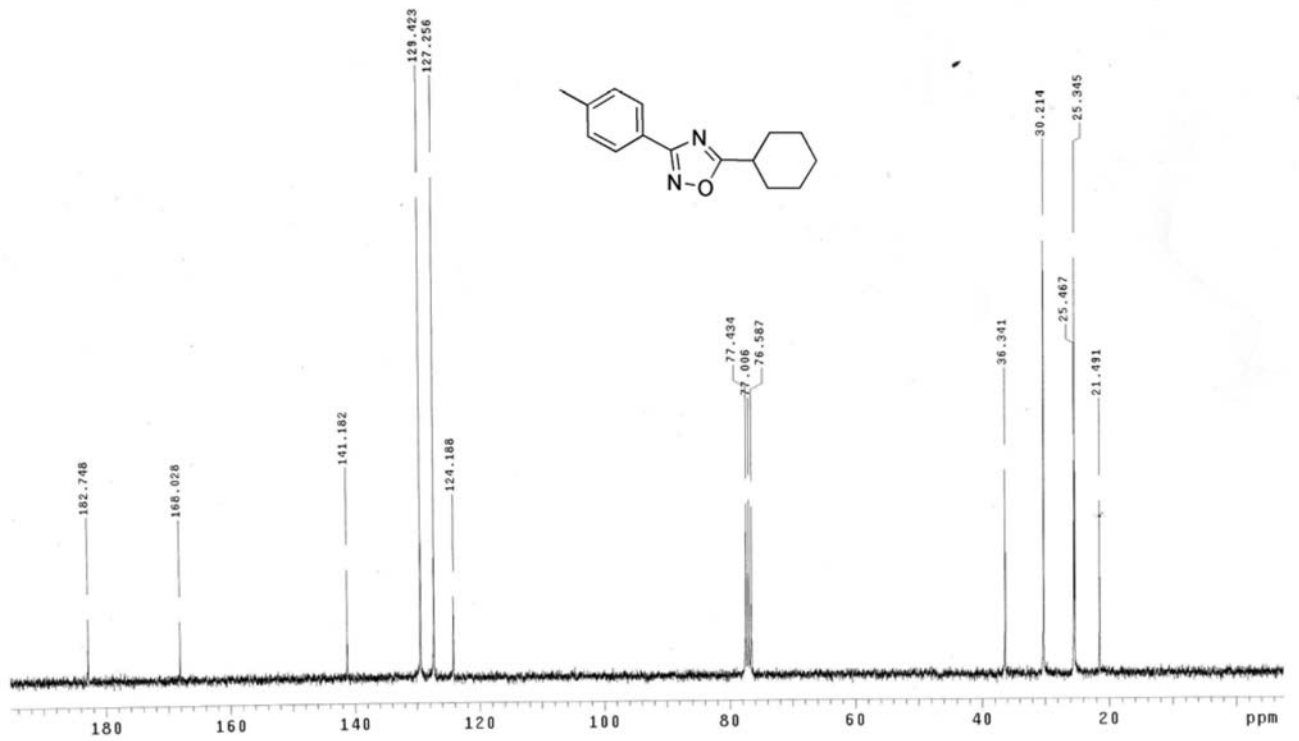


Figure S14. ^{13}C NMR (75 MHz) spectrum of compound **6s** in $CDCl_3$.

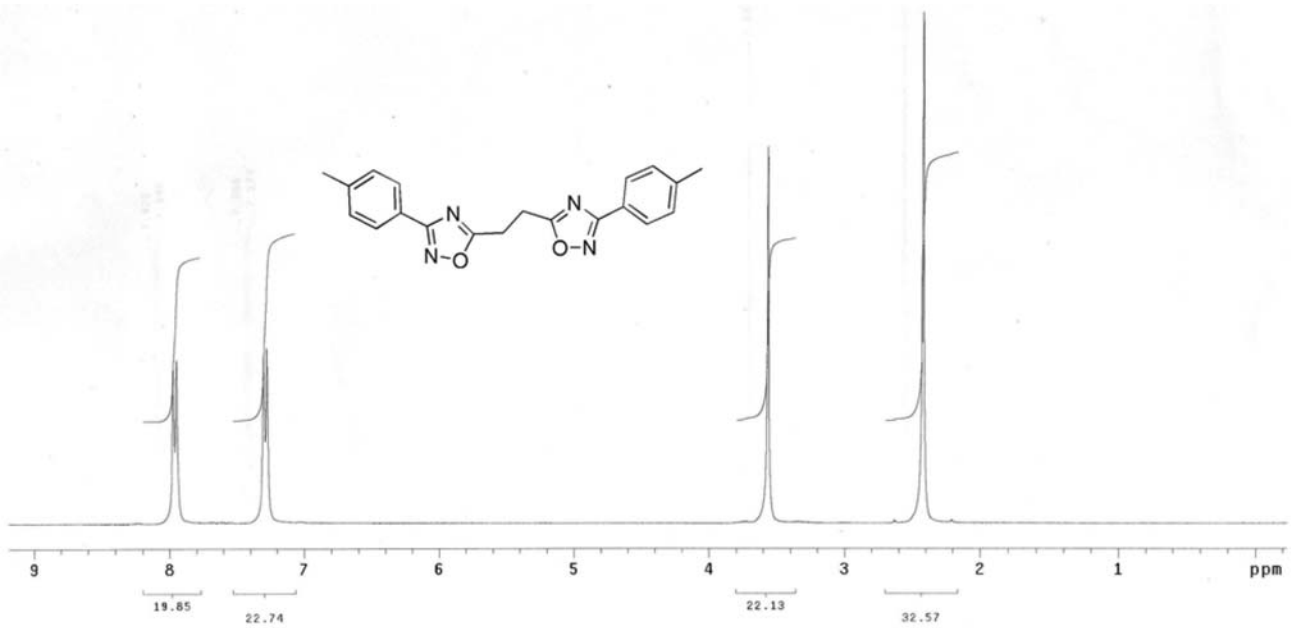


Figure S15. ^{1}H NMR (300 MHz) spectrum of compound **6t** in $CDCl_3$.