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α-CYCLISATION OF TERTIARY AMINES. PART 4. CYANO-IMIDOYL SUBSTITUTED FURANS FROM CAPTODATIVE ENAMINES AND DIBENZOYLACETYLENE

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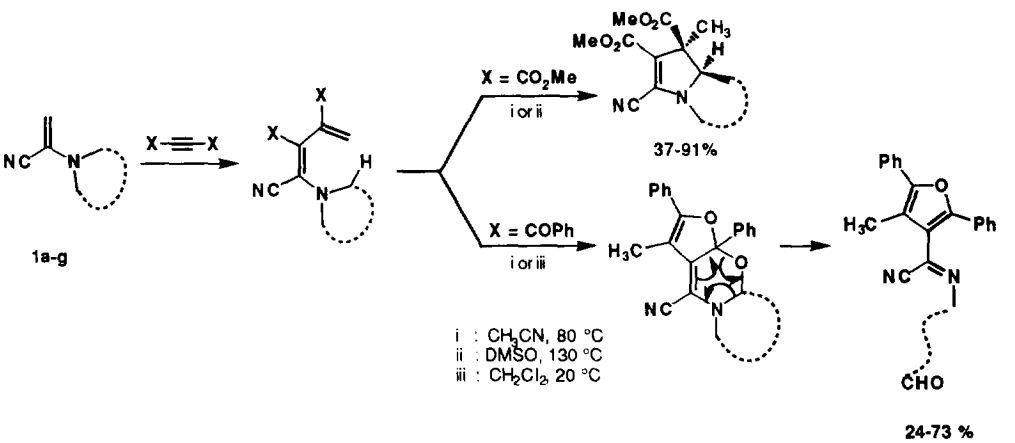
Dedicated to Professor Hans Suschitzky on the occasion of his 80th birthday.

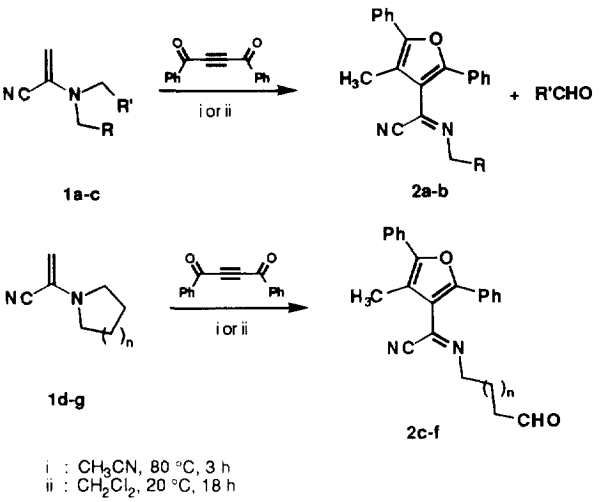
Abstract : α-Cyano-enamines and dibenzoylacetylene lead to dienes (via [2+2] cycloaddition followed by ring-opening). Their α-Cyclisation to oxygen produces the title compounds.

Captodative enamines **1a-g** and dimethyl acetylenedicarboxylate (DMAD) afford pyrroline derivatives more readily than their push-pull isomers in a reaction which we called "α-cyclisation of tertiary amines"[1] (Scheme 1, X = CO_2Me).



Scheme 1

We now report that dibenzoylacetylene also undergoes this reaction but deviates after formation of the intermediate diene, forming the title compounds **2a-f** (Scheme 1, X = COPh). Compared to DMAD[1a], the reaction with dibenzoylacetylene takes place at lower temperature and even at 20 °C for all enamines **1a-g** (Scheme 2 and table 1).



Scheme 2

Enamine	R	R'	Product	Yield (%) at 80 °C	Yield (%) at 20 °C
1a	H	H	**2a**	26	71
1b	CH_3	CH_3	**2b**	55	67
1c	H	CH_2Ph	**2a**	-	52
	n				
1d	1		**2c**	73	60
1e	2		**2d**	31	32
1f	3		**2e**	67	-
1g	4		**2f**	24	39

Table 1 : Reactions of 2-(N,N-dialkylamino)acrylonitriles with dibenzoylacetylene

The reaction proceeds from 2-dialkylamino acrylonitriles **1a**, **1b** or **1c** with loss of formaldehyde, acetaldehyde or phenylacetaldehyde respectively while, for cyclic 2-dialkylamino acrylonitriles **1d-g**, the lost aldehyde is still part of the products **2c-f**.

The structure assignement is based on the X-ray crystallography[2] of **2b** (Figure 1). Comparison of the ^1H and ^{13}C NMR data established the same skeleton for the whole series. In **2c-f**, the aldehyde appears in ^1H NMR as a triplet (J ~ 1.5 Hz) at 9.78 ± 0.02 ppm, in ^{13}C NMR as a doublet of triplets (J ~ 173 Hz and J ~ 4 Hz) at 201.7 ± 0.5 ppm and in IR as a strong band at 1724 cm^{-1}.

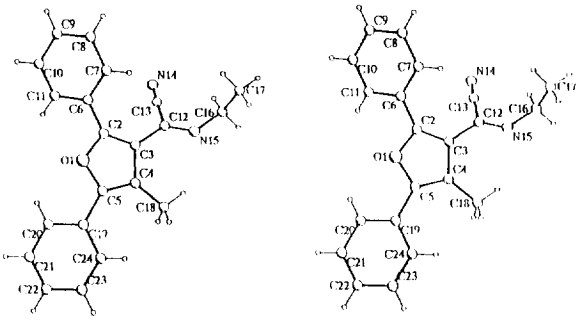
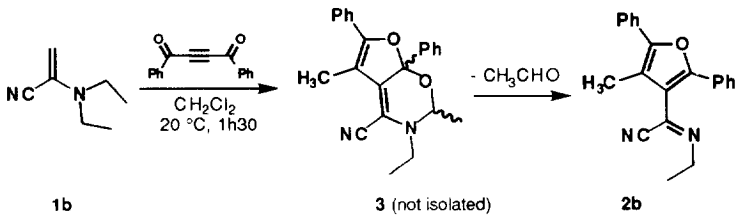


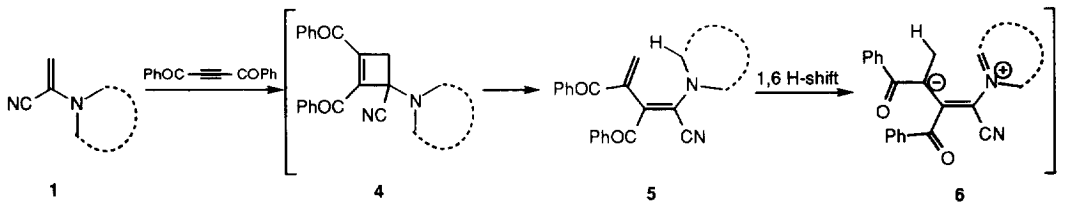
Figure 1 : Stereoscopic view of **2b**

The mechanism of this transformation was studied by following the course of the reaction of 2-diethylamino acrylonitrile **1b** with dibenzoylacetylene at room temperature. After 1.5 hour, the intermediate bicyclic dihydrofuran **3** was observed as a 1:1 mixture of cis and trans diastereoisomers and characterised by ^{1}H and ^{13}C NMR (Scheme 3). Prominent features of the NMR spectra (see Experimental part) include the two doublets of the hemiaminal carbons at 81.5 ppm (J = 158.8 Hz) and 83.9 ppm (J = 166.7 Hz) and the two quadruplets of the corresponding protons at 4.59 ppm (J = 5.8 Hz) and 4.67 ppm (J = 5.5 Hz).



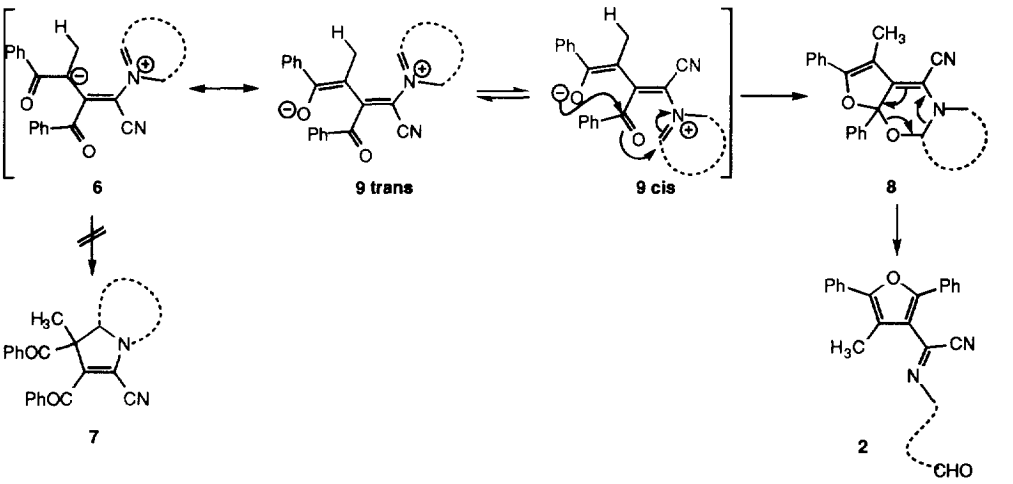
Scheme 3

These results agree with the mechanism shown in Schemes 4 and 5. The first steps involve the formation of the cyclobutene **4** followed by cycloreversion[3] to the aminodiene **5**. This compound undergoes a [1,6]-hydride shift leading to the 1,5-dipole **6** (Scheme 4).



Scheme 4

Instead of C-C bond formation to pyrrolines **7**, dihydrofuranes **8** are obtained by two-fold C-O bond formation starting from the enolate form **9 cis** in equilibrium with its isomer **9 trans**. Finally, a retro-hetero-Diels-Alder reaction concludes the sequence to the title compound **2** (Scheme 5).



Scheme 5

In summary, this reaction shows that the [1,6]-hydride shift is a general feature of dienes of type **5**; the fate of the resulting long-lived 1,5-dipole depends upon its environment. Other studies on these reactions are in progress.

Acknowledgements

We thank Mrs Phuong-Anh Nguyen for her help during the experimental work. The authors are grateful to the Services de la Programmation Scientifique (Belgium) and the Fonds National de la Recherche Scientifique (Belgium) for financial support. We thank Dr. B. Tinant for performing the X-ray crystallography analysis.

Experimental part

General

The ^1H NMR spectra were recorded on a Gemini-200 (200 MHz) and on a Gemini-300 (300 MHz) spectrometer. The ^{13}C NMR spectra were recorded on a Gemini-200 (50 MHz) and on a Gemini-300 (75 MHz) spectrometer (δ are given in ppm and J are given in Hz). The samples were dissolved in $CDCl_3$ with tetramethylsilane (TMS) as internal standard. The following abbreviations are used : S, s, singlet; D, d, doublet; T, t, triplet; Q, q, quartet; m, multiplet. IR and mass spectra were recorded on a Nicolet-205 and Finnigan-Mat TSQ-70 apparatus, respectively. Melting points were determined with a Leitz Wetzlar microscope and are uncorrected. Elemental analysis were carried out by Dr A. Stones at the University College London, London, UK. X-ray crystallography has been performed by Dr. B. Tinant and Prof. J.-P. Declercq at the Laboratoire de Chimie Physique et de Cristallographie, UCL, Louvain-la-Neuve.

Acetonitrile and CH_2Cl_2 were distilled on calcium hydride prior to use. All reactions were carried out under inert atmosphere. Column chromatography was performed with Merck Silica Gel 60 (70-230 mesh ASTM).

Synthesis of enamines and dibenzoylacetylene

2-(N,N-Dialkylamino)acrylonitriles **1a-g** are prepared[4] in medium to high yields by addition of amines to α-chloro acrylonitrile followed by elimination and rearrangement. They are distilled before use. Dibenzoylacetylene is prepared by addition of bromine to dibenzoylethylene followed by dehydrobromation with triethylamine in refluxing toluene.

Reaction of 2-dialkylamino acrylonitriles with dibenzoylacetylene

General procedure A

In a dry apparatus under argon atmosphere, dibenzoylacetylene diluted in acetonitrile (10 ml / mmole) is added at room temperature to a solution of one equivalent of 2-dialkylamino acrylonitrile in acetonitrile (20 ml / mmole). This solution is refluxed for 3 hours. After cooling, the solvent is evaporated under reduced pressure and the residual oil is purified by column chromatography over silica gel (eluent : ethyl acetate / light petroleum 10/90).

General procedure B

In a dry apparatus under argon atmosphere, dibenzoylacetylene diluted in dichloromethane (10 ml / mmole) is added at room temperature to a solution of one equivalent of 2-dialkylamino acrylonitrile in dichloromethane (20 ml / mmole). After stirring at room temperature for 18 hours, the solvent is evaporated under reduced pressure and the residual oil is purified by column chromatography over silica gel (eluent : ethyl acetate / light petroleum 10/90).

*Reaction of 2-dimethylamino acrylonitrile **1a** with dibenzoylacetylene. Synthesis of **2a**.*

General procedure A starting from 640 mg (6.6 mmoles) of **1a** and 1.56 g (6.6 mmoles) of dibenzoylacetylene affords **2a** (500 mg, 25 %) as a yellow oil which crystallises slowly.

General procedure B starting from 160 mg (1.6 mmoles) of **1a** and 380 mg (1.6 mmoles) of dibenzoylacetylene affords **2a** (340 mg, 71 %) as a yellow oil which crystallises slowly (m. p. : 65.5-67.5 °C); IR (cm^{-1}, KBr) : 3056, 3032, 2958, 2925, 2214 (CN), 1954*, 1889*, 1811*, 1751* (* arom. comb., weak), 1652, 1622 (C=N, strong), 1603 (C=C, strong), 1553, 1494, 1488, 1446; ^1H NMR (δ, ppm) : 2.33 (3 H, s, $OCCC\underline{H}_3$), 3.83 (3 H, s, $NC\underline{H}_3$), 7.30-7.50 (6 H, m, arom. C<u>H</u>), 7.60-7.70 (4 H, m, arom. C<u>H</u>); ^{13}C NMR (δ, ppm) : 10.32 (Q, J = 128.6 Hz, $OCC\underline{C}H_3$), 45.68 (Q, J = 136.8 Hz, $N\underline{C}H_3$), 109.34 (S, $OC\underline{C}C$=N), 117.13 (Sq, J = 6.8 Hz, $OC\underline{C}CH_3$), 119.55 (Sm, <u>C</u>N), 126.04 (Dt, J = 161.2 Hz and 6.8 Hz, arom. <u>C</u>H), 127.61 (Dt, J = 161.2 Hz and 7.2 Hz, arom. <u>C</u>H), 127.71 (Dt, J = 160.4 Hz and 6.8 Hz, arom. <u>C</u>H), 128.42 (Dt, J = ~160.8 Hz and ~6.0 Hz; arom. <u>C</u>H), 128.53 (Dt, J = ~160.8 Hz and ~7.2 Hz, arom. <u>C</u>H), 129.28 (Dt, J = ~163.5 Hz and 7.6 Hz, arom. <u>C</u>H), 130.40 (St, J = 6.8 Hz, arom. <u>C</u>), 137.39 (Sq, J = 10.0 Hz, $O\underline{C}CC$=N), 149.22 (Sm, $O\underline{C}CCH_3$), 153.06 (Sm, <u>C</u>=N); MS m/e : 300.4 ($M^{\cdot+}$), 299.2 (100 %, $M^{\cdot+}$ - H), 284.3 ($M^{\cdot+}$ - CH_3), 272.3, 258.1, 234.0, 202.4, 187.3, 177.8, 158.8, 149.1, 105.0, 77.2 ($C_6H_5^+$)

*Reaction of 2-diethylamino acrylonitrile **1b** with dibenzoylacetylene in refluxing acetonitrile. Synthesis of **2b**.*

General procedure A starting from 200 mg (1.6 mmoles) of **1b** and 380 mg (1.6 mmoles) of dibenzoylacetylene affords **2b** (280 mg, 55 %) as yellow crystals (recrystallised from ethanol; m. p. : 72.5-73 °C); IR (cm^{-1}, KBr) : 3056, 2976, 2933, 2871, 2210 (CN), 1955*, 1875*, 1810*, 1760* (* arom. comb., weak), 1620 (C=N, strong), 1603 (C=C, strong), 1493, 1489, 1445; ^1H NMR (δ, ppm) : 1.45 (3 H, t, J = 7.2

Hz, $NCH_2\underline{C}H_3$), 2.36 (3 H, s, $OCCC\underline{H}_3$), 4.05 (2 H, q, J = 7.2 Hz, $NC\underline{H}_2CH_3$), 7.34-7.50 (6 H, m, arom. C<u>H</u>), 7.60-7.70 (4 H, m, arom. C<u>H</u>); ^{13}C NMR (δ, ppm) : 10.18 (Q, J = 128.5 Hz, $OCC\underline{C}H_3$), 15.41 (Qt, J = 127.9 Hz and 4.3 Hz, $NCH_2\underline{C}H_3$), 53.26 (Tq, J = 136.2 Hz and 4.4 Hz, $N\underline{C}H_2CH_3$), 109.40 (S, $OC\underline{C}C$=N), 117.06 (Sq, J = 6.5 Hz, $OC\underline{C}CH_3$), 119.47 (Sm, <u>C</u>N), 125.95 (Dt, J = 160.8 Hz and 6.8 Hz, arom. <u>C</u>H), 127.55 (Dt, J = 161.6 Hz and 7.4 Hz, arom. <u>C</u>H), 128.31 (Dt, J = 160.8 Hz and 7.4 Hz, arom. <u>C</u>H), 128.45 (Dt, J = 161.0 Hz, 7.4 Hz, arom. <u>C</u>H), 129.14 (Dt, J = 161.6 Hz and 7.6 Hz, arom. <u>C</u>H), 130.36 (St, J = 7.6 Hz, arom. <u>C</u>), 135.24 (St, J = 9.6 Hz, O<u>C</u>CC=N), 149.13 (Sq, J = 4.5 Hz, $O\underline{C}CCH_3$), 152.79 (St, J = 3.8 Hz, <u>C</u>=N); MS m/e : 314.0 ($M^{\cdot+}$), 313.1 (100 %,. $M^{\cdot+}$ - H), 299.0 ($M^{\cdot+}$ - CH_3^+), 284.9 ($M^{\cdot+}$ - $C_2H_5^+$), 272.0 ($M^{\cdot+}$ - CH_3^+ - HCN), 257.6, 179.1, 125.1, 105.0, 77.0 ($C_6H_5^+$); Anal. Calcd. for $C_{21}H_{18}N_2O$ (314.37) : C : 80.23 %, H : 5.77 %, N : 8.91 %; Found : C : 80.07 %, H : 5.88 %, N : 8.97 %

Reaction of 2-diethylamino acrylonitrile ***1b*** *with dibenzoylacetylene at room temperature. Synthesis of* ***3*** *and rearrangement to* ***2b****.*

In a dry apparatus under argon atmosphere, dibenzoylacetylene (230 mg, 1.0 mmoles) diluted in 2 ml of dichloromethane is added at room temperature to a solution of **1b** (120 mg, 1.0 mmoles) in 5 ml of dichloromethane. After stirring at room temperature for 1.5 hour, the solvent is evaporated under reduced pressure and the residual oil is kept under argon atmosphere. ^1H and ^{13}C NMR spectra of the oil show an equimolar mixture of cis and trans isomers of **3** and traces of reactants and **2b**.

In a dry apparatus under argon atmosphere, **3** obtained as described hereupon is dissolved in 10 ml of dichloromethane. After 18 hours at room temperature, the solvent is evaporated under reduced pressure. Purification of the residual oil by column chromatography over silica gel (eluent : ethyl acetate / light petroleum 10/90) affords **2b** (210 mg, 67 %) as yellow crystals.

Spectral properties of **3** : ^1H NMR (δ, ppm) : 0.81 (3 H, t, J = 7.1 Hz, $C\underline{H}_3CH_2N$), 0.98 (3 H, t, J = 7.2 Hz, $C\underline{H}_3CH_2N$), 1.35 (3 H, d, J = 5.5 Hz, $C\underline{H}_3CHN$), 1.53 (3 H, d, J = 5.8 Hz, $C\underline{H}_3CHN$), 2.32 (3 H, s, $C\underline{H}_3C$=C-O), 2.36 (3 H, s, $C\underline{H}_3C$=C-O), 2.9-3.4 (4 H, m, $NCH_2\underline{C}H_3$), 4.59 (1 H, q, J = 5.8 Hz, NC<u>H</u>-O), 4.67 (1 H, q, J = 5.5 Hz, NC<u>H</u>-O), 7.2-7.7 (20 H, m, arom. C<u>H</u>); ^{13}C NMR (δ, ppm) : 9.33 (Q, J = 128.7 Hz, $\underline{C}H_3C$=C-O), 9.49 (Q, J = 128.3 Hz, $\underline{C}H_3C$=C-O), 13.60 (Qm, J = 126.7 Hz, $\underline{C}H_3CH_2N$), 15.67 (Qm, J = 126.9 Hz, $\underline{C}H_3CH_2N$), 16.58 (Q, J = 128.0 Hz, $\underline{C}H_3CH$-N), 20.24 (Q, J = 128.0 Hz, $\underline{C}H_3CH$-N), 40.00 (Tm, J = 136.6 Hz, $CH_3\underline{C}H_2N$), 43.63 (Tm, J = 134.8 Hz, $CH_3\underline{C}H_2N$), 81.51 (Dq, J = 158.8 Hz and 4.4 Hz, N<u>C</u>H-O), 83.93 (Dm, J = 166.7 Hz, N<u>C</u>H-O), 104.10 (Sm, O-<u>C</u>-O), 105.43 (Sm, O-<u>C</u>-O), 106.22 (Sm, NC=<u>C</u>), 106.83 (Sq, J = 6.6 Hz, $CH_3\underline{C}$=C-O), 107.65 (Sq, J = 6.8 Hz, $CH_3\underline{C}$=C-O), 108.63 (Sm, NC=<u>C</u>), 114.55 (Sd, J = 1.6 Hz, <u>C</u>N), 114.63 (S, <u>C</u>N), 124.87 (Dt, J = 158.9 Hz and 4.4 Hz, arom. <u>C</u>H), 125.28 (Dt, J = 162.1 Hz and 6.0 Hz, arom. <u>C</u>H), 127.18 (Dt, J = ~162.0 Hz and ~6.4 Hz, arom. <u>C</u>H), 127.31 (Dt, J = ~162.0 Hz and ~6.4 Hz, arom. <u>C</u>H), 127.78 (Dm, J = ~160 Hz, arom. <u>C</u>H), 128.03 (Dm, J= ~160 Hz, arom <u>C</u>H), 128.10 (Dm, J= ~160 Hz, arom <u>C</u>H), 128.29 (Dm, J = ~160 Hz, arom. <u>C</u>H), 128.74 (Dt, J = 161.2 Hz and ~6 Hz, arom. <u>C</u>H), 128.91 (Dt, J = 161.2 Hz and ~6 Hz arom. <u>C</u>H), 129.15 (Dt, J = 161.6 Hz and 7.5 Hz, arom. <u>C</u>H), 129.91 (S, arom. <u>C</u>), 129.99 (S, arom. <u>C</u>), 138 .70 (Sd, J = 4.4 Hz, N<u>C</u>=C), 145.97 (Sd, J = 5.6 Hz, N<u>C</u>=C), 141.13 (Sm, arom. <u>C</u>), 141.68 (Sm, arom. <u>C</u>), 154.60 (Sm, CH_3C=<u>C</u>-O), 154.90 (Sm, CH_3C=<u>C</u>-O)

Reaction of 2-[(N-methyl-N-phenylethyl)amino] acrylonitrile ***1c*** *with dibenzoylacetylene. Synthesis of* ***2a****.*

General procedure B starting from 160 mg (0.85 mmoles) of **1c** and 200 mg (0.85 mmoles) of dibenzoylacetylene affords **2a** (130 mg, 52 %) as a yellow oil which crystallises slowly.

*Reaction of 2-pyrrolidino acrylonitrile **1d** with dibenzoylacetylene. Synthesis of **2c**.*

General procedure A starting from 150 mg (1.2 mmoles) of **1d** and 290 mg (1.2 mmoles) of dibenzoylacetylene affords **2c** (310 mg, 73 %) as an oil.

General procedure B starting from 200 mg (1.6 mmoles) of **1d** and 380 mg (1.6 mmoles) of dibenzoylacetylene affords **2c** (350 mg, 60 %) as an oil; IR (cm^{-1}, neat) : 2960, 2931, 2872, 2218 (CN), 1956*, 1894*, 1806* (* arom. comb., weak), 1724 (C=O, strong), 1621 (C=N, strong), 1602 (C=C, strong), 1493, 1489, 1446; ^1H NMR (δ, ppm) : 2.13 (2 H, t, J = 7.0 Hz, $NCH_2C\underline{H}_2$), 2.33 (3 H, s, $OCCC\underline{H}_3$), 2.62 (2 H, t, J = 7.2 Hz, $C\underline{H}_2CHO$), 3.98 (2 H, t, J = 6.7 Hz, $NC\underline{H}_2CH_2$), 7.31-7.47 (6 H, m, arom. C<u>H</u>), 7.56-7.69 (4 H, m, arom. C<u>H</u>), 9.78 (1 H, t, J = 1.2 Hz, $CH_2C\underline{H}O$); ^{13}C NMR (δ, ppm) : 10.33 (Q, J = 128.6 Hz, $OCC\underline{C}H_3$), 22.72 (Tm, J = 128.7 Hz, $NCH_2\underline{C}H_2$), 41.33 (Tdt, J = 125.1 Hz, 24.3 Hz and 4.4 Hz, $\underline{C}H_2CHO$), 57.28 (Tt, J = 136.0 Hz and 4.4 Hz, $N\underline{C}H_2CH_2$), 109.38 (S, $OC\underline{C}C{=}N$), 116.90 (Sq, J = 6.8 Hz, $OC\underline{C}CH_3$), 119.36 (Sm, <u>C</u>N), 126.04 (Dt, J = 160.8 Hz and 6.8 Hz, arom. <u>C</u>H), 127.63 (Dm, J = ~161.2 Hz, arom. <u>C</u>H), 127.83 (Dm, J = ~161.2 Hz, arom. <u>C</u>H), 128.34 (Dt, J = 161.4 Hz and 7.4 Hz, arom. <u>C</u>H), 128.49 (Dt, J = 161.4 Hz and 7.4 Hz, arom. <u>C</u>H), 129.04 (Sm, arom. <u>C</u>), 129.34 (Dt, J = ~161.2 Hz and 7.6 Hz, arom. <u>C</u>H), 130.25 (St, J = 8.4 Hz, arom. <u>C</u>), 136.18 (St, J = 9.0 Hz, $O\underline{C}CC{=}N$), 149.29 (Sm, $O\underline{C}CCH_3$), 153.36 (St, J = 4.0 Hz, <u>C</u>=N), 201.22 (Dm, J = 172.3 Hz, <u>C</u>HO); MS m/e : 356.1 ($M^{\cdot+}$), 327.3, 313.0, 300.4, 299.2 ($M^{\cdot+}$ - C_3H_5O), 287.0, 284.9 ($M^{\cdot+}$ - C_4H_7O), 279.3 (100 %, $M^{\cdot+}$ - $C_6H_5^+$), 258.1, 167.0 ($M^{\cdot+}$ - 2 x $C_6H_5^+$), 149.1 ($M^{\cdot+}$ - 2 x $C_6H_5^+$ - H_2O)

*Reaction of 2-piperidino acrylonitrile **1e** with dibenzoylacetylene. Synthesis of **2d**.*

General procedure A starting from 190 mg (1.4 mmoles) of **1e** and 330 mg (1.4 mmoles) of dibenzoylacetylene affords **2d** (160 mg, 31 %) as an oil.

General procedure B starting from 200 mg (1.5 mmoles) of **1e** and 350 mg (1.5 mmoles) of dibenzoylacetylene affords **2d** (180 mg, 32 %) as an oil; IR (cm^{-1}, neat) : 3056, 2956, 2933, 2870, 2724, 2214 (CN, weak), 1958*, 1886*, 1808* (* arom. comb., weak), 1724 (C=O, strong), 1680, 1621 (C=N, strong), 1602 (C=C, strong), 1554, 1493, 1489, 1446; ^1H NMR (δ, ppm) : 1.70-2.00 (4 H, m, $NCH_2(C\underline{H}_2)_2$), 2.36 (3 H, s, $OCCC\underline{H}_3$), 2.56 (2 H, tm, J = 6.8 Hz, $C\underline{H}_2CHO$), 4.02 (2 H, tm, J = 5.7 Hz, $NC\underline{H}_2CH_2$), 7.30-7.43 (6 H, m, arom. C<u>H</u>), 7.55-7.64 (4 H, m, arom. C<u>H</u>), 9.81 (1 H, t, J = 1.7 Hz, $CH_2C\underline{H}O$); ^{13}C NMR (δ, ppm) : 10.36 (Q, J = 128.6 Hz, $OCC\underline{C}H_3$), 19.74 (Tm, J = 129.8 Hz, $NCH_2(\underline{C}H_2)_2$), 29.67 (Tt, J = 128.1 Hz and 4.2 Hz, $NCH_2(\underline{C}H_2)_2$), 43.35 (Tdm, J = 124.0 Hz and 24.7 Hz, $\underline{C}H_2CHO$), 58.21 (Tm, J = 134.0 Hz, $N\underline{C}H_2CH_2$), 109.51 (S, $OC\underline{C}C{=}N$), 117.03 (Sm, $OC\underline{C}CH_3$), 119.47 (Sm, <u>C</u>N), 126.11 (Dt, J = 160.4 Hz and 7.0 Hz, arom. <u>C</u>H), 127.68 (Dt, J = 161.2 Hz and 8.0 Hz, arom. <u>C</u>H), 127.82 (Dt, J = 161.2 Hz and 7.2 Hz, arom. <u>C</u>H), 128.42 (Dt, J = ~153.6 Hz and ~6.4 Hz, arom. <u>C</u>H), 128.56 (Dt, J = ~153.6 Hz and ~6.4 Hz, arom. <u>C</u>H), 129.17 (Sm, arom. <u>C</u>), 129.36 (Dt, J = ~162.4 Hz and 7.2 Hz, arom. <u>C</u>H), 130.37 (Sm, arom. <u>C</u>), 135.99 (St, J = 9.4 Hz, $O\underline{C}CC{=}N$), 149.33 (Sm, $O\underline{C}CCH_3$), 153.24 (Sm, <u>C</u>=N), 201.80 (Dm, J = 175.5 Hz, <u>C</u>HO); MS m/e : 369.7 ($M^{\cdot+}$), 362.1, 279.2, 262.1, 167.1, 149.1 (100 %), 122.1, 105.1, 87.1, 85.2, 82.8, 77.0 ($C_6H_5^+$), 75.1, 59.1

*Reaction of 2-(1-azacycloheptyl) acrylonitrile **1f** with dibenzoylacetylene. Synthesis of **2e**.*

General procedure A starting from 100 mg (0.6 mmoles) of **1f** and 220 mg (0.94 mmoles) of dibenzoylacetylene affords **2e** (155 mg, 67 %) as an oil; IR (cm^{-1}, neat) : 3057, 3023, 2936, 2861, 2722, 2218 (CN), 1915*, 1850* (* arom. comb., weak), 1750 (C=O, strong), 1724 (C=O, strong), 1673, 1650, 1620 (C=N, strong), 1602 (C=C, strong), 1493, 1489, 1446; ^1H NMR (δ, ppm) : 1,42-1,94 (6 H, m, $NCH_2(C\underline{H}_2)_3$), 2.34 (3 H, s, $OCCC\underline{H}_3$), 2.45 (2 H, td, J = 7.1 Hz and 1.2 Hz, $C\underline{H}_2CHO$), 4.03 (2 H, t, J = 6.8 Hz, $NC\underline{H}_2CH_2$), 7.30-7.50 (6 H, m, arom. C<u>H</u>), 7.60-7.72 (4 H, m, arom. C<u>H</u>), 9.76 (1 H, t, J = 1.5 Hz,

CH_2CHO); ^{13}C NMR (δ, ppm) : 10.28 (Q, J = 128.6 Hz, $OCC\underline{C}H_3$), 21.60 (Tm, J = 130.1 Hz, $NCH_2(\underline{C}H_2)_3$), 26.75 (Tm, J = 127.7 Hz, $NCH_2(\underline{C}H_2)_3$), 30.00 (Tm, J = 125.1 Hz, $NCH_2(\underline{C}H_2)_3$), 43.55 (Tdt, J = 123.3 Hz, 22.4 Hz and 4.0 Hz, $\underline{C}H_2CHO$), 58.40 (Tt, J = 135.7 Hz and 4.0 Hz, $N\underline{C}H_2CH_2$), 109.51 (S, $OC\underline{C}C{=}N$), 117.01 (Sq, J = 6.5 Hz, $OC\underline{C}CH_3$), 119.47 (Sm, $\underline{C}N$), 126.01 (Dt, J = 161.2 Hz and 6.8 Hz, arom. $\underline{C}H$), 127.60 (Dm, J = ~161.2 Hz, arom. $\underline{C}H$), 127.68 (Dm, J = ~160.0 Hz, arom. $\underline{C}H$), 128.36 (Dt, J = 161.6 Hz and 7.4 Hz, arom. $\underline{C}H$), 128.50 (Dt, J = 161.6 Hz and 7.4 Hz, arom. $\underline{C}H$), 129.12 (Sm, arom. $\underline{C}$), 129.25 (Dt, J = ~163.2 Hz and 7.6 Hz, arom. $\underline{C}H$), 130.33 (St, J = 8.0 Hz, arom. $\underline{C}$),, 135.69 (St, J = 9.6 Hz, $O\underline{C}CC{=}N$), 149.24 (Sm, $O\underline{C}CCH_3$), 153.00 (St, J = 3.8 Hz, $\underline{C}{=}N$), 202.20 (Dt, J = 175.5 Hz and 4.6 Hz, $\underline{C}HO$); MS m/e : 384.2 ($M^{\cdot+}$), 299.1 ($M^{\cdot+}$ - C_5H_9O), 286.9, 167.0, 152.0, 149.0, 105.0, 85.1, 82.8 (100 %), 77.0 ($C_6H_5^+$)

Reaction of 2-(1-azacyclooctyl) acrylonitrile ***1g*** *with dibenzoylacetylene. Synthesis of* ***2f****.*

General procedure A starting from 170 mg (1.0 mmoles) of **1g** and 320 mg (1.3 mmoles) of dibenzoylacetylene affords **2f** (95 mg, 24 %) as an oil.

General procedure B starting from 200 mg (1.2 mmoles) of **1g** and 280 mg (1.2 mmoles) of dibenzoylacetylene affords **2f** (190 mg, 39 %) as an oil; IR (cm^{-1}, neat) : 3056, 3031, 2933, 2858, 2721, 2212 (CN), 1956*, 1887*, 1806* (* arom. comb., weak), 1724 (C=O, strong), 1721 (C=O, strong), 1621 (C=N, strong), 1602 (C=C, strong), 1554, 1493, 1489, 1446; ^1H NMR (δ, ppm) : 1.43 (4 H, m, $NCH_2(CH_2)_4$), 1.64 (2 H, quint, J = 7.1 Hz, $NCH_2(CH_2)_4$), 1.82 (2 H, quint, 7.1, $NCH_2(CH_2)_4$), 2.34 (3 H, s, $OCCCH_3$), 2.40 (2 H, td, J = 7.1 Hz and 1.5 Hz, CH_2CHO), 3.98 (2 H, t, J = 6.7 Hz, NCH_2CH_2), 7.20-7.45 (6 H, m, arom. $\underline{C}H$), 7.55-7.65 (4 H, m, arom. $\underline{C}H$), 9.72 (1 H, t, J = 1.6 Hz, CH_2CHO); ^{13}C NMR (δ, ppm) : 10.24 (Q, J = 128.6 Hz, $OCC\underline{C}H_3$), 21.75 (Tm, J = 130.0 Hz, $NCH_2(\underline{C}H_2)_4$), 26.96 (Tm, J = 127.5 Hz, $NCH_2(\underline{C}H_2)_4$), 28.64 (Tm, J = 127.1 Hz, $NCH_2(\underline{C}H_2)_4$), 29.97 (Tm, J = 124.9 Hz, $NCH_2(\underline{C}H_2)_4$), 43.55 (Tdm, J = 125.5 Hz and 24.1 Hz, $\underline{C}H_2CHO$), 58.58 (Tm, J = 135.6 Hz, $N\underline{C}H_2CH_2$), 109.51 (S, $OC\underline{C}CH_3$), 117.01 (Sq, J = 6.6 Hz, $OC\underline{C}CH_3$), 119.54 (Sm, $\underline{C}N$), 125.98 (Dt, J = 160.8 Hz and 7.2, arom. $\underline{C}H$), 127.55 (Dt, J = 161.6 Hz and 7.4 Hz, arom. $\underline{C}H$), 127.63 (Dt, J = 160.0 Hz and 7.2 Hz, arom. $\underline{C}H$), 128.31 (Dt, J = 161.2 Hz and 7.4 Hz, arom. $\underline{C}H$), 128.47 (Dt, J = 161.2 Hz and 7.4 Hz, arom. $\underline{C}H$), 129.17 (Dt, J = 160.8 Hz and 7.4 Hz, arom. $\underline{C}H$), 130.34 (St, J = 7.2 Hz, arom. $\underline{C}$), 135.55 (St, J = 9.6 Hz, $O\underline{C}CC{=}N$), 148.17 (Sq, J = 5.2 Hz, $O\underline{C}CCH_3$), 152.86 (St, J = 4.0 Hz, $\underline{C}{=}N$), 202.17 (Dt, J = 170.3 Hz and 4.5 Hz, $\underline{C}HO$); MS m/e : 397.8 ($M^{\cdot+}$), 299.1 ($M^{\cdot+}$ - $C_6H_{11}O$), 284.9($M^{\cdot+}$ - $C_7H_{13}O$), 254.3, 211.1, 183.0, 105.0 (100 %), 77.0 ($C_6H_5^+$)

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