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SYNTHESIS AND CYCLIZATION OF 1-ARYLALK-1-ENE-3,5-DIYNYLAMINES

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An investigation of the reaction of 1-lithio-1,3-diynes, generated in situ, with nitriles has been carried out. In the case of aromatic nitriles 1-arylalk-1-ene-3,5-diynylamines are formed, which undergo dimerization and cyclization on isolation, giving 3-(alka-1,3-diynyl)-4-(alk-2-ynyl)-2,6-diarylpyridines. The effect of the nature of the substituent in the benzonitrile molecule on the selectivity of the reaction and the yield of the products has been determined. A scheme is proposed for the conversions and the structures of the intermediates have been established.

Keywords: 3-(alka-1,3-diynyl)-4-(alk-2-ynyl)-2,6-diarylpyridines, lithium 2-aminoethylamide, 1-arylalk-1-en-3,5-diynylamines, diacetylenes, 1-lithio-1,3-diynes, nitriles, prototropic isomerization.

Acetylenic and diacetylenic compounds are used widely in syntheses of various classes of heterocycles [1, 2], but only individual reports are known for heterocyclic diynes, reacting with retention of triple bonds in substituents of the resulting heterocycles [3-5].

We discovered previously that in the reaction of 1-lithiodeca-1,3-diyne (**2a**) with benzonitrile, in place of the expected ketone, 1-phenylundec-1-ene-3,5-diynylamine (**3a**) is formed, which on chromatography on silica gel or in the presence of mineral acids is converted into 3-(nona-1,3-diynyl)-4-(oct-2-ynyl)-2,6-diphenylpyridine **4a** [6]. Similar conversions of diacetylenic enamines are the first examples of the retention of three triple bonds in the substituents of the resulting pyridine ring. Results are given in the present work of further investigations directed towards establishing the mechanism of this unusual conversion, and also of determining the possibility and limitations of this approach to the synthesis of 1-arylalk-1-en-3,5-diynylamines and of 3-(1,3-alkadiynyl)-4-(2-alkynyl)-2,6-diarylpyridines.

The disubstituted diacetylenes **1a,b** were used as starting materials for obtaining 1-lithio-1,3-diynes **2a,b** *in situ* in an acetylenic lightning reaction [7, 8] by the action of a three-fold excess of lithium 2-aminoethylamide (LAETA) in a mixed solvent (benzene, hexane, THF). A series of experiments was carried out with benzonitrile and aromatic nitriles having both donating and withdrawing substituents. The results are given in Scheme 1 and Table 1.

Isolation in a pure state was successful only for enamine **3a** (expt. 1, Table 1). In difference to the experiments with compound **2a**, pyridine **4b** (expt. 2, Table 1) was obtained in yields of 70-74% in the reaction of 1-lithiododeca-1,3-diyne (**2b**) with benzonitrile after chromatographic separation of the reaction mixture. Pyridine **4c** (expt. 3) was also isolated in 90% yield in the reaction of **2a** with 4-methoxybenzonitrile. Enamines **3b,c** were successfully isolated only in a mixture with cyclization products by modifying the chromatographic

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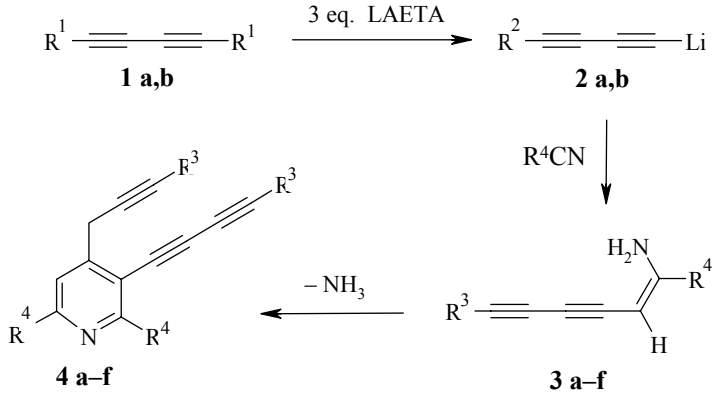
Scheme 1



1 a R^1 = Pr, **b** R^1 = Bu; **2 a** $R^2 = C_6H_{13}$, $R^2 = C_8H_{17}$;

3,4 a $R^3 = C_5H_{11}$, R^4 = Ph; **b** $R^3 = C_7H_{15}$, R^4 = Ph; **c** $R^3 = C_5H_{11}$, R^4 = 4-$MeOC_6H_4$;

d $R^3 = C_7H_{15}$, R^4 = 4-MeC_6H_4; **e** $R^3 = C_5H_{11}$, R^4 = 3,4-$(MeO)_2C_6H_3$; **f** $R^3 = C_7H_{15}$, R^4 = 4-ClC_6H_4

isolation procedure*. In all the remaining experiments the formation of enediynylamines **3d-f** was established only by data of NMR and mass spectra of the reaction mixture. In the isolation process they were completely converted into the corresponding pyridines **4d-f**.

The yields of pyridines **4d** and **4e** obtained from reactions of 4-methylbenzonitrile with **2b** and 3,4-dimethoxybenzonitrile with **2a** were 69 and 59% respectively (experiments 4 and 5). In both cases significant amounts of the terminal diynes, 21 and 17% respectively, were isolated from the reaction mixture. The reduction of the yield in the case of pyridine **4e** is linked with the low stability of the product.

The reaction of compound **2b** with 4-chlorobenzonitrile at a temperature of -8 to -10°C led to the formation of 4-chlorobenzoic acid amide as the main product (58%), and the yield of pyridine **4f** was 3% (expt. 6). The presence of a withdrawing substituent in the benzene ring probably reduces the selectivity of the

TABLE 1. Yields of Enediynylamines **3** and Pyridines **4**

Expt. No.	Diyne	R^4–CN	Yield, %	
1	**1a**	Ph	**3a** 78 (96)*	
2	**1b**	Ph	**3b** 9	**4b** 74
3	**1a**	4-$MeOC_6H_4$	–	**4c** 90
4	**1b**	4-MeC_6H_4	–	**4d** 69*[2]
5	**1a**	3,4-$(MeO)_2C_6H_3$	–	**4e** 59*[2]
6	**1b**	4-ClC_6H_4	–	**4f** 3
7	**1b**	4-ClC_6H_4	–	**4f** 13

* Without chromatographic purification (purity according to ^{1}H NMR spectral data was not less than 95%).

*[2] Allowing for the hydrocarbon recovered from the reaction.

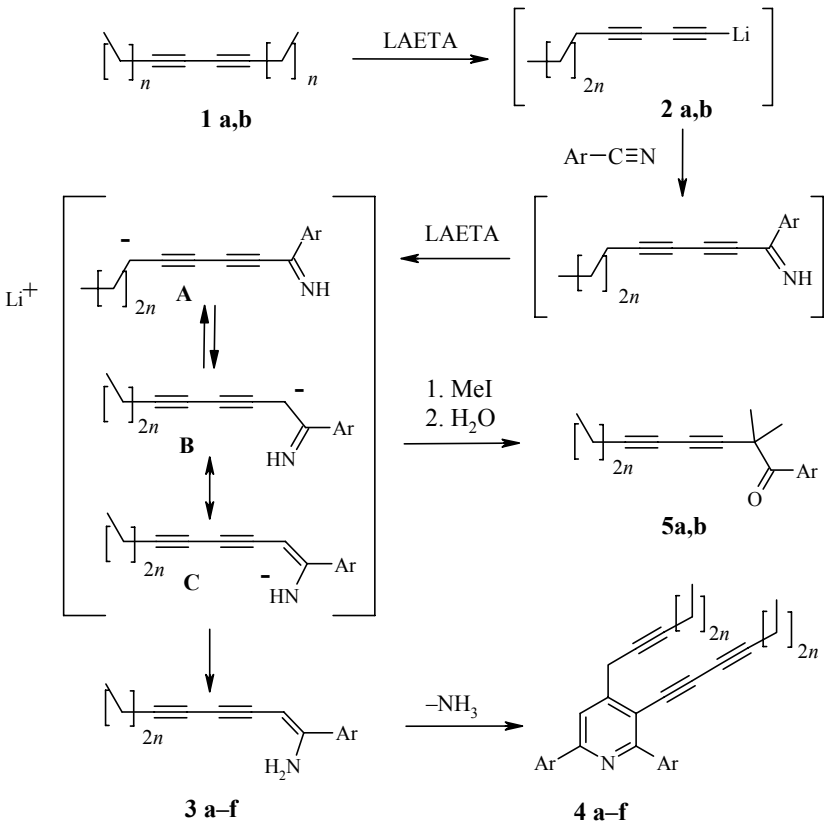
* On chromatographic separation diethyl ether was used in place of dichloromethane as polar component.

reaction of lithium acetylide with the nitrile in the presence of an excess of lithium 2-aminoethylamide. The formation of the amide of 4-chlorobenzoic acid may be explained as the result of the competing addition reaction of lithium amide to the nitrile group and hydrolysis of the amidine on isolation. On reducing the reaction temperature to -20°C the formation of amide was not observed, but pyridine **4e** was successfully isolated in only 13% yield (expt. 7). In addition a significant amount of a product of oligomeric character was isolated from the reaction mixture, in the NMR spectrum of which a broadening was observed of the signals in the regions of aromatic and aliphatic protons.

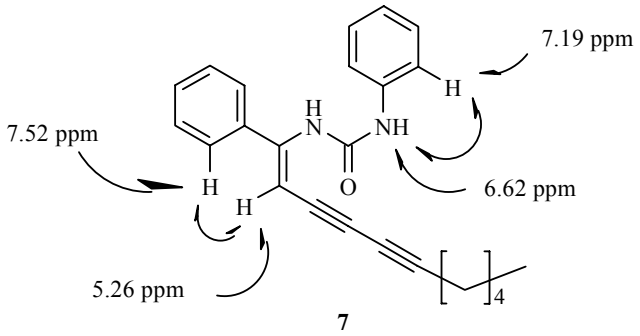
The series of cascade conversions in the reactions of 1-lithio-1,3-diynes with benzonitriles is caused by carrying out the reaction in the presence of an excess of lithium amide. The addition of lithium acetylide to the CN bond obviously leads initially to the formation of an imine. The most probable mechanism of the subsequent conversion is the formation of the anionic intermediate (**A**) in the presence of an excess of LAETA, followed by its isomerization, and subsequent transition from **B** to **C**.

The formation of anionic intermediates was confirmed by experiments in which, after the end of the reaction of 1-lithio-1,3-diynes **2a,b** with benzonitrile, an excess of methyl iodide was added to the reaction mixture. In this case the diacetylenic ketones **5a** and **5b** were isolated in 19 and 36% yield respectively.

Scheme 2



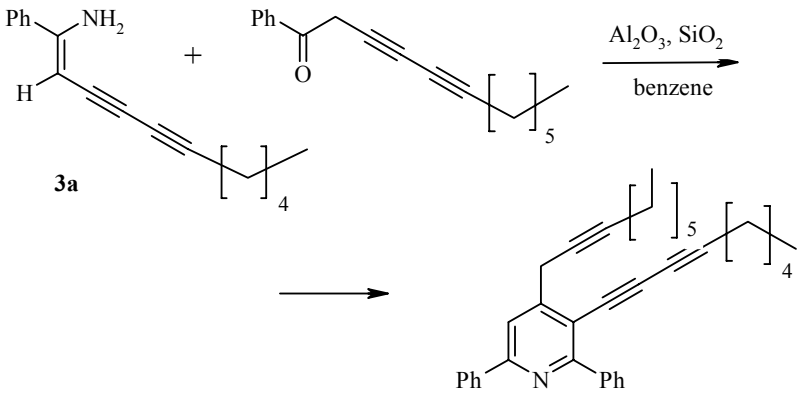
To establish the configuration of the double bond of the enediynylamine **3a** the corresponding carbamide **7** was obtained (31%) in a reaction with phenyl isocyanate. The cyclization product, pyridine **4a** (43%), was also isolated from the reaction mixture. In the NOESY spectra of carbamide **7** there was no cross-peak between the proton at the double bond and the amide proton. A nuclear Overhauser effect (of the order of 10%) was observed for the *ortho* protons of the benzene ring on exciting the amide proton at 6.62 ppm and for the *ortho* protons of the second benzene ring on exciting the proton at the double bond. The data obtained point in favor of a *Z*-configuration for the initial enediynylamine **3a.**



7

The enediynylamines **3a-f** were dimerized under the action of traces of acid or on chromatography on silica gel and underwent cyclization with the formation of the thermodynamically stable pyridine derivative. In this, one molecule of enamine reacts as NC_3 and the second as the C_2 component. The analogous product, pyridine **6**, was obtained in 48% yield on condensation of enediynylamine **3a** with 1-phenyldodeca-3,4-diyn-1-one (Scheme 3).

Scheme 3



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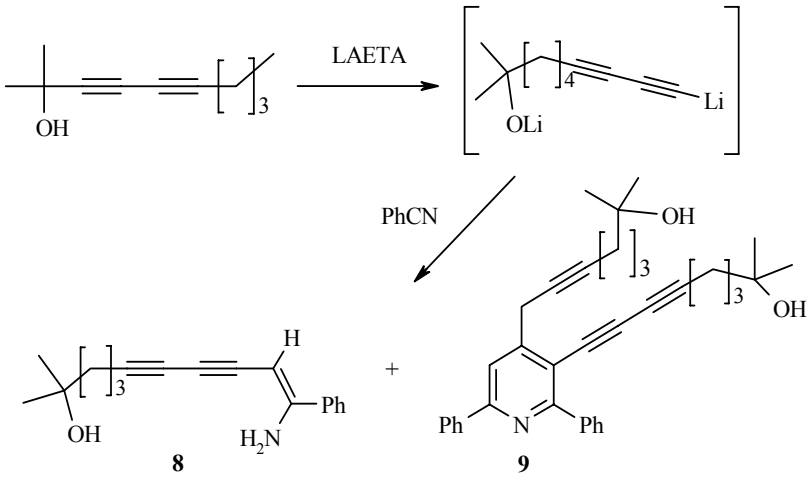
Pyridines **4a-f, 6** have similar spectral characteristics. The most characteristic in the ^{1}H NMR spectrum were the proton signals of the methylene group at the triple bonds, triplets with chemical shifts in the range 2.3-2.4 ppm. The weakly resolved triplet at 3.8 ppm belongs to the methylene group between the triple bond and the pyridine ring, in the ^{13}C NMR spectrum the signal at 22-24 ppm corresponds to the carbon atom of this methylene group. Also characteristic in the ^{1}H NMR spectrum is the singlet for a proton with chemical shift about 8 ppm on carbon-5 of the pyridine ring. In the ^{13}C NMR spectrum the signal at about 117 ppm corresponds to this carbon atom. In addition, signals are present in the ^{13}C NMR spectrum for the six acetylenic carbon atoms in the range 65-90 ppm and signals for the carbon atoms of the polarized double bond at about 76 (CH) and 150 ppm (CNH_2).

The synthetic application of the reaction proved to be markedly limited. The interaction of lithium acetylide **2b** with 4-dimethylaminobenzonitrile, 4-iodobenzonitrile, crotonitrile, phenylpropiolonitrile, and 2-pyridinecarbonitrile is accompanied by significant resin formation. It was not possible to isolate and characterize the products. In reactions of **2b** with the O-tetrahydropyranyl derivative of acetonecyanohydrin and 2,3-dihydro-1-benzothiophene-2-carbonitrile, in which the nitrile group is at an sp^3-hydridized carbon atom, no product formation was observed even on heating to 65°C. The initial nitriles and dodeca-1,3-diyne were isolated from the reaction mixture.

Previously we investigated the prototropic isomerization of disubstituted diacatylenic alcohols [9], but the reactions of the resulting lithium acetylides with electrophilic reagents were not studied. Isomerization of the tertiary diacetylenic alcohol 2-methyldeca-3,5-diyn-2-ol and subsequent reaction of the lithium 10-lithio-2-methyldeca-7,9-diyn-2-olate obtained *in situ* with benzonitrile led to the formation of enediynylamine **8**, which was isolated in 15% yield.

Scheme 4



The corresponding pyridine **9** was also isolated from the reaction in 5% yield in addition to aminoalcohol **8**. Diacetylenic alcohols are less stable compared with hydrocarbons under the conditions of the isomerization reaction [9]. Furthermore the acetylide-alcoholate of the terminal diacetylenic alcohol is strongly associated. Dilution of the reaction mixture with an equal volume of THF before adding the nitrile enabled the yield of enediynylamine **8** to be increased from 15 to 29%. Further dilution did not lead to an increase in yield.

The use of the acetylene lightning reaction as a method of generating 1-lithio-1,3-diynes from readily available disubstituted isomers and their subsequent interaction with benzonitriles is a new synthetic approach to the preparation of ethynyl substituted pyridines. In spite of the synthetic limitations the developed method has enabled a series of 3-[alka(or alkoxy)-1,3-diynyl]-4-[alka(or alkoxy)-2-ynyl]-2,6-diarylpyridines to be obtained for the first time. The synthesis was effected by a one pot procedure in good yield.

EXPERIMENTAL

The IR spectra were taken on Specord IR 75 and UR 20 instruments in the range 4000-400 cm^{-1} using 2% solutions in CCl_4. The ^1H and ^{13}C NMR spectra were taken on a Bruker instrument (300 and 75 MHz respectively) in $CDCl_3$, CD_3CN, and CD_2Cl_2 solutions. Chemical shifts are given relative to the residual signals of the solvent ($^1H/^{13}C$: 7.27/77.16; 1.94/1.32; 5.30/53.25 ppm respectively). Data of elemental analysis were obtained on a Hewlett-Packard 185B instrument. Chromato-mass spectra were taken on a Finnigan INCOS 50 instrument, with ionization by electron impact (70 eV). Capillary quartz column type SE-30, internal diameter 0.25 mm, length 30 m, phase DB-5, layer thickness 0.25 μm. Temperature programming from 100-300°C (5°/min).

Preparation of Solvents. Benzene, hexane, THF: commercial preparations were boiled under reflux over sodium in the presence of benzophenone until the appearance of a dark blue color, after which they were distilled and stored over sodium.

Ethylenediamine (EDA), the commercial preparation was stored over NaOH, distilled several times over alkali, and then distilled over sodium.

Sequential Interaction of 1-Lithio-1,3-diynes with Benzonitrile (General Procedure). Lithium (0.105 g, 0.015 mol) was introduced in small portions in an atmosphere of argon into a solution of ethylenediamine (1.2 ml, 0.015 mol) in absolute THF (3.6 ml). After the end of the exothermic reaction forming lithium 2-aminoethylamide, dry benzene (3.6 ml) and hexane (3.6 ml) were added to the suspension, the mixture was cooled to 16-18°C, and the disubstituted diacetylene (5 mmol) was added. In the case of a diacetylenic alcohol a 4-fold excess of LAETA was used and EDA (4.8 ml, 60 mmol) was added to the mixture of solvents. The coloration of the reaction mixture changed from yellowish-grey to dark brown, which indicates the formation of the acetylide. Fifteen minutes after adding the diyne the reaction mixture was diluted with dry THF (10 ml), cooled to -15°C, and a solution of benzonitrile (5 mmol) in anhydrous THF (10-15 ml) was added dropwise. After adding the benzonitrile the reaction mixture was stirred at room temperature for 4-14 h. A check on the progress of the reaction was effected by TLC. After the reaction had completed, the mixture was poured onto ice, and the organic layer separated. The aqueous layer was extracted with diethyl ether (3 × 25 ml). The combined organic layer was washed with NH_4Cl solution until the aqueous phase was neutral, and dried over $MgSO_4$. After removing the solvent, the products were isolated by column chromatography or preparative thin layer chromatography (PTLC) on silica gel (40-60 μm), eluting with a hexane–diethyl ether mixture.

(*Z*)-1-Phenylundec-1-ene-3,5-diynylamine (3a) was obtained from deca-4,6-diyne (**1a**) [10] (0.67 g, 5 mmol) and benzonitrile (0.515 g, 5 mmol). Compound **3a** (0.92 g, 78%) was obtained by PTLC (eluting with hexane–Et_2O, 4:1). Oily liquid, R_f 0.52 (hexane–Et_2O, 4:1). IR spectrum, ν, cm^{-1}: 3490, 3380, 3150, 3030, 2955, 2850, 2230, 1600, 1490, 1440. ^{1}H NMR spectrum (CD_3CN), δ, ppm (*J*, Hz): 0.93 (3H, t, *J* = 7, CH_3); 1.37-1.59 [6H, m, $(CH_2)_3$]; 2.37 (2H, t, *J* = 7, $\equiv CCH_2$); 4.58 (1H, s, =CH); 5.12 (2H, s, NH_2); 7.32-7.42 (2H, m, H-C_{Ph}); 7.51-7.59 (3H, m, H-C_{Ph});. ^{13}C NMR spectrum (CD_3CN), δ, ppm: 13.7; 19.5 ($\underline{C}H_2C\equiv$); 22.3; 28.4; 31.2; 66.2 (C_{sp}); 74.4 (=CH); 74.9, 79.7, 85.7 (C_{sp}); 129.0, 129.7, 132.6, 136.9 (C_{Ph}); 158.2 (C-NH_2). Mass spectrum, *m/z* (I_{rel}, %): 238 (50) $[M+1]^+$, 237 (100) $[M]^+$, 208 (18), 194 (22), 180 (30), 167 (27), 105 (24).

(*Z*)-1-Phenyltridec-1-ene-3,5-diynylamine (3b). IR spectrum, ν, cm^{-1}: 3500, 3400, 3100, 3080, 3040, 2970, 2950, 2870, 2250, 2130, 1620, 1500, 1455. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.89 (3H, t, *J* = 7, CH_3); 1.22-1.64 [10H, m, $(CH_2)_5$]; 2.37 (2H, t, *J* = 7, $\equiv CCH_2$); 4.57 (2H, s, NH_2); 4.68 (1H, s, =CH); 7.39 (1H, t, *J* = 7, C_{Ph}-H); 7.49 (2H, d, *J* = 7, C_{Ph}-H); 7.68 (2H, t, *J* = 7, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 14.5; 20.2 ($\equiv CCH_2$); 23.0; 23.1; 28.9; 29.2; 32.1; 66.2, 74.3 (C_{sp}); 77.7 (=CH); 80.3, 85.9 (C_{sp}); 125.8, 129.0, 129.5, 137.2 (C_{Ph}); 157.2 (C-NH_2). Mass spectrum, *m/z* (I_{rel}, %): 265 (100) $[M]^+$, 180 (92), 152 (89), 143 (15), 104 (94), 77 (12).

(*Z*)-1-(4-Methoxyphenyl)undec-1-ene-3,5-diynylamine (3c). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.93 (3H, t, *J* = 7, CH_3); 1.25-1.42 [6H, m, $(CH_2)_3$]; 2.31 (2H, t, *J* = 7, $\equiv CCH_2$); 3.83 (3H, s, OCH_3); 4.53 (2H, s, NH_2); 4.60 (1H, s, =CH); 6.89 (2H, d, *J* = 9, C_{Ph}-H); 7.74 (2H, d, *J* = 9, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.4; 20.2 ($\equiv C\underline{C}H_2$); 22.6; 28.3; 31.5; 55.8 (CH_3O); 63.6, 66.3 (C_{sp}); 75.9 (=CH); 79.9, 85.8 (C_{sp}); 114.4, 127.2, 128.9 (C_{Ph}); 157.0 (C-NH_2); 161.1 (C_{Ph}).

3-(Nona-1,3-diynyl)-4-(oct-2-ynyl)-2,6-diphenylpyridine (4a) was obtained from compound **3a** (0.24 g, 1 mmol) in Et_2O (10 ml) with vigorous stirring on adding hydrochloric acid (1 drop). After 15 min the organic layer was separated, washed with water, and the aqueous layers were extracted with ether (1 × 5 ml). The combined organic layers were dried over $MgSO_4$. After removing the solvent and purifying by PTLC (eluent hexane–Et_2O, 4:1), compound **4a** (0.23 g, 98%) was obtained. Oily liquid, R_f 0.89 (hexane–Et_2O, 4:1). IR spectrum, ν, cm^{-1}: 3110, 3080, 3050, 2970, 2940, 2870, 2245, 1590, 1500, 1455, 1430. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.94 (3H, t, *J* = 7, CH_3); 0.96 (3H, t, *J* = 7, CH_3); 1.38-1.63 [12H, m, $2(CH_2)_3$]; 2.34 (2H, t, *J* = 6, $\equiv CCH_2$); 2.38 (2H, t, *J* = 7, $\equiv CC\equiv CCH_2$); 3.89 (2H, s, $CH_2C\equiv$); 7.41-7.56 (6H, m, H-C_{Ph}); 8.06 (2H, d, *J* = 6, H-C_{Ph}); 8.16 (2H, d, *J* = 6, H-C_{Ph}); 8.08 (1H, s, H-C_{Py}). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 14.4; 19.3, 20.4 (2 $\equiv C\underline{C}H_2$); 22.6 ($\underline{C}H_2C\equiv$); 22.7; 28.6; 29.1; 29.2; 31.5; 31.8; 65.5, 70.7, 74.3, 77.4, 85.3, 88.3

(C_{sp}); 114.7 (C_{Py}); 117.7 (C_{Py}-H); 127.4, 128.3, 129.2, 129.4, 129.8, 129.9, 138.8, 140.(C_{Ph}); 152.5; 155.6; 160.9 (C_{Py}). ^{13}C {^1H} spectrum (75 MHz, $CDCl_3$), δ, ppm (*J*, Hz); 117.7 (d, *J* = 169, C_{Py}-H). Mass spectrum, *m/z*, (I_{rel}, %): 458 (100) $[M+1]^+$, 457 (20) $[M]^+$, 414 (15), 400 (20), 358 (40), 344 (43), 330 (56), 136 (53), 103 (77), 77 (55). Found, %: C 88.74; H 7.95; N 2.52. $C_{34}H_{35}N$. Calculated, %: C 89.23; H 7.71; N 3.06.

4-(Dec-2-ynyl)- 2,6-diphenyl-3-(undeca-1,3-diynyl)pyridine (4b) was obtained from dodeca-5,7-diyne (**1b**) [10] (0.81 g, 5 mmol) and benzonitrile (0.515 g, 5 mmol). The product (0.94 g, 74%) was isolated by PTLC (eluent was hexane–CH_2Cl_2, 1:1). Oily liquid, R_f 0.89 (hexane–CH_2Cl_2, 1:1). Also a fraction (0.12 g, 9%) was isolated, containing **3b**, R_f 0.86 (hexane–CH_2Cl_2, 1:1). IR spectrum, ν, cm^{-1}: 3080, 3030, 2960, 2850, 2240, 1580, 1570, 1470. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.89 (3H, t, *J* = 7, CH_3); 0.92 (3H, t, *J* = 7, CH_3); 1.20-1.65 [20H, m, $2(CH_2)_5$]; 2.31 (2H, t, *J* = 6, ≡CCH_2); 2.39 (2H, t, *J* = 7, ≡CC≡CCH_2); 3.81 (2H, s, CH_2C≡); 7.40-7.55 (6H, m, H-C_{Ph}); 7.95 (2H, d, *J* = 6, H-C_{Ph}); 8.14 (2H, d, *J* = 6, H-C_{Ph}); 8.05 (1H, s, H-C_{Py}). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 13.9; 14.2; 19.0, 19.8 (2 ≡C$\underline{C}H_2$); 22.8 ($\underline{C}H_2C$≡); 22.9; 24.9; 25.0; 28.3; 28.4; 29.0; 29.3; 29.5; 32.0; 32.1; 65.3, 70.6, 84.4, 85.2, 85.4, 88.7 (C_{sp}); 114.7 (C_{Py}); 117.6 ($\underline{C}_{Py}$-H); 127.4, 128.3, 129.2, 129.4, 129.8, 129.9, 138.8, 140.0 (C_{Ph}); 152,5, 155.6, 160.9 (C_{Py}). ^{13}C {^1H} spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 117.3 (d, *J* = 169, $C_{Py\text{-}H}$). Mass spectrum, *m/z* (I_{rel}, %): 513 (31) $[M]^+$, 456 (12), 442 (22), 428 (41), 414 (53), 358 (47), 344 (66), 330 (100), 318 (37), 280 (16), 264 (18), 252 (18), 239 (16), 105 (22), 91 (38). Found, %: C 88.84; H 8.32; N 2.89. $C_{38}H_{43}N$. Calculated, %: C 88.84; H 8.44; N 2.73.

2,6-Bis(4-methoxyphenyl)-3-(nona-1,3-diynyl)-4-(oct-2-ynyl)pyridine (4c) was obtained from compound **1a** (0.67 g, 5 mmol) and 4-methoxybenzonitrile (0.67 g, 5 mmol). The product was isolated by column chromatography (gradient elution: hexane–hexane:Et_2O, 7:1). Yield was 1.29 g (90%). Mp 61-63°C (from hexane), R_f 0.77 (hexane–Et_2O, 3:1). A fraction (0.09 g) was also isolated, containing according to NMR spectra, compound **4c** and **3c** in a 5:2 ratio. IR spectrum, ν, cm^{-1}: 3070, 3000, 2955, 2870, 2230, 1730, 1600, 1400, 1370, 1340, 1290, 1230, 1100, 1020, 810. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.95 (3H, t, *J* = 7, CH_3); 0.97 (3H, t, *J* = 7, CH_3); 1.30-1.63 [12H, m, $2(CH_2)_3$]; 2.31 (2H, t, *J* = 7, ≡CCH_2); 2.39 (2H, t, *J* = 7, ≡CC≡CCH_2); 3.86 (2H, s, CH_2C≡); 3.89 (3H, s, C_{Ph}-OCH_3); 3.91 (3H, s, C_{Ph}-OCH_3); 7.00 (2H, d, *J* = 9, C_{Ph}-H); 7.03 (2H, d, *J* = 9, C_{Ph}-H); 7.96 (1H, s, H-C_{Py}); 8.07 (2H, d, *J* = 9, C_{Ph}-H); 8.12 (2H, d, *J* = 9, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 14.4; 19.3, 20.2 (2 ≡C$\underline{C}H_2$); 22.6; 22.7 ($\underline{C}H_2C$≡); 25.0; 28.8; 29.1; 31.6; 31.8; 55.7 ($2CH_3O$); 65.6, 71.3, 75.9, 77.9, 85.1, 88.0 (C_{sp}); 113.3 (C_{Py}); 113.7, 114.5 (C_{Ph}); 116.4 (C_{Py}-H); 131.3, 131.7, 131.9, 132.8 (C_{Ph}); 152.2 (C_{Py}); 155.3, 160.3 (C_{Ph}); 160.7, 161.2 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 518 (88) $[M+1]^+$, 517 (38) $[M]^+$, 488 (10), 474 (24), 460 (38), 446 (64), 432 (18), 304 (52), 105 (100), 91 (14), 77 (44). Found, %: C 83.17; H 8.05; N 2.72. $C_{36}H_{39}NO_2$. Calculated, %: C 83.52; H 7.59; N 2.71.

4-(Dec-2-ynyl)-2,6-bis(4-tolyl)-3-(undeca-1,3-diynyl)pyridine (4d) was obtained from compound **1b** (0.81 g, 5 mmol) and 4-methylbenzonitrile (0.587 g, 5 mmol). Pyridine **4d** (0.79 g, 69%) and dodecadiyne (0.17 g, 21%) were isolated by PTLC (eluting system hexane–Et_2O, 4:1). Oily liquid, R_f 0.74 (hexane–Et_2O, 4:1). IR spectrum, ν, cm^{-1}: 3090, 3070, 3045, 2965, 2930, 2855, 2235, 2210, 1560, 1520, 1445, 1420. ^1H NMR spectrum (CD_2Cl_2), δ, ppm (*J*, Hz): 0.89 (3H, t, *J* = 7, CH_3); 1.20-1.67 [10H, m, $(CH_2)_5$]; 2.34 (2H, t, *J* = 7, ≡CCH_2); 2.39 (2H, t, *J* = 7, ≡CC≡CCH_2); 2.42 (3H, s, C_{Ph}-CH_3); 2.45 (3H, s, C_{Ph}-CH_3); 3.82 (2H, s, CH_2C≡); 7.31 (4H, m, C_{Ph}-H); 7.88 (2H, d, *J* = 9, C_{Ph}-H); 8.03 (2H, d, *J* = 9, C_{Ph}-H); 8.01 (1H, s, H-C_{Py}). ^{13}C NMR spectrum (CD_2Cl_2), δ, ppm: 14.3; 14.4; 19.1, 19.9 (2 ≡C$\underline{C}H_2$); 21.2 ($\underline{C}H_2C$≡); 21.3; 22.9; 23.0; 24.8; 28.5; 29.0; 29.1, 29.2; 29.3, 29.5 ($2CH_3$); 32.0; 32.1; 65.0, 70.8, 75.6, 83.2, 84.0, 85.1 (C_{sp}); 110.5 (C_{Py}); 116.3 (C_{Py}-H); 127.3, 128.9, 129.6, 129.8, 137.3, 139.4, 140.1 (C_{Ph}); 152.4 (C_{Ar}); 155.6 (C_{Ar}); 156.9, 158.2 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 541 (11) $[M]^+$, 111 (15), 85 (33), 69 (100), 57 (77), 55 (40).

2,6-Bis(3,4-dimethoxyphenyl)-3-(nona-1,3-diynyl)-4-(oct-2-ynyl)pyridine (4e) was obtained from compound **1a** (0.67 g, 5 mmol) and 3,4-dimethoxybenzonitrile (0.815 g, 5 mmol). Compound **4e** (0.704 g, 59%) and 1,3-decadiyne (0.11 g, 17%) were isolated by column chromatography (gradient elution hexane–hexane: Et_2O, 3:1). Yellow crystalline substance, mp 61-63°C (chloroform). R_f 0.69 (hexane–Et_2O, 3:1). IR spectrum, ν, cm^{-1}: 3025, 2980, 2955, 2890, 2875, 2855, 2250, 1610, 1515, 1470, 1425. ^1H NMR spectrum ($CDCl_3$), δ, ppm

(*J*, Hz): 0.91 (6H, t, *J* = 7, $2CH_3$); 1.25-1.68 [12H, m, $2(CH_2)_3$]; 2.30-2.39 (4H, m, 2 ≡CCH_2); 3.83 (2H, s, CH_2C≡); 3.91-4.21 (12H, $4OCH_3$); 6.90-7.06 (2H, m, C_{Ph}-H); 7.64-7.84 (4H, m, H-C_{Ph}); 7.94 (1H, s, C_{Py}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 14.4; 19.3, 20.1 (2 ≡C$\underline{C}H_2$); 22.5; 22.7 ($\underline{C}H_2C$≡); 25.0; 28.3; 29.2; 31.4; 31.6; 56.26 $(2CH_3O)_2$, 56.30, 56.34 ($2CH_3O$); 65.5, 71.3, 75.8, 85.2, 85.65, 88.3 (C_{sp}); 110.6, 111.0, 111.4 (C_{Ph}-H); 113.1 (C_{Py}); 113.3 (C_{Ph}-H); 116.6 (C_{Py}-H); 120.3, 120.8 (C_{Ph}-H); 132.1, 132.7, 148.5, 149.6, 150.2, 150.8 (C_{Ph}); 152.2, 155.2, 160.0 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 577 (100) $[M]^+$, 520 (31), 506 (49), 490 (46), 476 (36), 464 (49), 434 (57). Found, %: C 78.68; H 7.66; N 2.26. $C_{38}H_{43}NO_4$. Calculated, %: C 79.00; H 7.50; N 2.42.

2,6-Bis(4-chlorophenyl)-4-(dec-2-ynyl)-3-(undeca-1,3-diynyl)pyridine (4f) was obtained from compound **1b** (0.81 g, 5 mmol) and 4-chlorobenzonitrile (0.685 g, 5 mmol). The product was isolated by column chromatography (gradient elution: hexane–hexane:Et_2O, 3:1). Yield 0.189 g (13%), of oily liquid. R_f 0.75 (hexane–Et_2O, 3:1). IR spectrum, ν, cm^{-1}: 3010, 2950, 2920, 2850, 2220, 1550, 1490, 1425, 1400. ^{1}H NMR spectrum (CD_2Cl_2), δ, ppm (*J*, Hz): 0.90 (6H, m, $2CH_3$); 1.27-1.38 [16H, m, $2(CH_2)_4$]; 1.58-1.62 [4H, m, $(CH_2)_2$]; 2.30-2.42 4H, m, 2 ≡CCH_2); 3.86 (2H, s, CH_2C≡); 7.41-7.52 (4H, m, C_{Ph}-H); 7.96-8.14 (5H, m, C_{Ar}–H). ^{13}C NMR spectrum (CD_2Cl_2), δ, ppm: 14.3; 14.5; 19.3, 20.2 (2 ≡C$\underline{C}H_2$); 23.0 ($\underline{C}H_2C$≡); 25.1; 28.5; 29.2; 29.31; 29.35; 29.38; 29.4; 30.1; 32.1; 32.2; 65.2, 70.2, 75.4, 85.5, 86.2, 88.9 (C_{sp}); 115.0 (C_{Py}); 117.7 (C_{Py}-H); 128.6, 128.8, 129.3, 131.2, 135.5, 136.0, 137.4, 138.2 (C_{Ph}); 152.8, 154.6, 159.7 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 583 (63) $[M+2]^+$, 581 (94) $[M]^+$, 546 (31), 524 (19), 510 (38), 486 (44), 484 (63), 482 (63), 470 (31), 462 (31), 440 (56), 426 (100), 412 (75), 398 (99), 388 (53), 378 (75), 364 (61).

2,2-Dimethyl-1-phenylundeca-3,5-diyn-1-one (5a) was obtained from compound **1a** (0.67 g, 5 mmol) and benzonitrile (0.515 g, 5 mmol) on adding MeI (2 ml, 25 mmol) in diethyl ether (8 ml) at the end of the reaction with benzonitrile (absence of hydrocarbon according to TLC). The product (0.25 g, 19%) was isolated by PTLC (hexane–Et_2O, 4:1). Oily liquid, R_f 0.62 (hexane–Et_2O, 9:2). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.91 (3H, t, *J* = 7, CH_3); 1.22-1.58 [6H, m, $(CH_2)_3$]; 1.59 (6H, s, $2CH_3$); 2.27 (2H, t, *J* = 7, ≡CCH_2); 7.46 (2H, t, *J* = 7, C_{Ph}-H); 7.56 (1H, d, *J* = 7, C_{Ph}-H); 8.24 (2H, d, *J* = 7, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 19.7 (≡C$\underline{C}H_2$); 22.9; 27.9; 28.3; 31.4; 42.3 ($2CH_3$); 65.1, 70.5, 79.5, 81.6 (C_{sp}); 128.6, 130.2, 133.1, 135.2 (C_{Ph}); 198.4 (C=O).

2,2-Dimethyl-1-phenyltrideca-3,5-diyn-1-one (5b) was obtained from compound **1b** (0.81 g, 5 mmol) and benzonitrile (0.515 g, 5 mmol) on adding MeI (2 ml, 25 mmol) in diethyl ether (8 ml) at the end of the reaction with benzonitrile (absence of hydrocarbon according to TLC). The product (0.53 g, 36%) was isolated by PTLC (hexane–Et_2O, 4:1). Oily liquid, R_f 0.67 (hexane–Et_2O, 4:1). IR spectrum, ν, cm^{-1}: 3100, 3070, 3010, 2855, 2240, 1680 br, 1600, 1470, 1450. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.89 (3H, t, *J* = 7, CH_3); 1.21-1.58 [10H, m, $(CH_2)_5$]; 1.56 (6H, s, $2CH_3$); 2.28 (2H, t, *J* = 7, ≡CCH_2); 7.52 (2H, t, *J* = 7, C_{Ph}-H); 7.62 (1H, d, *J* = 7, C_{Ph}-H); 8.14 (2H, d, *J* = 7, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.2; 19.5 (≡C$\underline{C}H_2$); 22.9; 27.9; 28.5; 29.1; 30.0; 32.0; 42.2 ($2CH_3$); 65.3, 70.6, 79.4, 81.6 (C_{sp}); 128.6, 129.9, 133.1, 135.3 (C_{Ph}); 197.5 (C=O). Mass spectrum, *m/z* (I_{rel}, %): 294 (100) $[M]^+$, 279 (6), 251 (6), 237 (9), 223 (7), 105 (70). Found (for the 2,4-dinitro-phenylhydrazone, mp 71-73°C), %: C 68.52; H 6.30; N 11.45. $C_{27}H_{30}N_4O_4$. Calculated, %: C 68.34; H 6.37; N 11.81.

3-(Nona-1,3-diynyl)-4-(non-2-ynyl)-2,6-(diphenyl)pyridine (6). A mixture of 1-phenyldodeca-3,5-diynyl-1-one [8] (42 mg, 0.18 mmol) and enediynylamine **3a** (40 mg, 0.17 mmol) in benzene (1 ml) was stirred with heating (78°C) for 72 h with acid calcined Al_2O_3 (10 mg) and silica gel (10 mg). After removing the benzene the product (34 mg, 48%) was isolated by PTLC (hexane─Et_2O, 4:1). Oily liquid, R_f 0.88 (hexane–Et_2O, 4:1). IR spectrum, ν, cm^{-1}: 3050, 2970, 2900, 2870, 2200, 1590, 1490. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.95 (6H, m, CH_3); 1.28-1.61 [14H, m, $(CH_2)_7$]; 2.28-2.48 (4H, m, 2 ≡CCH_2); 3.89 (2H, s, CH_2C≡); 7.41-7.60 (5H, m, C_{Ph}-H); 8.03-8.12 (3H, m, C_{Ph}-H); 8.13-8.25 (2H, m, C_{Ar}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 14.4; 19.3, 20.2 (2 ≡C$\underline{C}H_2$); 22.5 {$\underline{C}H_2C$≡]; 22.6; 22.7; 25.1; 28.3; 29.1; 31.5; 31.6; 65.5, 70.7,

75.7, 85.30, 85.6, 88.3 (C_{sp}); 114.8 (C_{Py}); 117.7 (C_{Py}-H); 127.6, 128.3, 129.1, 129.3, 129.8, 129.9, 139.2, 140.0 (C_{Ph}); 152.4, 155.8, 160.9 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 472 (18) $[M+1]^+$, 471 (100), 429 (11), 401 (14), 373 (10), 359 (33), 345 (45), 105 (21), 91 (48).

N-Phenyl-N′-[(*Z*)-1-phenylundec-1-ene-3,5-diynyl]carbamide (7) was obtained on interacting compound **3a** (0.237 g, 1 mmol) and phenyl isocyanate (0.357 g, 3 mmol) in acetonitrile with heating to 40°C for 36 h. Carbamide **7** (110 mg, 31%) and pyridine **4a** (98 mg, 43%) were isolated. IR spectrum, ν, cm^{-1}: 3430, 3325, 3055, 2955, 2925, 2850, 2210, 1650, 1570, 1460. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.92 (3H, t, *J* = 7, CH_3); 1.24-1.63 [6H, m, $(CH_2)_3$]; 2.36 (2H, t, *J* = 7, ≡CCH_2); 5.26 (1H, s, =CH); 6.62 (1H, s, NH); 7.02-7.12 (2H, m, C_{Ph}-H); 7.18-7.28 (3H, m, C_{Ph}-H); 7.37-7.44 (3H, m, C_{Ph}-H; NH); 7.47-7.54 (2H, m, H-C_{Ph}). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 14.3; 20.1 ($\underline{C}H_2C$≡); 22.6; 28.3; 32.4; 71.2; 77.6; 82.9; 88.1 (C_{sp}); 95.1 (=CH); 120.8; 124.5; 127.1; 127.9; 129.4; 130.4 (C_{Ph}-H); 135.9, 138 (C_{Ph}); 149.7 (C-NH); 152.4 (C=O). Mass spectrum, *m/z* (I_{rel}, %): 356 (100) $[M]^+$, 237 (75), 208 (37), 194 (37), 180 (50), 119 (87), 104 (68), 103 (68), 93 (100), 77 (100).

11-Amino-2-methyl-11-phenylundec-10-ene-6,8-diyn-2-ol (8) was obtained from 2-methyldeca-3,5-diyn-2-ol [11] (0.82 g, 5 mmol) and benzonitrile (0.515 g, 5 mmol). Before adding the nitrile, the reaction mixture was diluted with THF (15 ml). Compound **8** (0.39 g, 29%) was isolated by column chromatography (eluting system hexane–hexane:Et_2O, 1:2). Oily liquid. R_f 0.50 (hexane–Et_2O, 1:1). Compound **9** (0.066 g, 5%), the product of dimerization of the enamine, was also isolated from the reaction mixture. IR spectrum, ν, cm^{-1}: 3635, 3495 br, 3495, 3390, 3060, 2980, 2920, 2875, 2210, 2180, 1950, 1870, 1790, 1770, 1610, 1580, 1410. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 1.25 (6H, s, $2CH_3$); 1.52-1.71 [4H, m, $(CH_2)_2$]; 2.42 (2H, t, *J* = 7, ≡CCH_2); 2.40 (1H, s, OH); 4.61 (2H, s, NH_2); 4.65 (1H, s, =CH); 7.36-7.39 (3H, m, C_{Ph}-H); 7.49 (2H, d, *J* = 6, C_{Ph}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 20.7 (≡C$\underline{C}H_2$); 23.8; 29.7 ($2CH_3$); 43.4; 66.6 (C_{sp}); 71.3 (C-OH); 74.6 (C_{sp}); 76.9 (=CH); 80.2, 85.5 (C_{sp}); 125.9, 129.1, 130.0, 137.1 (C_{Ph}); 157.4 (C-NH_2). Mass spectrum, *m/z* (I_{rel}, %): 268 (23) $[M+1]^+$, 267 (100) $[M]^+$, 193 (100), 104 (30).

3-(8-Hydroxy-8-methylnona-1,3-diynyl)-4-(7-hydroxy-7-methyloct-2-ynyl)-2,6-diphenylpyridine (9). Oily liquid, R_f 0.27 (hexane–Et_2O, 1:1). IR spectrum, ν, cm^{-1}: 3625, 3550-3275 br, 2970, 2940, 2880, 2245, 1750, 1680, 1585, 1450. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 1.26 (12H, s, $4CH_3$); 0.96-1.72 [8H, m, $2(CH_2)_2$]; 2.36 (2H, t, *J* = 7, ≡CCH_2); 2.42 (2H, t, *J* = 7, ≡CC≡CCH_2); 2.2-2.4 (2H, br, 2OH); 3.88 (2H, s, CH_2C≡); 7.38-7.53 (6H, m, C_{Ph}-H); 8.05 (2H, d, *J* = 7, C_{Ph}-H); 8.15 (2H, d, *J* = 7, C_{Ph}-H); 8.04 (1H, s, C_{Py}-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 19.8 (≡C$\underline{C}H_2$); 20.6 ≡CC≡C$\underline{C}H_2$); 23.6; 24.3; 25.1 ($\underline{C}H_2C$≡); 29.7 ($4CH_3$); 43.3; 43.6; 71.2 (2C-OH); 65.8, 70.9, 76.1, 84.8, 85.4, 87.8 (C_{sp}); 114.7 (C_{Py}); 117.8 (C_{Py}-H); 127.6, 129.1, 129.3, 129.4, 129.8, 132.5, 139.1, 140.0 (C $_{Ph}$); 152.3, 155.9, 161.0 (C_{Py}). Mass spectrum, *m/z* (I_{rel}, %): 517 (43) $[M]^+$, 515 (36) $[M-2]^+$, 484 (41), 430 (57), 370 (60), 356 (100), 342 (67), 105 (78).

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