SYNTHESIS AND NMR-INVESTIGATION OF ANNELATED PYRROLE DERIVATIVES

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Abstract - The synthesis of annelated pyrrole, namely isoindole derivatives by reaction of α,β-unsaturated ketones, benzo- and naphthoquinone monoketals with tosylmethyl isocyanide is described. Moreover, detailed NMR spectroscopic studies (^{1}H, ^{13}C) with the title compounds are presented.

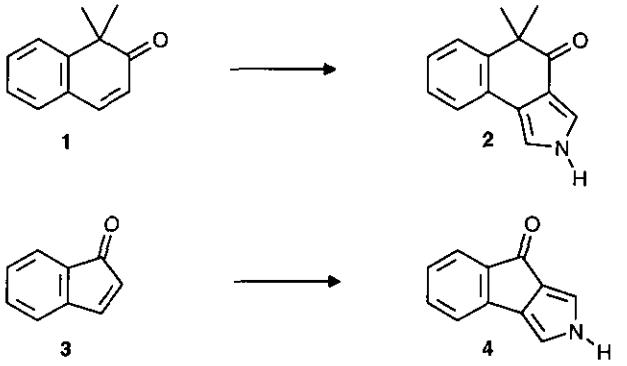
In continuation of our studies[1] concerning the synthesis of pharmacologically active pyrrole and isoindole derivatives we were interested in compounds (**2**), (**4**), (**7**), and (**10**), which should serve as starting materials in the projected syntheses of potentially cytostatic agents. As synthetic route to these [c]-annelated pyrroles the reaction of tosylmethyl isocyanide[2,3] (TosMIC) with appropriate enones according to known method[3] was envisaged. Additionally, as a one-step synthesis of the isoindolone derivative (**13**) *via* reaction of naphthoquinone (**11**) with tosylmethyl isocyanide was described[4] and this approach seems in contradiction to previous results obtained in additions of C-nucleophiles to quinones,[5] this direct access to **13** was reinvestigated in order to find a practicable route for the synthesis of benzo- and naphthoquinone annelated pyrroles of type (**7**) and (**10**). Moreover, in view of the fact that there is only little ^{13}C NMR data material available for [c]-annelated pyrroles,[6] detailed NMR spectroscopic studies with the title compounds are presented.

Synthesis

For the syntheses of the desired pyrrole derivatives (**2**) and (**4**) the enone (**1**)[7] and indenone (**3**)[8] served as starting materials (Scheme 1). Whereas **1** reacted smoothly with metallated tosylmethyl isocyanide to **2**, the reaction of **3** to **4** could only be realized with difficulty as a result of the high tendency of **3** to decompose.

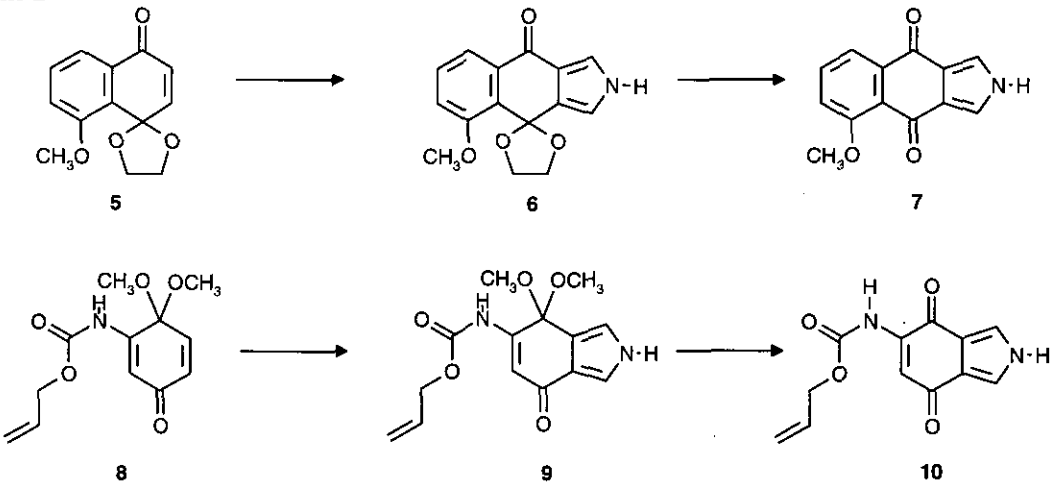
As application of usual reaction conditions (0°C - room temperature) was completely unsuccessful, we had to test a series of different reaction conditions and the use of different bases for the metallation step to finally gain **4**, however in low yield.

Scheme 1



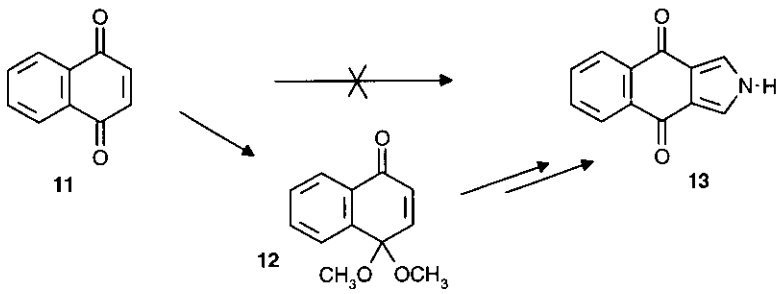
It is known that Michael-type addition of nucleophiles to the enone moiety of quinones is followed by aromatisation of the intermediatly generated carbanion.[5] Therefore, quinone monoketals[9,10] serve as useful quinone equivalents since they undergo 1,4-addition with soft nucleophiles and annelation reactions with dipolar reagents. Thus, for the construction of quinone annelated pyrroles (**7**) and (**10**) the appropriate monoketals (**5**)[11] and (**8**)[12] were treated with tosylmethyl isocyanide (Scheme 2) to give the ring-closure products (**6**) and (**9**), respectively. Subsequent removal of the ketal protecting group by careful treatment with PPTS and TsOH in aqueous acetone (pH = 2)[12] then furnished the desired pyrrole derivatives (**7**) and (**10**). Usual deprotection conditions using PPTS in refluxing aqueous acetone only led to polymerized products.[13]

Scheme 2



During this work was under progress M. Artico *et al.* published the staightforward synthesis of **13** by reaction of naphthoquinone (**11**) and tosylmethyl isocyanide (Scheme 3).[4]

Scheme 3



This seemed remarkable because 1,4-addition of nucleophiles to quinones, as mentioned above, immediately leads to aromatisation, which should prevent cyclisation to the pyrrole ring. Considering this, it seemed very doubtful that the above reaction should lead to the naphthoquinone annelated pyrrole (**13**). Indeed, several repetitions of this reaction unveiled that under the reported conditions compound (**13**) was not accessable. In comparison, we found that the route *via* naphthoquinone monoketal (**12**)[14] furnished **13** in high yields.

NMR Spectroscopic Investigations

The NMR data of compounds (**2**), (**4**), (**6**), (**7**), (**9**), (**10**), and (**13**) are given in the Experimental. Complete assignment of signals in the ^{1}H and ^{13}C-NMR spectra was achieved by a combination of different NMR techniques such as fully ^{1}H-coupled ^{13}C-NMR, APT,[15] NOE-difference spectroscopy,[16] 1D-TOCSY,[17] ^{13}C,^{1}H shift correlations *via* one bond couplings (HMQC)[18] and more than one bond couplings (HMBC),[19] 1D-HETCOR[20] and long-range INEPT[21] experiments with selective excitation. As an example, compound (**9**) may serve. In the ^{1}H NMR spectrum of **9**, the signals of the allyloxy group could be easily identified on basis of chemical shift and coupling considerations. In an NOE difference experiment, upon irradiation of the OCH_3 resonance clear NOEs to the signals of CON**H**, H-6 and H-3 were observed which permits to distinguish H-3 from H-1 and CONH from N^2-H, respectively, and thus leads to a complete assignment of all signals. In an HMQC experiment, all carbon atoms carrying protons now could be unambiguously assigned. The assignment of signals due to quaternary carbon atoms was achieved on basis of long-range INEPT experiments with selective excitation. Thus, excitation of the transition of the allylic methylene-H

allowed to identify the signal of OCONH, whereas upon excitation of H-6 the resonances of C-5, C-4 and C-7a were enhanced which permits to discriminate the C-7a signal from that due to C-3a (Figure 1).

Figure 1. Long-range INEPT spectrum of **9** resulting from selective excitation of the the singlet resonance due to H-6 (optimized for J = 6 Hz). The signals of C-5 (149.3 ppm), C-7a (119.9 ppm) and C-4 (96.2 ppm) are enhanced.

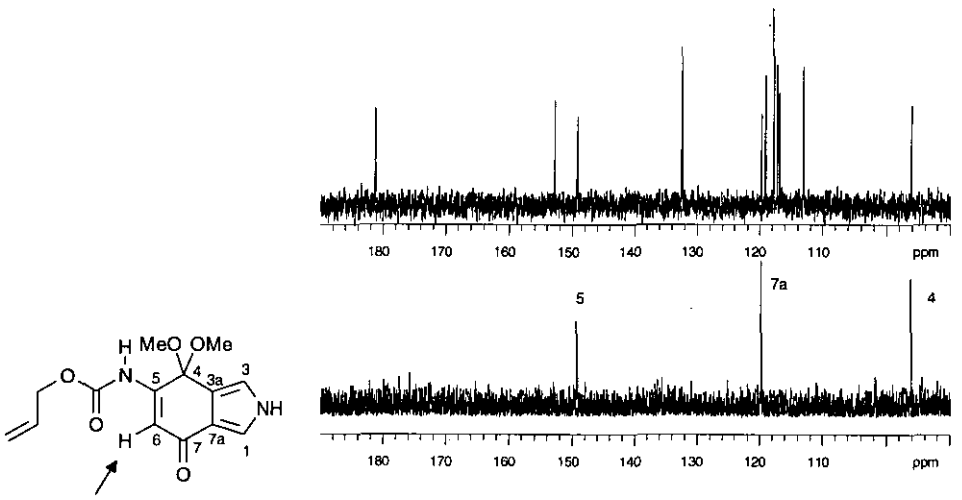
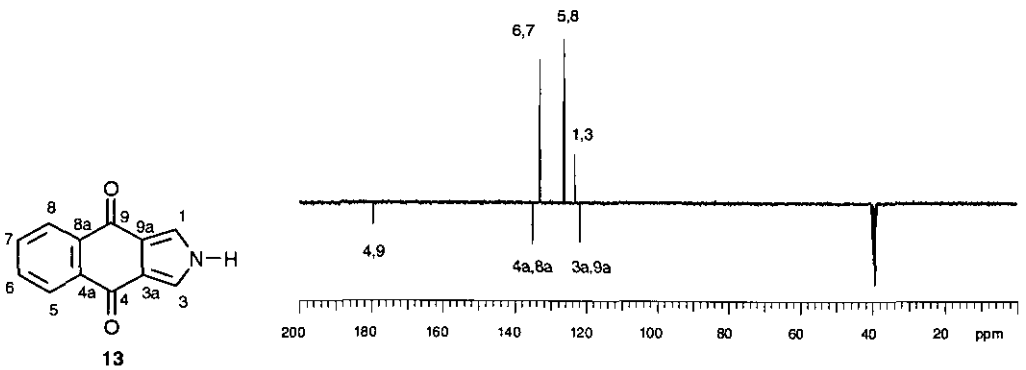


Figure 2 shows the APT (attached proton test) spectrum of compound (**13**). Due to the symmetrical structure of the molecule the number of signals is reduced to six lines. The intensity of the signal of C-1/C-3 is somewhat reduced because the experiment was recorded under "standard conditions" being optimized for an averaged direct C,H coupling of 140 Hz. However, ^{1}J(C1,H1) is 191.7 Hz which is relatively far from the optimum.

Figure 2. ^{13}C-NMR (APT) spectrum of **13** in DMSO-d_6



EXPERIMENTAL

Melting points were detected on a Reichert-Kofler hot-stage microscope and are uncorrected. The IR spectra were recorded on a Perkin-Elmer FTIR 1605 spectrophotometer. MS spectra were obtained on a Hewlett Packard 5890A/5970B-MSD instrument or on a Shimadzu QP 1000 spectrometer. All NMR spectra were recorded on a Varian Unity*plus* 300 spectrometer (299.95 MHz for ^{1}H, 75.43 MHz for ^{13}C) at 28°C. The solvent signal was used as an internal standard which was related to TMS with δ 7.26 ppm (^{1}H, $CDCl_3$), δ 2.49 ppm (^{1}H, DMSO-d_6), δ 77.0 ppm(^{13}C, $CDCl_3$), δ 39.5 ppm (^{13}C, DMSO-d_6),). The digital resolutions were 0.25 Hz/data point for the ^{1}H-NMR spectra and 0.56 Hz/data point for the broad-band decoupled ^{13}C-NMR spectra. For column chromatographic separations Merck silica gel 60, 70 - 230 mesh ASTM (Nr. 1.07734) was used. Thin layer chromatography was performed on silica gel 60 F_{254} plates (Merck-Nr. 1.05554: 0.2 mm; Merck-Nr. 1.07734: 2.0 mm, 20 x 20 cm) or aluminium oxide 60 F_{254} plates (Merck-Nr. 1.05550: 0.2 mm).

5,5-Dimethyl-2,5-dihydro-4*H*-benzo[*e*]isoindol-4-one (**2**)

Enone (**1**)[7] (3.7 g, 21.6 mmol) and 4.2 g (21.6 mmol) of tosylmethyl isocyanide were dissolved in 27 mL of dry THF under Ar-atmosphere. Under vigorous stirring 2.97 g (26 mmol) of potassium *tert*-butoxide in 27 mL of dry THF were added and the mixture was stirred for 1 h at rt. After addition of water the mixture was exhaustively extracted with ether. The combined etheral extracts were dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The residue was subjected to column chromatography (silica gel, eluent: ethyl acetate/light petroleum 4/1) to afford 2.6 g (57 %) of **2** as yellowish crystals of mp 136°C (ether). IR (KBr): cm^{-1} 3200 (N-H), 1640 (C=O); MS: m/z (%) 212 (M^++1, 13), 211 (M^+, 86), 196 (100), 168 (100), 167 (41), 141 (12), 139 (16), 115 (14); ^{1}H-NMR ($CDCl_3$): δ (ppm) 10.23 (NH), 7.63 (m, 1H, H-9), 7.50 (dd, $^4J_{3,1}$ = 1.8 Hz, $^3J_{3,NH}$ = 3.2 Hz, 1H, H-3), 7.46 (m, 1H, H-6), 7.25 (m, 2H, H-7, H-8), 7.19 (dd, $^4J_{1,3}$ = 1.8 Hz, $^3J_{1,NH}$ = 2.5 Hz, 1H, H-1), 1.56 (s, 6H, C5-Me); ^{13}C-NMR ($CDCl_3$): δ (ppm) 200.1 (C-4), 143.8 (C-5a), 127.0 (C-6), 127.0 (C-9a), 126.7 (C-7), 126.4 (C-8), 124.7 (C-10a), 122.8 (C-9), 121.5 (C-3, $^1J_{C3,H3}$ = 188.9 Hz, $^3J_{C3,H1}$ = 6.5 Hz, $^2J_{C3,NH}$ = 3.2 Hz), 118.3 (C-3a), 112.6 (C-1, $^1J_{C1,H1}$ = 186.6 Hz, $^3J_{C1,H3}$ = 7.1 Hz, $^2J_{C1,NH}$ = 4.0 Hz), 47.9 (C-5, $^2J_{C5,Me}$) = 3.7 Hz), 28.2 (Me, $^1J_{Me}$ = 129.2 Hz, $^3J_{CH3,CH3}$ = 4.9 Hz). *Anal.* Calcd for $C_{14}H_{13}NO$: C, 79.57; H, 6.20; N, 6.66. Found: C, 79.35; H, 6.19; N, 6.54.

Indeno[1,2-*c*]pyrrol-8(2*H*)-one (**4**)

Indenone (**3**)[8] (5.2 g, 40 mmol) and 8.0 g (40 mmol) of tosylmethyl isocyanide were dissolved in 50 mL of dry THF under Ar-atmosphere. The reaction flask was plunged into a oil bath and heated to 100°C. Immediately after the solution started to reflux a mixture of 5.5 g (49 mmol) of potassium *tert*-butoxide in

50 mL of dry THF was added rapidly. Then the oil bath was removed and the reaction mixture was stirred at rt for 30 min. Afterwards, water was added and the mixture was exhaustively extracted with ether. The combined ether extracts were dried over anhydrous Na_2SO_4 and evaporated *in vacuo*. The residue was extracted three times by refluxing with each 250 mL portions of 10% aqueous EtOH for 1 h. The three ethanolic portions were cooled in a refrigerator (+4°C) for 24 h and the precipitated crystals were filtered off. The combined filtrates were concentrated and again cooled for 24 h. Yield 622 mg (9.2 %) of yellow crystals; mp 183 - 184°C (ethanol). IR (KBr): cm^{-1} 3200 (N-H), 1635 (C=O); MS: m/z (%) 170 (M^++1, 12), 169 (M^+, 100), 141 (13), 140 (18), 114 (39), 113 (20), 87 (11), 63 (13); ^{1}H-NMR ($CDCl_3$): δ (ppm) 8.86 (br s, 1H, NH), 7.52 (d, $^3J_{6,7}$ = 7.5 Hz, 1H, H-7), 7.34 m (1H, H-5), 7.21 (d, $^3J_{4,5}$ = 7.6 Hz, 1H, H-4), 7.11 (m, 1H, H-6), 7.03 (m, 1H, H-1), 6.66 (m, 1H, H-3); ^{13}C-NMR ($CDCl_3$): δ (ppm) 188.4 (C-8), 140.4 (C-7a), 140.0 (C-3b), 133.6 (C-5), 131.9 (C-3a), 126.6 (C-6), 125.5 (C-8a), 124.0 (C-7), 120.6 (C-4), 118.4 (C-1), 111.3 (C-3). *Anal.* Calcd for $C_{11}H_7NO$: C, 78.07; H, 4.17; N, 8.31. Found: C, 77.81; H, 4.36; N, 8.04.

5-Methoxy-spiro[4*H*-benzo[*g*]isoindol-4,2'-[1,3]-dioxolane]-9(2*H*)-one (**6**)

Compound (**5**)[11] (1.32 g, 5.7 mmol) and 1.12 g (5.7 mmol) of tosylmethyl isocyanide were dissolved in 8 mL of dry THF under Ar-atmosphere. Under vigorous stirring 0.76 g (6.84 mmol) of potassium *tert*-butoxide in 8 mL of dry THF were added and the mixture was stirred for 1 h at rt. After addition of water the mixture was exhaustively extracted with ether. The combined etheral extracts were dried over anhydrous Na_2SO_4 and concentrated *in vacuo* to afford 1.62 g of crude **6**. For spectroscopic purposis 250 mg of this oil were purified by preparative TLC (silica gel, eluent: ethyl acetate) to give yellowish crystals of mp 194-195°C (ethyl acetate). IR (KBr): cm^{-1} 3250 (N-H), 1660 (C=O); MS: m/z (%) 272 (M^++1, 17), 271 (M^+, 100), 270 (14), 226 (50), 212 (21), 210 (26), 198 (14), 183 (17), 154 (14); ^{1}H-NMR (DMSO-d_6): δ (ppm) 11.90 (s, 1H, NH), 7.73 (dd, $^3J_{7,8}$ = 7.8 Hz, $^4J_{6,8}$ = 1.2 Hz, 1H, H-8), 7.50 (m, 2H, H-1, H-7), 7.29 (dd, $^3J_{6,7}$ = 7.8 Hz, $^4J_{6,8}$ = 1.2 Hz, 1H, H-6), 7.08 (dd, $^4J_{3,1}$ = 1.8 Hz, $^3J_{3,NH}$ = 2.4 Hz, 1H, H-3), 4.21 (s, 4H, OCH_2), 3.83 (s, 3H, OMe); ^{13}C-NMR (DMSO-d_6): δ (ppm) 179.1 (C-9), 158.6 (C-5), 135.2 (C-8a), 129.9 (C-7), 129.8 (C-4a), 128.1 (C-9a), 120.0 (C-1), 118.3 (C-8), 118.2 (C-3a), 117.1 (C-6), 116.2 (C-3), 101.6 (C-4), 64.7 (OCH_2), 56.3 (OMe). *Anal.* Calcd for $C_{15}H_{13}NO_4$: C, 66.40; H, 4.83; N, 5.18. Found: C, 66.47; H, 5.05; N, 5.01.

5-Methoxy-2*H*-benzo[*f*]isoindol-4,9-dione (**7**)

Crude oil of **6** (0.81 g), 0.72 g (2.85 mmol) of pyridinium *p*-toluenesulfonate (PPTS) and 0.83 g (0.44 mmol) of *p*-toluenesulfonic acid hydrate were dissolved in 80 mL of acetone and 10 mL of H_2O. The reaction mixture was stirred for 4 d, diluted with ethyl acetate (100 mL) and washed successively with

saturated aqueous $NaHCO_3$ solution, 1 N HCl and brine. The organic layer was dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was crystallized from ethyl acetate to give 0.37 g (53 %, starting from **6**) of yellowish crystals of mp 219 - 221°C. IR (KBr): cm^{-1} 3450 (N-H), 1660, 1640 (C=O); MS: m/z (%) 227 (M^+, 100), 198 (35), 181 (20), 71 (30), 70 (26), 69 (24), 57 (35), 55 (44);); ^{1}H-NMR (DMSO-d_6): δ (ppm) 12.38 (br s, 1H, NH), 7.76 (dd, $^3J_{7,8}$ = 7.7 Hz, $^4J_{6,8}$ = 1.4 Hz, 1H, H-8), 7.68 (dd, $^3J_{6,7}$ = 8.3 Hz, $^3J_{7,8}$ = 7.7 Hz, 1H, H-7), 7.60 (dd, $^4J_{1,3}$ = 1.7 Hz, $^3J_{1,NH}$ = 2.8 Hz, 1H, H-1), 7. 50 (dd, $^4J_{3,1}$ = 1.7 Hz, $^3J_{3,NH}$ = 2.8 Hz, 1H, H-3), 7.42 (dd, $^3J_{6,7}$ = 8.3 Hz, $^4J_{6,8}$ = 1.4 Hz, 1H, H-6), 3.88 (s, 3H, OMe); ^{13}C-NMR (DMSO-d_6): δ (ppm) 179.3 (C-4), 179.1 (C-9), 160.2 (C-5), 137.6 (C-8a), 134.0 (C-7), 123.4 (C-9a), [22] 122.5 (C-4a), 122.1 (C-3), 122.0 (C-1), 120.6 (C-3a)[22], 118.3 (C-6), 56.2 (OMe). *Anal.* Calcd for $C_{13}H_9NO_3 \bullet H_2O$: C, 63.66; H, 4.52; N, 5.73. Found: C, 63.32; H, 4.45; N, 5.49.

N-(4,7-Dihydro-4,4-dimethoxy-7-oxo-2*H*-isoindol-5-yl)-*O*-(prop-2-enyl)carbamate (**9**)

Compound (**8**)[12] (3.50 g, 13.8 mmol) and 3.0 g (29.4 mmol) of tosylmethyl isocyanide were dissolved in 36 mL of dry THF under Ar-atmosphere. After dropwise addition of 3.94 g (35.2 mmol) of potassium *tert*-butoxide in 33 mL of dry THF the mixture was stirred overnight. After treating with H_2O the mixture was exhaustively extracted with ethyl acetate, the combined organic extracts were dried over anhydrous Na_2SO_4 and evaporated *in vacuo* to afford 5.36 g of crude product. For spectroscopic purposes 60 mg of this oil was purified by praparative TLC (aluminium oxide, eluent: ethyl acetate/light petroleum 4/1) to give colorless crystals of mp 130°C (decomp; ethyl acetate - light petroleum). IR (KBr): cm^{-1} 3300 (N-H), 1750 (C=O), 1640 (C=O); MS: m/z (%) 292 (M^+, 11), 262 (55), 261 (100), 260 (33), 219 (62), 189 (40), 94 (39), 93 (40), 91 (30); ^{1}H-NMR (DMSO-d_6): δ (ppm) 11.83 (br s, 1H, N2-H), 8.47 (s, 1H, CONH), 7.37 (dd, $^4J_{1,3}$ = 1.8 Hz, $^3J_{1,NH}$ = 3.0 Hz, 1H, H-1), 7.03 (dd, $^4J_{3,1}$ = 1.8 Hz, $^3J_{3,NH}$ = 2.4 Hz, 1H, H-3), 6.84 (s, 1H, H-6), 5.96 (m, $^3J_{CH,=CH2(Z)}$ = 17.2 Hz, $^3J_{=CH,=CH2(E)}$ = 10.5 Hz, $^3J_{=CH,OCH2}$ = 5.3 Hz, 1H, =C**H**-CH_2), 5.41 (m, $^3J_{=CH2(Z),=CH}$ = 17.2 Hz, $^2J_{=CH2(Z),=CH2(E)}$ = 1.7 Hz, $^4J_{=CH2(Z),OCH2}$ = 1.5 Hz, 1H, $H_{(Z)}$ of $C=CH_2$), 5.24 (m, $^3J_{=CH2(E),=CH}$ = 10.5 Hz, $^2J_{=CH2(E),=CH2(Z)}$ = 1.7 Hz, $^4J_{=CH2(E),OCH2}$ = 1.5 Hz, 1H, $H_{(E)}$ of $C=CH_2$), 4.62 (m, $^3J_{OCH2,=CH}$ = 5.3 Hz, $^4J_{OCH2,=CH2(Z)}$ = 1.5 Hz, $^4J_{OCH2,=CH2(E)}$ = 1.5 Hz, 2H, OCH_2), 3.04 (s, 6H, OMe); ^{13}C-NMR (DMSO-d_6): δ (ppm) 181.4 (C-7), 152.9 (OCON), 149.3 (C-5), 132.5 (=**C**H-CH_2), 119.9 (C-7a), 119.1 (C-3), 117.8 (=CH_2), 117.2 (C-1), 116.9 (C-3a), 113.2 (C-6), 96.2 (C-4), 65.4 (CH_2), 50.7 (OMe). *Anal.* Calcd for $C_{14}H_{16}N_2O_5$: C, 57.51; H, 5.52; N, 9.62. Found: C, 57.22; H, 5.80; N, 9.43.

N-(4,7-Dihydro-4,7-dioxo-2*H*-isoindol-5-yl)-*O*-(prop-2-enyl)carbamate (**10**)

Crude **9** (2.0 g), 1.66 g (6.6 mmol) of pyridinium *p*-toluenesulfonate (PPTS), and 193 mg (1 mmol) of *p*-toluenesulfonic acid hydrate were dissolved in 204 mL of acetone and 25 mL of H_2O. The reaction mixture was stirred for 4 d, diluted with ethyl acetate (250 mL) and successively washed with saturated

aqueous $NaHCO_3$, 1 N HCl and brine. The organic layer was dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting crude oil was subjected to column chromatography (silica gel, eluent: ethyl acetate/light petroleum 4/1) to yield 1.13 g (89 %) of yellowish crystals of mp 150°C (decomp; ethyl acetate - light petroleum). IR (KBr): cm^{-1} 3300 (N-H), 1740 (C=O), 1670, 1635 (C=O); MS: m/z (%): 246 (M^+, 100), 205 (80), 187 (53), 185 (51), 94 (72), 93 (75), 78 (27), 66 (66); ^{1}H-NMR (DMSO-d_6): δ (ppm) 12.37 (br s, 1H, N2-H), 8.75 (s, 1H, CONH), 7.68 (d, $^4J_{3,1}$ = 1.5 Hz, 1H, H-3),[22] 7.47 (d, $^4J_{1,3}$ = 1.5 Hz, H-1),[22] .01 (s, 1H, H-6), 5.95 (m, $^3J_{=CH,=CH2(Z)}$ = 17.2 Hz, $^3J_{=CH,=CH2(E)}$ = 10.5 Hz, $^3J_{=CH,OCH2}$ = 5.3 Hz, 1H, =C**H**-CH_2), 5.40 (m, $^3J_{=CH2(Z),=CH}$ = 17.2 Hz, $^2J_{=CH2(Z),=CH2(E)}$ = 1.7 Hz, $^4J_{=CH2(Z),OCH2}$ = 1.5 Hz, 1H, $H_{(Z)}$ of $C=CH_2$), 5.24 (m, $^3J_{=CH2(E),=CH}$ = 10.5 Hz, $^2J_{=CH2(E),=CH2(Z)}$ = 1.7 Hz, $^4J_{=CH2(E),OCH2}$ = 1.5 Hz, 1H, $H_{(E)}$ of $C=CH_2$), 4.64 (m, $^3J_{OCH2,=CH}$ = 5.3 Hz, $^4J_{OCH2,=CH2(Z)}$ = 1.5 Hz, $^4J_{OCH2,=CH2(E)}$ = 1.5 Hz, 2H, OCH_2); ^{13}C-NMR (DMSO-d_6): δ (ppm) 181.9 (C-7), 175.6 (C-4), 152.3 (OCON), 142.5 (C-5), 132.3 (=**C**H-CH_2), 124.3 (C-3)[22], 121.9 (C-1)[22], 120.5 (C-7a), 118.4 (C-3a), 117.9 (=CH_2), 115.7 (C-6), 65.7 (CH_2). *Anal.* Calcd for $C_{12}H_{10}N_2O_4$: C, 58.54; H, 4.09; N, 11.38. Found: C, 58.41; H, 4.07; N, 11.23.

2*H*-Benzo[*f*]isoinol-4,9-dione (**13**)

To a solution of 6.36 g (31.2 mmol) of **12**[14] and 6.88 g (35.3 mmol) of tosymethyl isocyanide in 44 mL of dry THF were added slowly under Ar-atmosphere 8.55 g (74.9 mmol) of potassium *tert*-butoxide in 80 mL of dry THF. After stirring at rt for 24 h the mixture was worked up as described for the preparation of **2** to yield 7.2 g of crude product. A sample of 1.0 g of this crude product was cautiously hydrolysed (127 mL of acetone, 15.9 mL of H_2O, 1.04 g of pyridinium *p*-toluenesulfonate (PPTS) and 121 mg of *p*-toluenesulfonic acid) as described for the preparation of **7** and **10**. The crude product was chromatographed on silica gel (eluent: ethyl acetate/light petroleum 4/1) to afford 777 mg (91 %) of yellowish crystals of mp 295-297°C (ethyl acetate - light petroleum). IR (KBr): cm^{-1} 3250 (N-H), 1670, 1640 (C=O); MS: m/z (%): 197 (M^+, 96), 169 (50), 141 (37), 114 (84), 113 (42), 85 (48), 73 (34), 70 (100); ^{1}H-NMR (DMSO-d_6): δ (ppm) 12.53 (br s, 1H, N2-H), 8.11 (m, 2H, H-5, H-8), 7.78 (m, 2H, H-6, H-7), 7.71 (s, 2H, H-1, H-3); ^{13}C-NMR (DMSO-d_6): δ (ppm) 179.4 (C-4, C-9), 135.1 (C-4a, C-8a), 133.2 (C-6, C-7), 126.4 (C-5, C-8), 123.2 (C-1, C-3, $^1J_{C1,H1}$ = 191.7 Hz, $^3J_{C1,H3}$ = 7.3 Hz), 121.6 (C-3a, C-9a). HRMS: Calcd for $C_{12}H_7NO_2$: 197.047679. Found: 197.0470 ± 0.00099.

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22. Assignments of the indicated resonances within one spectrum may be interchanged.

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