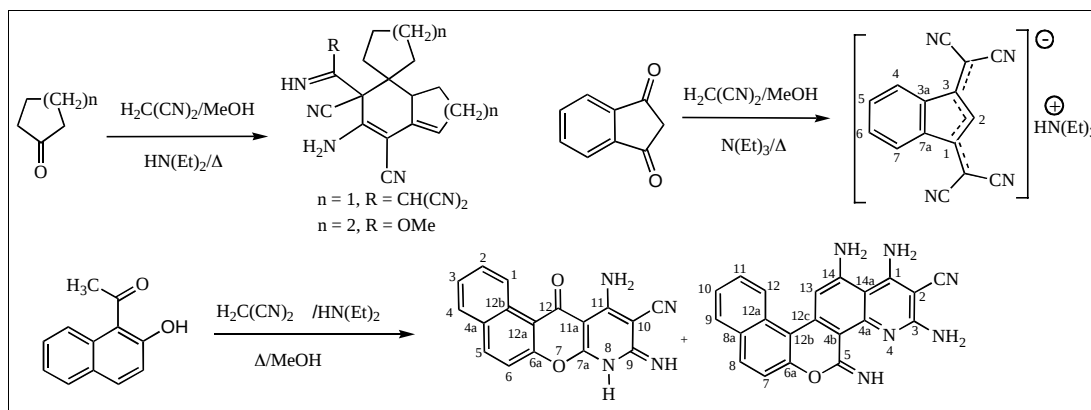


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Received November 4, 2005

*Dedicated to Professor M. Tišler at the occasion of his 80th birthday.*

Condensations of some ketones, such as cyclopentanone, cyclohexanone, indan-1,3-dione, 2-acetyl-1-naphthol, 1-acetyl-2-naphthol, with some active methylene compounds, such as malononitrile and cyanoacetate, in the presence of amine bases, diethylamine or triethylamine, were studied. The structures of the Knoevenagel condensation products were determined by spectral analyses.

J. Heterocyclic Chem., **43**, 1037 (2006).

Introduction.

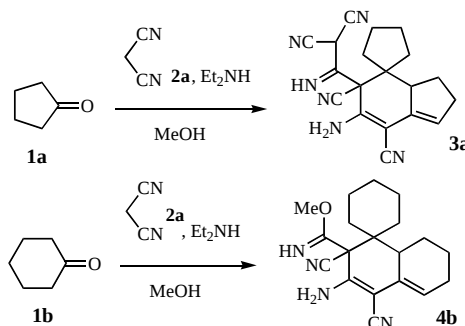
The Knoevenagel condensation reaction [1-3] of ketones with methylene active nitriles (malononitrile, alkyl cyanoacetate, *etc.*) is the key step in the synthesis of 2-aminothiophene derivatives through both variants of the Gewald method [4-13]. We here report the results of various attempts to prepare the intermediates in both one and two-pot procedures of the Gewald synthesis, from cyclopentanone, cyclohexanone, indan-1,3-dione, 1-acetyl-2-naphthol and 2-acetyl-1-naphthol and methylene active nitriles (malononitrile, methyl and ethyl cyanoacetate) in the presence of bases (diethylamine and triethylamine).

Results and Discussion.

The condensation of cyclopentanone (**1a**) with malononitrile (**2a**) in refluxing methanol in the presence of diethylamine gave the bicyclic compound (**3a**) as colorless needles, mp 274-276 °C instead of the anticipated compound **5a**. The IR spectrum of **3a** showed NH bands at 3443, 3327, 3284, and 3237 cm⁻¹ and the nitrile band at 2212 cm⁻¹. The mass spectrum of **3a** showed the molecular ion peak at *m/z* 330 (100%), corresponding to the molecular formula C₁₉H₁₈N₆. The ¹H NMR spectrum (DMSO-d₆) showed the multiplets signals at 1.53-2.91 ppm (six methylenes), 3.16

ppm (3a-H), 4.09-4.12 ppm (olefinic 1-H), 5.47 ppm (CH(CN)₂), and also showed two broad singlets, exchangeable with D₂O, around 6.70 and 9.46 ppm (NH₂ and N=H). The ¹³C NMR (DMSO-d₆) showed resonances corresponding to six methylene carbon atoms, three tertiary carbon atoms, and ten quaternary carbon atoms.

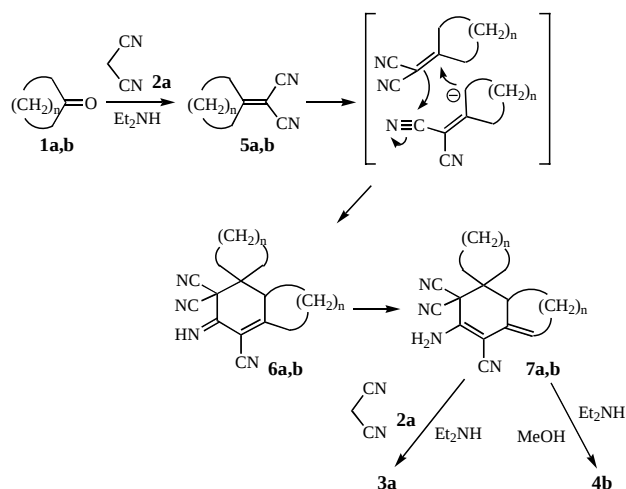
Scheme 1

Condensation of Cyclopentanone (**1a**) or Cyclohexanone (**1b**) with malononitrile (**2a**).

The analogous condensation of cyclohexanone (**1b**) with malononitrile (**2a**) under the same reaction conditions also

gave a bicyclic compound (**4b**) [14-17] as colorless needles, mp 216-218 °C instead of the anticipated compound **5b**. The IR spectrum of **4b** showed NH bands at 3423, 3327, and 3217 cm⁻¹ and nitrile bands at 2240 and 2207 cm⁻¹.

Scheme 2

Mechanism for **3a** and **4b**.

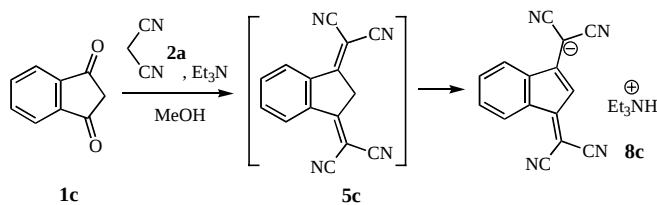
The mass spectrum of **4b** revealed the molecular ion peak at 324 (45%), corresponding to the molecular formula C₁₉H₂₄N₄O. The ¹H NMR spectrum (DMSO-d₆) showed multiplet signals at 1.20-2.26 ppm (eight methylenes), 3.61 ppm (8a-H), 3.70 ppm (OCH₃), 5.71 ppm (olefinic 5-H), and also showed two broad singlets, exchangeable with D₂O, around 6.53 and 7.98 ppm (NH₂ and N=H). The ¹³C NMR (DMSO-d₆) showed resonances for one methoxy carbon atom, eight methylene carbon atoms, two tertiary carbon atoms, and eight quaternary carbon atoms.

Nucleophilic attacks in **6a,b** might be possible on both types of nitrile groups, but the conjugated nitrile is less reactive than the unconjugated nitrile groups.

The analogous condensation of indan-1,3-dione (**1c**) with malononitrile (**2a**) in refluxing methanol in the presence of triethylamine the salt **8c** as deep blue needles, mp 198-200 °C. The IR spectrum of **8c** showed the NH bands at 3429 cm⁻¹ and the nitrile bands at 2209 and 2191 cm⁻¹. The elemental analysis of **8c** proved the molecular formula C₂₁H₂₁N₅ and the mass spectrum of **8c** showed the peak at m/z 242 (M-Et₃N, 79%). The ¹H NMR spectrum (DMSO-d₆) showed the three triplet methyl signals at 1.19 ppm (N-CH₂CH₃) and three methylene signals at 3.11 ppm (N-CH₂CH₃), 5.52 ppm (olefinic 2-H), 7.42 and 7.92 ppm (aromatic protons), and also showed two broad singlets, exchangeable with D₂O, around 8.85 ppm (NH⁺). The ¹³C NMR (DMSO-d₆) showed resonances corresponding to one methoxy

carbon atom, eight methylene carbon atoms, two tertiary carbon atoms, and eight quaternary carbon atoms.

Scheme 3

Condensation of indan-1,3-dione (**1c**) with malononitrile (**2a**).

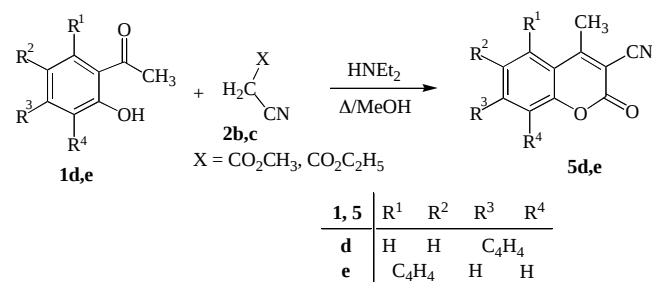
The formation of the product **5c** might be explained by double Knoevenagel condensation of **1c** with 2 moles of malononitrile **2a** followed by deprotonation with triethylamine.

In refluxing methanol 2-acetyl-1-naphthol (**1d**) and 1-acetyl-2-naphthol (**1e**) react with cyanoacetic esters **2b,c** in the presence of diethylamine to yield the known [20,21] benzocoumarins **5d,e** (Scheme 4).

The condensation of 2-acetyl-1-naphthol (**1d**) with malononitrile in the presence of diethylamine and sulfur in a one pot-procedure [4-13], did not give as expected the condensed 2-aminothiophene **11d**, but instead the mixture of compounds **9d** and **10d** (Schemes 5 and 6).

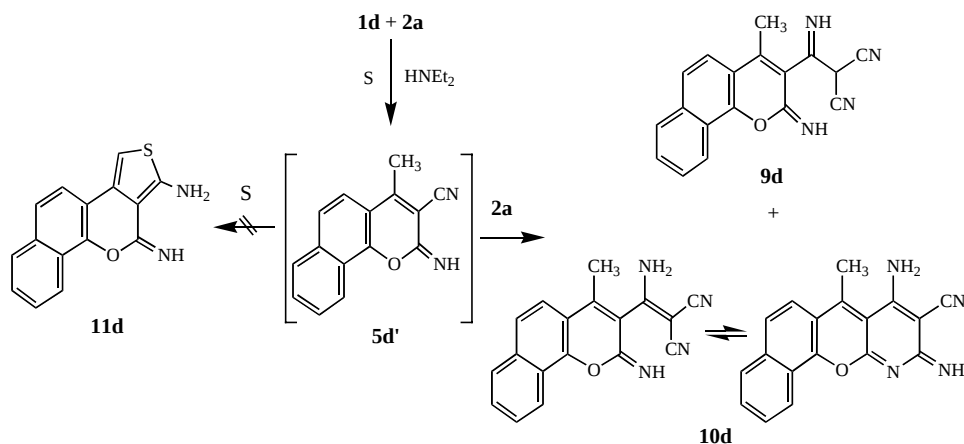
Similarly the reaction of 1-acetyl-2-naphthol (**1e**) with ethyl cyanoacetate in the presence of diethylamine in a one pot-procedure [4-13] gave compound **5e** (Scheme 7) instead of the anticipated fused 2-aminothiophene **11e** [22].

Scheme 4

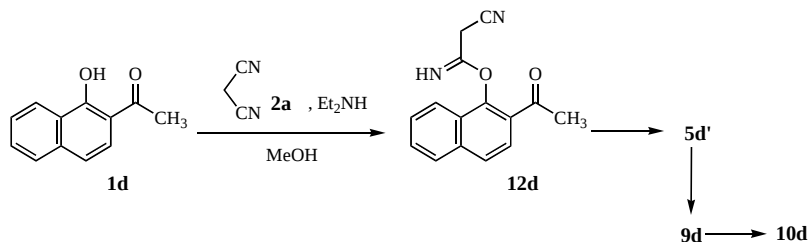
Condensation of 2-acetyl-1-naphthol (**1d**) and 1-acetyl-2-naphthol (**1e**) with cyanoacetates (**2b,c**).

The reaction of **1e** with malononitrile in boiling methanol in the presence of diethylamine did not give as the expected compound **5e'**, but rather the two polycyclic compounds **13e** and **14e** (Scheme 8) in 25 and 10% yields respectively.

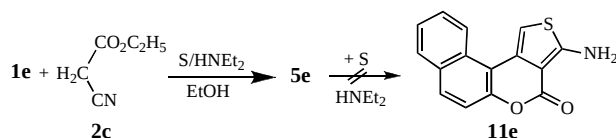
Scheme 5

Condensation of 2-acetyl-1-naphthol (**1d**) with malononitrile (**2a**).

Scheme 6

Formation of **9d** and **10d**.

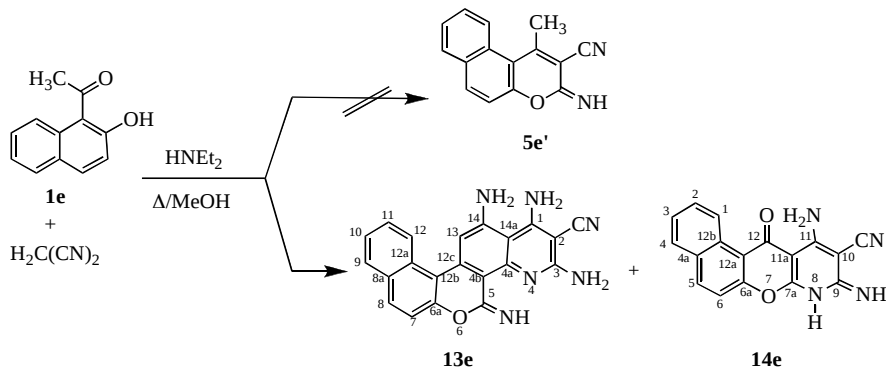
Scheme 7

Condensation of 1-acetyl-2-naphthol (**1e**) with ethyl cyanoacetate (**2c**).

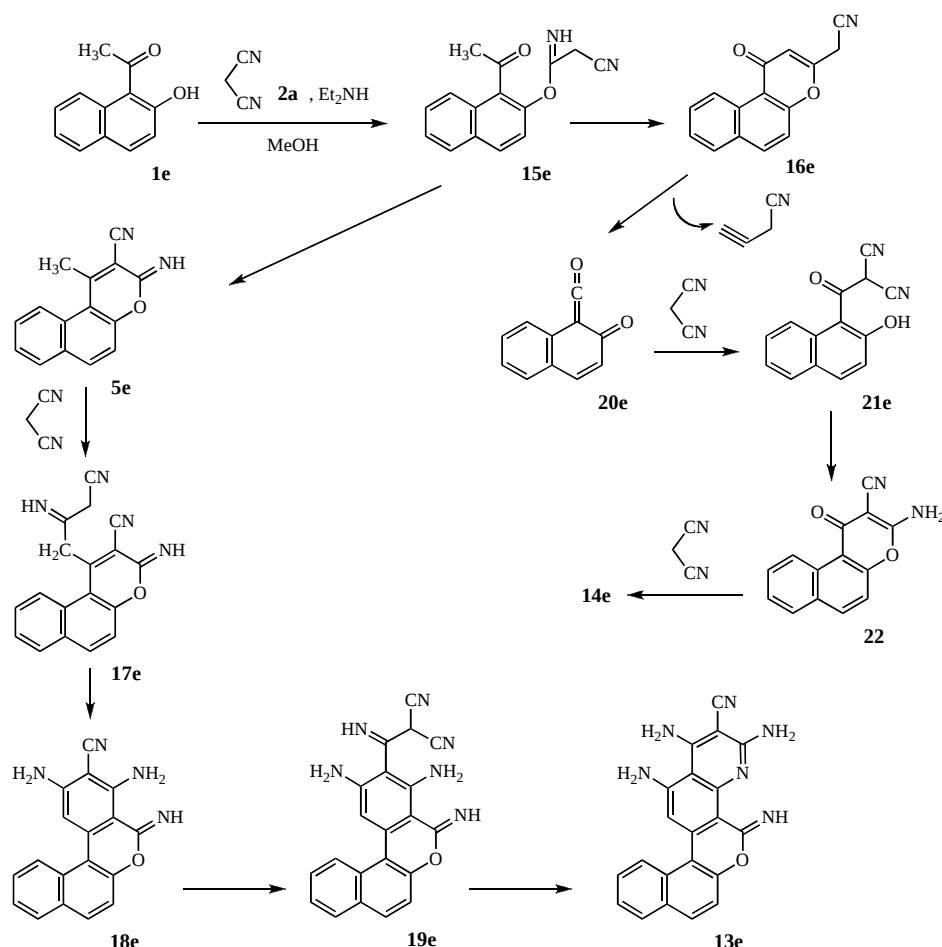
Compound **14e** was obtained as the first precipitate, crystallizing as high melting (mp > 350 °C) yellow powder from acetone. In the high frequencies region of the IR spectrum the absorptions bands of the N-H-stretchings of the =NH, -NH- and NH_2 -groups could be seen at ν 3452, 3353 and 3270 cm^{-1} .

The absorption frequencies of the nitrile and carbonyl groups appear at ν 2205 and 1636 cm^{-1} , respectively. The

Scheme 8

Condensation of 1-Acetyl-2-naphthol (**1e**) with malononitrile (**2a**).

Scheme 9

Proposed formation of **13e** and **14e**.

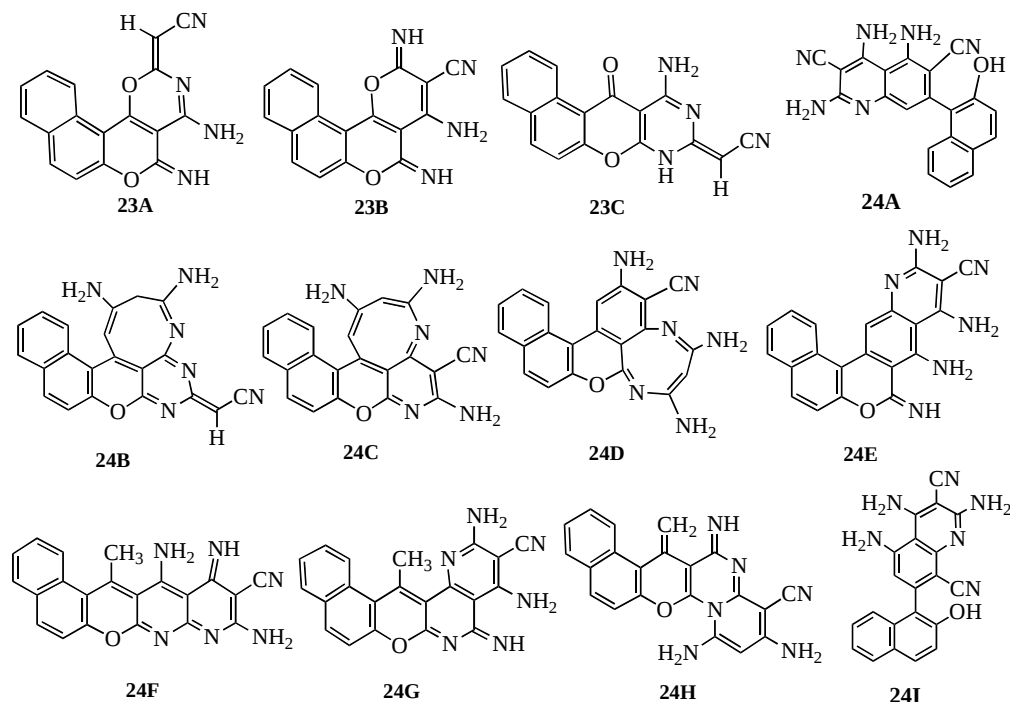
mass spectrum showed the molecular ion peak at m/z 302 (100%) and characteristic fragment ion peaks at m/z 275 (6%, cleavage of HCN), m/z 274 (13%, cleavage of the carbonyl function). The peaks at m/z 66 (7%), 44 (11%) and 42 (7%) were respectively attributed to the fragment ions $(\text{H}_2\text{N}-\text{CC}-\text{CN})^+$, $(\text{CO}_2)^+$ and $(\text{HN}=\text{C}=\text{NH})^+$.

Besides the multiplet of the naphthalene protons between δ_{H} 9.89–7.54 ppm, a D_2O -exchangeable broad singlet could be identified from the 500 MHz ^1H NMR ($\text{DMSO}-d_6$) spectrum. The integral pattern is consistent with the existence of ten protons. The doublet of doublets (dd) at δ_{H} 9.88 ppm has a broad basis and corresponds to two protons. The ^1H , ^1H -COSY-45 spectrum showed only a single cross-peak between this dd and the 1H-ddd at δ_{H} 7.76 ppm. The dd at 9.88 ppm that should be assigned to 1-H overlaps with the broad singlet of $-\text{NH}-$ or $=\text{NH}$. Consequently, the ddd at δ_{H} 7.76 ppm and δ_{H} 7.64 ppm should be assigned to 2-H and 3-H. Aside from the cross-peak between $\delta_{3\text{H}}$ and $\delta_{2\text{H}}$, there is another cross-peak

between $\delta_{3\text{H}}$ and the poorly resolved dd at δ_{H} 8.07 ppm consisting of one proton, which was logically assigned to 4-H. Furthermore, the spectrum showed two doublets at δ_{H} 8.32 ppm and δ_{H} 7.63 ppm, connected by a single cross-peak. These signals should consequently be assigned to 5-H and 6-H, respectively. The spectrum exhibited also at δ_{H} 7.79 ppm and δ_{H} 7.54 ppm two broad singlets for one and two protons, respectively assigned to $=\text{NH}$ (or $-\text{NH}-$) and $-\text{NH}_2$. The ^{13}C (^1H)-NMR ($\text{DMSO}-d_6$, 125 MHz) spectrum consisted of seventeen lines, amongst which a downfield peak at δ_{C} 179.83 ppm, which is an unequivocal proof of the presence of a carbonyl group in **14e**. The DEPT-135 spectrum showed the signals of six tertiary carbon atoms. Ten other signals of quaternary carbon atoms could be found and readily assigned.

The mother liquor of **14e** was kept in the refrigerator for several days, after which a yellow precipitate consisting of **13e** was isolated. This compound crystallizes as yellow powder from

Scheme 10



Other possible isomers of 13e and 14e.

acetone and has a sharp melting point at 328 °C. In the IR spectrum, the absorption bands of the amino- and imino-groups are observed at ν 3458, 3347 and 3231 cm^{-1} , whereas the absorption of the nitrile group appeared at ν 2204 cm^{-1} . The mass spectrum exhibited the molecular ion peak at m/z 366 (75%) and the base peak at m/z 349 (100%). The latter is certainly due to the elimination of an NH_3 molecule from the molecular ion.

The ^1H NMR (DMSO-d_6 , 300 MHz) spectrum contained signals in the range 10.03–5.71 ppm, the integrals of which represent a total of fourteen protons. The most down field 1H-broad singlet at δ_{H} 10.03 ppm, which disappeared after treatment with D_2O , was assigned to $=\text{NH}$. Similarly, the broad singlets at δ_{H} 6.65, 6.47 and 5.71 ppm, which are equally D_2O -exchangeable and represent two protons each, were respectively attributed to the amino-groups at C-14, C-1 and C-3. The signal of 13-H is found at δ_{H} 6.23 ppm as a sharp singlet integrating for one proton. Moreover, the characteristic splitting of the AB-(7-H and 8-H) and ABCD-(9-H to 12-H) systems belonging to the naphthalene ring could be identified in the aromatic region between 7.96–7.12 ppm. The exact assignments of these protons were achieved with the help of the following experiments [23]:

NOE-difference Spectroscopy.

Irradiation of the signal at δ_{H} 6.23 ppm (sole singlet in the ArH-region and attributed to 13-H) resulted in the enhancement of the signals at δ_{H} 6.65 ppm (14- NH_2) and δ_{H} 7.13 ppm (12-H). Irradiation at δ_{H} 7.13 ppm (12-H) induced an effect on the signal of the directly opposite "bay"-proton 13-H. Another resulting intensity enhancement is observed at δ_{H} 7.88 ppm (assigned 11-H). Because of the poor resolution of the multiplet at δ_{H} 7.31–7.40 ppm (for 11-H, 10-H and 7-H), an accurate irradiation is uncertain. One could nevertheless recognize the interactions with 13-H, 12-H and 9-H (δ_{H} 7.88 ppm). The irradiation into this signal intensifies the resonances of 8-H and 10-H. Enhancements of the signals 9-H (δ_{H} 7.88 ppm) and 7-H (δ_{H} 7.31 ppm) were observed when 8-H (δ_{H} 7.95 ppm) was irradiated. The irradiation of 14- NH_2 (δ_{H} 6.65 ppm) produced an effect on 13-H (δ_{H} 6.23 ppm);

^1H - ^{13}C (^1H)-COSY

Only the ^1H -signals at δ_{H} 7.95 (8-H), 7.88 (9-H), 7.37 (11-H), 7.33 (10-H), 7.30 (7-H), 7.13 (12-H) and 6.23 ppm (13-H) showed cross-peaks with carbon atoms. Therefore the broad singlets at δ_{H} 6.65, 6.47 and 5.71 ppm could be attributed to NH_2 -groups, and that at δ_{H} 10.03 ppm to $=\text{NH}$.

^1H , ^1H -COSY.

The following correlations were observed: 7-H with 8-H, 9-H with 10-H, 10-H with 11-H, 11-H with 10-H and 12-H.

Moreover 14 signals of quaternary carbon atoms could be easily identified from the spectrum and readily assigned.

The failure to isolate the anticipated compound **5e'**, might certainly be due to the drastic reaction conditions (reflux), compared with the usual ones [1-3]. The formation of compounds **13e** and **14e** can be rationalized as shown in Scheme 9. All the other possible isomeric structures of **14e** (**23A-C**, Scheme 10) and **13e** (**24A-I**, Scheme 10) were ruled out on the basis of the above discussed spectroscopic data. Furthermore, the ferric chloride enol test [24] carried out with compound **13e** gave no positive result, excluding therefore the presence of a free phenolic OH group as in isomers **24A** and **24I**.

EXPERIMENTAL

All the elemental and spectroscopic analyses were performed in the chemistry department analytical centre of Gerhard Mercator Universität-GH-Duisburg, Duisburg (Germany). All the melting points were determined with a Reichert Thermovar microscope and are uncorrected. The IR and UV spectra were measured with Perkin-Elmer 983 and 554 spectrophotometers, respectively. ^1H and ^{13}C NMR spectra were recorded on WM 300 and 500 instruments, with TMS as internal standard. Coupling constants in brackets are reported in Hertz. Mass spectra were obtained on Varian MAT 311A and AMD 604 instruments by Electron Impact Ionisation (EI) at 70 eV, on direct inlet system. Combustion analyses were carried out with CHN + O/S elemental analyser "CARLO ERBA" Model 1106.

[6-Amino-5,7-dicyano-3,4,5-tetrahydro-(4-spirocyclopentan-2H-inden)-5-yl]iminomethylpropanedinitrile (**3a**).

A stirred mixture of diethylamine (ca. 2 ml), cyclopentanone (2.1 g, 25 mmol) and malononitrile (1.65 g, 25 mmol) dissolved in methanol (15 ml), was heated to reflux for 2 hours and kept in the refrigerator for several days. The precipitate, was crystallized from methanol to give **3a** as colourless crystals (1.42 g, 17%), m.p. 274-276 °C; ir (potassium bromide): 3443, 3327, 3237 (=NH- and NH₂-groups), 2963, 2878 (aliph. C-H), 2212 (CN-groups), 1648, 1596, 1532 (C=N, C=C) cm⁻¹; ^1H nmr [500 MHz; DMSO-d₆]: δ 2.91-2.64 and 2.46-1.53 (m, 12H, methylene groups), 3.18-3.16 (m, 1H, 3a-H), 4.12-4.09 (m, 1H, 1-H), 5.47 (s, 1H, -CH(CN)₂), 6.70 (broad s, 2H, NH₂, deuterium oxide-exchangeable), 9.46 (broad s, 1H, =NH, deuterium oxide-exchangeable); ^{13}C nmr (DMSO-d₆): δ 136.36, 120.28, 117.25, 116.49, 51.03, 48.61, 48.48, 40.79, 34.19, 33.34, 31.59, 28.15, 26.81, 26.79; ms: m/z (%) 330 (M⁺, 100), 329 (M⁺, 16), 304 (5), 303 (M⁺ - C₂H₅, 21), 302 (M⁺ - C₂H₄, 17), 301 (M⁺ - C₂H₅, 20), 67 (H₂C(CN)₂ + H, 9), 41 (C₃H₅⁺, 6).

Anal. Calcd. for C₁₉H₁₈N₆ (330.40): C, 69.10; H, 5.45; N, 25.45. Found C, 68.83; H, 5.66; N, 24.57.

3-Amino-2,4-cyano-1,2,6,7,8,8a-hexahydronaphthalin-1-spirocyclohexan-2-imidic acid methyl ester (**4b**).

A stirred mixture of cyclohexanone (2.45 g, 25 mmol), malononitrile (1.65 g, 25 mmol) and diethylamine (ca. 2 ml) dissolved in methanol (15 ml), was heated to reflux for 3 hours and kept in the refrigerator for several days. The precipitate was crystallized from methanol to give **4b** (4.35 g, 54%) as white powder, mp 216-218 °C (Lit. [15] 227-230- from acetone); ir (potassium bromide): 3423, 3327, 3217 (=NH and NH₂-Groups), 2942, 2847 (aliph. C-H), 2240, 2207 (CN-groups), 1647, 1597 (C=N/C=C) cm⁻¹; ^1H nmr (DMSO-d₆): δ 2.26-1.20 (m, 16H, 8 methylene groups), 3.61 (s, 1H, 8a-H), 3.70 (s, 3H, OCH₃), 5.71 (m, 1H, 5-H), 6.53 (broad s, 2H, NH₂, deuterium oxide-exchangeable), 7.98 (broad s, 1H, =NH, deuterium oxide-exchangeable); ^{13}C nmr (DMSO-d₆): δ 162.16 (C=NH), 147.55 (C-3), 129.35 (C-4), 120.66 (C-5), 118.14 (C-4a), 116.92 (CN), 82.34 (CN), 61.85 (C-2), 54.61 (OCH₃), 41.95 (C-1), 41.45 (C-8a), 31.82, 27.94, 26.13, 24.91, 23.53, 23.20, 22.90, 22.42 (8 methylene groups); ms: m/z (%) 324 (M⁺, 45), 323 (M⁺ - 1, 7), 309 (M⁺ - CH₃, 15), 295 (M⁺ - HC=O⁺, 14), 294 (M⁺ - H₂C=O, 49), 293 (M⁺ - OCH₃, 100), 292 (M⁺ - HOCH₃, 49), 77 (7), 67 (H₂C(CN)₂ + H, 8), 60 (10), 58 (15), 55 (C₄H₇⁺, 7), 41 (C₃H₅⁺, 35).

Anal. Calcd. for C₁₉H₂₄N₄O (324.43): C, 70.37; H, 7.41; N, 17.28. Found: C, 70.55; H, 7.45; N, 17.23.

Triethylammonium-1,3-bis(dicyanomethylene)-2-indanide (**8c**).

A solution of triethylamine (2 ml), indan-1,3-dione (0.73 g, 5 mmol) and malononitrile (0.66 g, 10 mmol) in methanol, was heated to reflux for 4 hours. The deep blue precipitate (720 mg), which resulted by immediate cooling, was not further purified for analyses. The filtrate was concentrated to half of its volume and kept for few days in the refrigerator. The solid was crystallized from methanol and subsequently sublimed at 150-160/-1.8.10⁻² mbar as deep blue prisms (200 mg, 12%), m.p. 198-200 °C; ir (potassium bromide): 3429 (NH), 3055 (aromatic C-H), 2835, 2436 (aliph. C-H), 2209, 2191 (CN), 1635, 1554 (C=N/C=C) cm⁻¹; uv/vis (ethanol): λ_{max} (log ϵ): 247 (4.46) 390 (sh, 4.05), 367 (4.24), 510 (sh, 3.80), 546 (4.26), 584 (4.42), 633 (4.30) nm; λ_{min} (log ϵ): 281 (3.42), 422 (2.40) nm; ^1H nmr (DMSO-d₆): δ 1.19 (t, 9 H, HN⁺(CH₂CH₃)₃, J = 7.29 Hz), 3.11 (dq, 6H, HN⁺(CH₂CH₃)₃, J = 4.81, 7.26 Hz), 5.72 (s, 1H, 2-H), 7.42 (dd, 2H, 5-H and 6-H, J = 2.39, 8.31 Hz), 7.92 (dd, 2H, 4-H and 7-H, J = 3.91, 10.61 Hz), 8.85 (broad s: 1H, NH, deuterium oxide-exchangeable); ^{13}C nmr (DMSO-d₆): δ 158.10 (C(CN)₂), 137.82 (C-1 and C-3), 130.01 (C-4 and C-7), 121.49 (C-5 and C-6), 117.87/102.70 (CN), 117.76 (C-3a and C-7a), 50.31 (C-2), 45.77 (CH₂CH₃)₃, 8.57 (CH₂CH₃)₃; ms: m/z (%) 243 (14), 242 (M⁺ - N(CH₂CH₃)₃, 79), 241 (3), 216 (9), 215 (46), 214 (8), 189 (7), 188 (19), 187 (4), 178 (6), 151 (4), 108 (4), 102 ((CH₃CH₂)₃NH⁺, 3), 101 ((CH₃CH₂)₃N⁺, 44), 100 (13), 87 ((CH₃CH₂)₃NH⁺ - CH₃, 12), 86 ((CH₃CH₂)₃N⁺ - CH₃, 100), 72 ((CH₃CH₂)₂N⁺, 8), 70 (6), 58 ((CH₃CH₂)₂N⁺ - CH₂, 67), 57 (CH₂CH₃)₂N⁺ - CH₃, 3), 56 (10), 44 ((CH₃)₂N⁺, 26).

Anal. Calcd. for C₂₁H₂₁N₅ (343.44): C, 73.47; H, 6.12; N, 20.41. Found: C, 73.16; H, 6.14; N, 20.17.

4-Methyl-2-oxo-2H-benzo[h]chromene-3-carbonitrile (**5d**).

To a mixture of 2-acetyl-1-naphthol (7.44 g, 0.04 mol), methylcyanoacetate (9.90 g, 0.1 mol) or ethylcyanoacetate (11.30 g, 0.1 mol) dissolved in methanol, diethylamine (7.30 g, 0.1 mol) was added. The solution was heated to reflux for 3 hours. The resulted precipitate was crystallized from acetone as yellow powder 8.73 g (86%), respectively 7.90 g

(94%), m.p. 286–288 °C (Lit. 237–239 °C [21], 280 °C from DMF [20]); ir (potassium bromide): 2229 (CN), 1727 (C=O coumarin), 1630, 1601, 1585, 1551, 1501 (C=C) cm^{-1} ; uv (ethanol): λ_{max} (log ϵ): 282 (4.65), 272 (4.55), 239 (4.05), 317 (4.15), 331 (4.19), 378 (4.00), 396 (3.90) nm; ^1H nmr (DMSO- d_6): δ 2.83 (s, 3H, CH_3), 7.78 (ddd, 1H, 9-H, J = 1.24, 6.56, 8.00 Hz), 7.84 (ddd, 1H, 8-H, J = 1.25, 6.50, 7.83 Hz), 7.94 (d, 1H, 5-H, J = 8.89 Hz), 7.98 (d, 1H, 6-H, J = 9.05 Hz), 8.12 (dd, 1H, 7-H, J = 1.64, 7.35 Hz), 8.42 (dd, 1H, 10-H, J = 1.06, 7.65 Hz); ^{13}C (^1H) nmr (DMSO- d_6): δ 164.53 (C-2), 157.10 (C-10b), 150.77 (C-3), 135.96 (C-4), 130.54 (C-8), 128.33 (C-7), 128.24 (C-9), 125.13 (C-6), 122.53 (C-10), 121.95 (C-4a), 121.83 (C-5), 114.62 (C-10a), 114.22 (C-6a), 100.65 (CN), 19.00 (CH_3); ms: m/z (%) 236 (M^+ + 1, 19), 235 (M^+ , 100), 208 (M^+ – HCN, 9), 207 (M^+ – CO, 54), 206 (M^+ – HCO, 22), 76 (C_6H_4^+ , 18).

Anal. Calcd. for $\text{C}_{15}\text{H}_9\text{NO}_2$ (235.25): C, 76.60; H, 3.83; N, 5.96. Found: C, 76.37; H, 3.97; N, 6.06.

1-Methyl-3-oxo-3H-benzo[*f*]chromene-2-carbonitrile (**5e**).

To a mixture of 1-acetyl-2-naphthol (3.72 g, 0.2 mol), methylcyanoacetate (9.90 g, 0.1 mol) or ethylcyanoacetate (11.30 g, 0.1 mol) dissolved in methanol, diethylamine (7.30 g, 0.1 mol) was added. The solution was heated to reflux for 3 hours. The precipitate was crystallized from acetone as yellow powder (3.50 g, 74%) respectively (1.2 g, 26%), m.p. 240 °C (Lit. [21] > 148 °C); ir (potassium bromide): 2222 (CN), 1729 (C=O coumarin), 1619, 1600, 1581, 1535, 1513 (C=C/C=O) cm^{-1} ; ^1H nmr (DMSO- d_6): δ 3.16 (s, 3H, CH_3), 7.61 (d, 1H, 5-H, J = 8.98 Hz), 7.69 (ddd, 1H, 8-H, J = 1.00, 6.96, 7.95 Hz), 7.79 (ddd, 1H, 9-H, J = 1.65, 6.99, 8.67 Hz), 8.13 (dd, 1H, 7-H, J = 0.8, 8.67 Hz), 8.38 (d, 1H, 6-H, J = 9.01 Hz), 8.64 (dd, 1H, 10-H, J = 1.44, 8.00 Hz); ^{13}C (^1H) nmr (DMSO- d_6): δ 164.66 (C-3), 156.86 (C-4a), 154.98 (C-2), 137.84 (C-6), 131.31 (C-1), 130.16 (C-7), 129.35 (C-9), 126.54 (C-8), 125.79 (C-10), 117.42 (C-5), 115.02 (C-10b), 113.52 (C-10a), 113.52 (C-6a), 101.72 (CN), 25.17 (CH_3); ms: m/z (%) 236 (M^+ + 1, 17), 235 (M^+ , 100), 234 (M^+ – H, 11), 208 (M^+ – HCN, 6), 207 (M^+ – CO, 37), 206 (M^+ – HCO, 40), 190 (M^+ – HCO_2 , 9), 76 (C_6H_4^+ , 20), 75 (7).

Anal. Calcd. for $\text{C}_{15}\text{H}_9\text{NO}_2$ (235.25): C, 76.60; H, 3.83; N, 5.96. Found: C, 76.02; H, 3.98; N, 6.00.

2-[Imino-(2-imino-4-methyl-2H-benzo[*h*]chromen-3-yl)-methyl] malononitrile (**9d**).

A mixture of **1d** (1.86 g, 10 mmol), malononitrile (2.64 g, 40 mmol), sulphur (0.32 g, 10 mmol) and diethylamine (2.92 g, 40 mmol) in dioxan was stirred for 3 hours, then left standing at room temperature for few days. The resulted precipitate was crystallized from acetone/dioxane to give **9d** as off white powder (1.125 g, 38%), m.p. 223–225 °C; ir (potassium bromide): 3718–3296 (=NH groups), 2997 (arom. and aliph. C-H), 2220 (CN groups), 1647 (C=N), 1616, 1573, 1543 (C=C) cm^{-1} ; ^1H nmr (DMSO- d_6): δ 2.36 (s, 3H, CH_3), 3.35 (s, 1H, $\text{CH}(\text{CN})_2$), 7.68 (d, 1H, 7-H, J = 9.6 Hz), 7.69 (ddd, 1H, 8-H, J = 1.46, 8.42, 8.49 Hz), 7.75 (d, 1H, 5-H, J = 8.79 Hz), 7.78 (d, 1H, 6-H, J = 8.68 Hz), 8.00 (ddd, 1H, 9-H, J = 1.94, 8.11, 8.34 Hz), 8.37 (dd, 1H, 10-H, J = 1.72, 7.77 Hz), 8.99 (broad s, 1H, =NH, deuterium oxide-exchangeable), 9.06 (broad s, 1H, =NH, deuterium oxide-exchangeable); ^{13}C (^1H) nmr (DMSO- d_6): δ

168.51 (C-2), 152.95 (C-10b), 149.02 (C-1'), 142.94 (C-3), 134.49 (C-4a), 128.65 (C-10), 127.94 (C-8), 127.24 (C-6), 123.27 (C-10a), 121.65 (C-7), 121.57 (C-9), 121.29 (C-5), 116.45 (C-4), 115.07 (C-6a), 113.80 (CN), 50.26 ($\text{CH}(\text{CN})_2$), 15.56 (s, 3H, CH_3); ms: m/z (%) 300 (M^+ , 39), 299 (M^+ – 1, 18), 272 (M^+ – 28, 4), 271 (6), 235 (M^+ – $\text{CH}(\text{CN})_2$, 18), 234 (M^+ – $\text{H}_2\text{C}(\text{CN})_2$, 100), 233 (3), 208 (M^+ – $\text{HN}=\text{C}-\text{CH}(\text{CN})_2$, 8), 207 (M^+ – $\text{HN}=\text{CH}-\text{CH}(\text{CN})_2$, 53), 76 (10), 75 (4), 66 ($\text{H}_2\text{C}(\text{CN})_2$, 52), 65 ($(\text{CN})_2\text{CH}^+$, 5), 64 ($(\text{CN})_2\text{C}^+$, 3), 63 (7), 44 ($\text{O}=\text{C}=\text{NH}_2^+$, 8).

Anal. Calcd. for $\text{C}_{18}\text{H}_{12}\text{N}_4\text{O}$ (300.33): C, 72.00; H, 4.00; N, 18.67. Found: C, 71.54; H, 3.88; N, 18.56.

2-[Amino-4-methyl-2H-benzo[*h*]chromen-3-yl]-methylene]-malononitrile or 8-Amino-10-imino-7-methyl-10H-12-oxa-11aza-benzo[*a*]anthracene-9-carbonitrile (**10d**).

From the filtrate of the above recrystallization, a solid material was collected, consisting of **10d** as yellow powder (848 mg, 29%), m.p. 288–290 °C; ir (potassium bromide): 3415, 3324, 3222 (=NH and NH_2 -groups), 2993 (aromatic and aliphatic C-H), 2223, 2207 (CN groups), 1654 (C=N), 1622, 1592, 1566, 1527 (C=C) cm^{-1} ; ms: m/z (%) 300 (M^+ , 100), 299 (M^+ – 1, 47), 298 (3), 284 (M^+ – NH_2 , 4), 274 (M^+ – CN, 4), 273 (M^+ – HCN, 4), 272 (M^+ – 28, 11), 271 (14), 257 (4), 254 (3), 246 (3), 245 (4), 244 (3), 235 (M^+ – $\text{CH}(\text{CN})_2$, 15), 234 (M^+ – $\text{H}_2\text{C}(\text{CN})_2$, 75), 233 (5), 229 (4), 228 (3), 208 (M^+ – $\text{HN}=\text{C}-\text{CH}(\text{CN})_2$, 6), 207 (M^+ – $\text{HN}=\text{CH}-\text{CH}(\text{CN})_2$, 39), 76 (9), 75 (4), 67 (3), 66 ($\text{H}_2\text{C}(\text{CN})_2^+$, 36), 65 ($(\text{CN})_2\text{CH}^+$, 4).

Reaction of 2-Hydroxy-1-acetonaphthone (**1e**) with Malononitrile.

A stirred mixture of **1e** (1.86 g, 10 mmol), malononitrile (1.32 g, 20 mmol) and diethylamine (1.46 g, 20 mmol) in methanol was heated to reflux for 2 hours. The precipitate was crystallized from acetone to give compound **14e** (364 mg, 10%) as yellow powder, mp > 350 °C. The filtrate was kept for few days in the refrigerator to give another precipitate, which was also crystallized from acetone to afford compound **13e** (766 mg, 25%) as yellow powder, m.p. 326–328 °C.

11-Amino-9-imino-12-oxo-8,9-dihydro-12H-benzo[*f*](4H)chromeno[2,3-*b*]pyridin-10-carbonitrile (**14e**).

Ir (potassium bromide): 3452, 3353, 3270 (=NH, -NH- and NH_2 -groups), 2205 (CN), 1636 (C=O), 1606, 1573, 1543, 1515 (C=C, C=N) cm^{-1} ; ^1H nmr (DMSO- d_6): δ 7.54 (broad s, 2H, NH_2 , deuterium oxide-exchangeable), 7.62 (d, 1H, 5-H, J = 9.05 Hz), 7.64 (ddd, 1H, 3-H, J = 1.20, 6.89, 8.09 Hz), 7.76 (ddd, 1H, 2-H, J = 1.49, 7.06, 8.63 Hz), 7.79 (broad s, 1H, -NH/-NH, deuterium oxide-exchangeable), 8.07 (d, 1H, 4-H, J = 7.24 Hz), 8.32 (d, 1H, 6-H, J = 8.82 Hz), 9.88 (dd, 1H, 1-H, J = 0.6, 8.51 Hz), 9.88 (broad s, 1H, =NH/-NH-, deuterium oxide-exchangeable); ^{13}C (^1H) nmr (DMSO- d_6): δ 179.83 (C-12), 162.50 (C-7a), 161.75 (C-9), 160.35 (C-11), 155.02 (C-6a), 136.52 (C-5), 130.37 (C-11a), 130.11 (C-12a), 129.27 (C-4), 128.88 (C-2), 126.19 (C-3), 125.82 (C-1), 117.68 (C-6), 115.33 (C-12a), 113.54 (C-4a), 95.42 (C-10), 70.03 (C=N); ms: m/z (%) 302 (M^+ , 100), 301 (M^+ – 1, 11), 275 (M^+ – HCN, 6), 274 (M^+ – C=O, 13), 67 ($\text{H}_3\text{N}^+-\text{CC}-\text{CN}$, 3), 66 ($\text{H}_2\text{N}-\text{CC}-\text{CN}$, 7), 44 (CO_2^+ , 11), 42 ($\text{HN}=\text{C}=\text{NH}^+$, 7).

Anal. Calcd. for $\text{C}_{17}\text{H}_{10}\text{N}_4\text{O}_2$ (302.30): C, 67.55; H, 3.31; N, 18.54. Found: C, 67.13; H, 3.58; N, 18.22.

1,3,14-Triamino-5-imino-5*H*-benzo[*f*](2*H*)chromeno[3,4-*h*]chinolin-2-carbonitrile (**13e**).

Ir (potassium bromide): 3458, 3347, 3231 (=NH und -NH₂), 2204 (CN), 1619, 1592, 1565, 1501 (C=N, C=C) cm⁻¹; ¹H nmr (DMSO-d₆): δ 5.71 (broad s, 2H, 3-NH₂, deuterium oxide-exchangeable), 6.23 (s, 1H, 13-H), 6.47 (broad s, 2H, 1-NH₂, deuterium oxide-exchangeable), 6.65 (broad s, 2H, 14-NH₂, deuterium oxide-exchangeable), 7.14 (dd, 1H, 12-H, J = 1.71, 8.33 Hz), 7.31 (d, 1H, 7-H, J = 8.90 Hz), 7.34 (ddd, 1H, 10-H, J = 1.55, 6.73, 7.68 Hz), 7.38 (ddd, 1H, 11-H, J = 1.60, 6.90, 8.79 Hz), 7.89 (dd, 1H, 9-H, J = 2.21, 7.09 Hz), 7.95 (1H, d, 8-H, J = 8.97 Hz), 10.03 (broad s, 1H, =NH deuterium oxide-exchangeable); ¹³C(1H) nmr (DMSO-d₆): δ 158.53 (C-5), 156.38 (C-3), 155.03 (C-6a), 154.25 (C-4a), 151.85 (C-1), 138.94 (C-14), 132.73 (C-2), 130.73 (C-8), 128.30 (C-9), 127.89 (C-4b), 127.59 (C-11), 123.85 (C-12), 123.64 (C-10), 118.85 (C-12c), 118.56 (C-7), 117.75 (C-12b), 116.66 (C-12a), 115.18 (C-13), 102.84 (C-14a), 86.82 (C-8a), 70.83 (CN); ms: m/z (%) 366 (M⁺, 75), 365 (M⁺ - 1, 4), 351 (4), 350 (27), 349 (M⁺ - NH₃, 100).

Anal. Calcd. for C₂₁H₁₄N₆O (366.39): C, 68.85; H, 3.83; N, 22.95. Found: C, 68.86; H, 3.88; N, 22.83.

Acknowledgements.

The authors thank Deutscher Akademischer Austauschdienst (DAAD) for granting Dr. E. Sopbué Fondjo a Ph-D fellowship (grant N° A/96/11507). Technical and financial support from Gerhard-Mercator-Universität Duisburg is gratefully acknowledged. Thanks are also due to the University of Dschang and the Ministry of Higher Education of the Republic of Cameroon for kindly releasing the above named author for the implementation of this work. Generous donation of chemicals by Fonds der Chemischen Industrie is gratefully acknowledged.

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