Reactions of Fischer's base with cyclic and acyclic conjugated nitro-olefins and nitrovinyl ethers

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Abstract

The reactions of 2,3-dihydro-2-methylene-1,3,3-trimethyl-1*H*-indole (Fischer's base) with nitro-olefins and alkoxy- nitro-olefins have been examined. Formation of the corresponding Michael-type adducts has been observed in all cases with the exception of 2-nitropropene for which the spiro- 1,2-oxazine *N*-oxide derivative could be isolated. The Michael-type adducts derived from alkoxy- nitro-olefins underwent a rapid elimination reaction resulting in the eventual formal nitro-olefination of the Fischer's base. The geometry of the products has been determined by means of DIFNOE experiments and their UV properties have been examined.

Keywords: 2,3-Dihydro-2-methylene-1,3,3-trimethyl-1*H*-indole, nitro-olefins, spiro- 1,2-oxazine N-oxides, nitrodienes, spectroscopy

Introduction

At the beginning of the 1960s, the pioneering work of Stork and his coworkers on enamine chemistry opened the way to an impressive amount of work in this field.[1] Several reviews,[2] books,[3] and a few volumes of the series of The Chemistry of Functional Groups[4] have been devoted to the chemistry of enamines. Special classes of substituted enamines have also been reviewed.[5]

However, the first reaction of an enamine system was the double alkylation of 1,3,3-trimethyl-2-methyleneindoline, the so-called Fischer's base, which was performed with methyl iodide by Zotti and Ferratini in 1890.[6] Subsequently, other electrophilic reagents such as acyl halides,[7] diketene,[8] sulfenyl-[9] and sulfonyl halides,[10] isocyanates,[11] diazonium salts,[12] and several other electrophiles[13] were reacted with Fischer's base. Strangely enough, among this sequence of reactants the electrophilic olefins, which are important partners for enamines,[14] are missing—
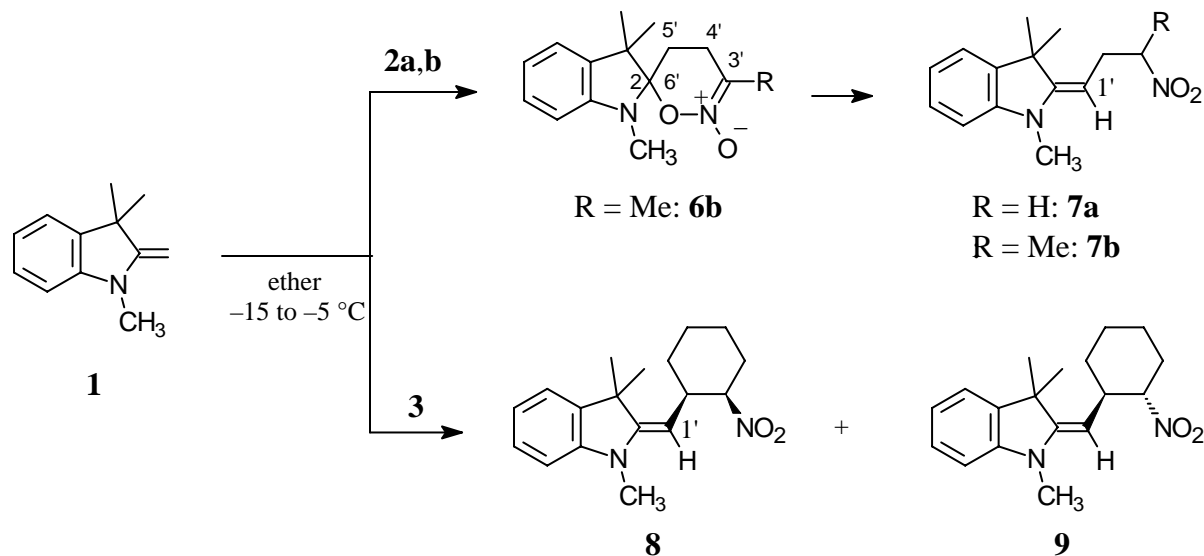
with the exception of tetracyanoethene (TCNE),[15] whose reactivity with Fischer's base has been studied in detail.

Among the electrophilic olefins, nitro-olefins occupy a special position. Owing to the continuing interest in nitro-aliphatic compounds,[16] and our particular interest in the reactivity of nitro-olefins towards enamine systems,[17] we have investigated Fischer's base as the nucleophilic counterpart of conjugated nitro-olefins and nitrovinyl ethers. One of our aims was to look for the possible formation of 1,2-oxazine *N*-oxide derivatives,[18] whose formation in the reactions of nitro-olefins with enamines from aldehydes and ketones is well known.[17,19]

Results and Discussion

The electrophiles used in this study are listed in Figure 1. The nitro-olefins **2a,b** and **3** and the nitrovinyl ethers **4a,c** and **5** are known, while **4b** was prepared by a literature method used for the synthesis of **4a**.[20] All of them are in the *E-* configuration. For **4b** this was proved by means of difference NOE experiments: irradiation of the methyl group caused enhancement (4%) of the methylene quartet of the ethoxy group.

R = H: **2a**　　　　**3**　　　　R = H: **4a**　　　　**5**
R = Me: **2b**　　　　　　　　　R = Me: **4b**
　　　　　　　　　　　　　　　R = CO$_2$Et: **4c**

Figure 1

Reactions with the nitro-olefins

The reaction between the Fischer's base **1** and the nitro-olefins **2a,b** and **3** (Figure 2) have been carried out in ether, under argon at temperatures ranging from –15°C to –5°C. The reaction with nitroethylene **2a** was carried out in the presence of hydroquinone to minimize the polymerization of the olefin which was otherwise rapid even below –20°C.

The reaction products were the corresponding Michael-type adducts, namely **7a,b** starting from the linear nitro-olefins **2a,b** and a mixture of *cis-* and *trans-* diastereomers **8** and **9**, respectively, starting from the cyclic nitro-olefin **3**.

Figure 2

   All compounds were characterized spectroscopically by means of ^{1}H–^{1}H- and ^{1}H–^{13}C- 2D experiments. Compounds **7a,b** are in the *E-* configuration, as proved by difference NOE experiments, whose results are summarized in Table 1.

   Only in one case, namely when the nitro-olefin was 2-nitropropene **2b**, could the corresponding spiro-oxazine *N*-oxide **6b** be isolated, since it precipitated from the ethereal solution. While in the solid state it was rather stable and could be stored at –20°C for long periods, in chloroform solution it underwent nucleophilic ring fission to the corresponding open-chain product **7b**.

   The opening of the heterocycle **6b** into **7b** was followed by monitoring the reaction by IR and ^{1}H-NMR spectroscopies. The stretching band at 1620 cm^{-1}, characteristic of the C=N$^+$-O$^-$ group,[17,19] slowly disappeared in favor of two absorption bands at 1670 cm^{-1} and 1555 cm^{-1}, owing to the stretching of the conjugated carbon–carbon double bond, and to the asymmetric NO$_2$ stretching band respectively. The ^{1}H- NMR spectrum recorded at –20°C, showed no vinyl proton signal and no nitromethine proton signal, a result which is consistent with the spiro-structure assigned. The signals of the vinyl and nitromethine protons appeared slowly, even at –20°C, the opening reaction being surely catalyzed by traces of acid present in the deuteriated chloroform used as solvent. Opening of **6b** was complete within a few hours and the Michael-type adduct **7b** was isolated as a single diastereomer.

   From the reaction of 1-nitrocyclohexene, **3**, with Fischer's base, **1**, two diastereomeric Michael-type adducts were identified, namely **8** and **9**, differing in the orientation of the nitro group. The geometry of the double bond was *E-* in both cases, as shown by difference NOE measurements. The stereochemical assignment relative to the stereo-centers was possible since the axial- and equatorial- orientations of the nitro group were easily recognizable from the position and pattern of the relative nitromethine proton signals. In fact, in the *cis-* isomer **8** the

equatorial nitromethine proton resonated at lower field than the same proton in the *trans-* isomer **9** (4.72 ppm *vs.* 4.45 ppm). The two signals also exhibited different values of W_H, namely 12 Hz for **8** and 26 Hz for **9** (actually this latter signal was resolved into a doublet of double doublets, ddd, $J_1 = 11.9$ Hz, $J_2 = 9.5$ Hz, $J_3 = 4.0$ Hz), values which are in accordance with equatorial and axial orientations, respectively, of the nitromethine protons.

The foregoing attribution was further confirmed by an analysis of the corresponding ^{13}C NMR spectra. In the *cis-* isomer, **8,** the carbocyclic carbon signals were upfield with respect to those of the *trans-* isomer **9**, thus demonstrating the presence of steric interactions in the former compound bearing the nitro group in the *axial* orientation. On standing, the *cis-* diastereomer **8** was converted into the more stable *trans-* **9**. The eventual composition was 4:1 in favor of **9**. Since the *cis-* compound was the kinetically formed product, its formation was helpful in determining the reaction mechanism, as will be discussed later.

Table 1. The most meaningful data of the DIFNOE measurements

Compounds	Irradiated proton	Enhanced signal (% η)
7a	NCH$_3$	H-1´ (8)
7b	H-1´	NCH$_3$ (4)
8	NCH$_3$	H-1´ (4)
9	NCH$_3$	H-1´ (6)
11	NCH$_3$	H-1´ (4)
	CHO	CHNO$_2$ (8)
12	NCH$_3$	H-1´ (8)
	CHNO$_2$	H-1´ (6)
13a	NCH$_3$	H-1´ (14)
13b	NCH$_3$	H-1´ (11)
		CH$_3$ at C-3 (11)
13c	NCH$_3$	H-1´ (7)
14	NCH$_3$	H-1´ (11)
	H-1´	H-4´ (12)

Reactions with the nitrovinyl ethers

The reactions between Fischer's base and the nitrovinyl ethers **4a–c** and **5** followed the same pathway as above, namely that the corresponding Michael-type adducts **10a–c** and **11,12** were the first- formed products (Figure 3).

However, only compounds **10a**, **11** and **12** were isolated, whereas **10b** and **10c** converted easily into the corresponding nitrodiene derivatives **13b,c** by loss of ethanol.

The *cis-* and *trans-* diastereomers **11** and **12**, obtained from the reaction with 3-nitro-5,6-dihydro-4*H*-pyran, **5**, could be differentiated in the same manner as discussed above for the analogous compounds **8** and **9** bearing the carbocyclic six-membered ring. The equatorial nitromethine proton in **11** (W_H 12 Hz) resonated at lower field than the analogous *axial* proton in

12 (W$_H$ 26 Hz) (4.70 ppm *vs*. 4.39 ppm). The adjacent CH-O proton was *axial* in both compounds, as demonstrated by the patterns of their signals and the values of their respective vicinal coupling constants (**11**: dd, $^3J_{1'-2'}$ = 10.2 Hz, $^3J_{2'-3'}$ = 3.7 Hz; **12**: t, $^3J_{1'-2'}$ = $^3J_{2'-3'}$ = 9.5 Hz). A comparison of their respective ^{13}C NMR data strongly support this attribution (Experimental Section). It seems important to stress the easy formation of the open-chain derivative **14,** occurring without catalyst being added. Evidently the formation of a conjugated nitrodiene is such a strong driving force that opening of a tetrahydropyran ring is fully counterbalanced.

Of the nitrodiene derivatives, **13a**, **13b** and **14** were in the *E,E-* configuration, as established by DIFNOE measurements (Table 1) and by an analysis of the vicinal coupling constants between H-1´ and H-2´ and between H-2´ and H-3´ in **13a**. Compound **13c** was a 3:2 mixture of *E,E-*: *E,Z-* diastereomers, the conjugation of the ethoxycarbonyl group with the carbon–carbon double bonds being in competition with that of the nitro group. No assignment was made, although it seems reasonable that the *E,E-* form could slightly prevail in the mixture, owing to the stronger electron-withdrawing power of the nitro group.
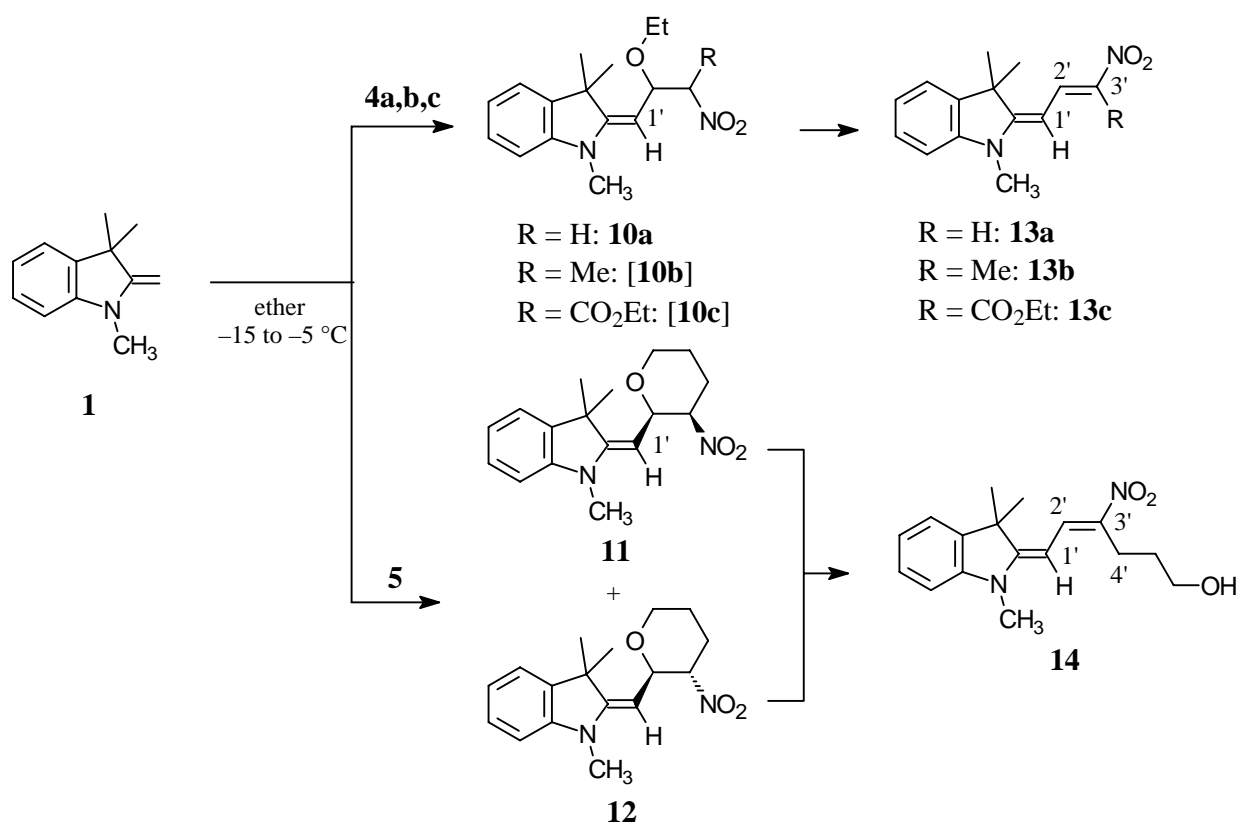

Figure 3

Compounds **13a** and **13b** were crystalline, with high melting points, while **13c**, which was an isomeric mixture, and **14** were sticky oils.

All the nitrodiene derivatives have an intense orange–red color. Their electronic spectra, recorded in three different solvents, are characterized by the presence of many intense absorption bands whose positions and intensities are listed in Table 2. The position of band 4 is particularly affected by solvent polarity. Band 2, which is present in the spectrum of **13c** in all solvents, might be attributed to the chromophore -CO_2Et, conjugated with the diene system. For the other derivatives the band at the same wavelength is visible only in cyclohexane.

Table 2. Electronic absorption spectra of compounds **13a,b,c** and **14**: λ_{max} [nm] (log ε)

	Solvent	Band 1	Band 2	Band 3	Band 4
13a	CH_3OH	211 (4.08)		277 (3.94)	481 (4.43)
13a	CH_3CN	196 (4.46)		280 (4.04)	474 (4.56)
13a	CyH[a]	215 (3.95)	251 (3.86)	275 (3.83)	438 (4.08)[b]
13b	CH_3OH	207 (4.34)		282 (4.09)	488 (4.55)
13b	CH_3CN	197 (4.45)		282 (4.06)	480 (4.53)
13b	CyH[a]	214 (3.99)	246 (3.89)	278 (3.96)	446 (4.30)[b]
13c	CH_3OH	210 (4.17)	258 (3.96)	308 *sh* (3.92)	469 (4.86)
13c	CH_3CN	200 (4.21)	258 (3.86)	307 (3.81)	471 (4.80)
13c	CyH[a]	216 (3.88)	254 (3.92)	302 (3.77)	450 (4.42)[b]
14	CH_3OH	208 (4.38)		283 (4.17)	491 (4.58)
14	CH_3CN	196 (4.38)		284 (4.01)	481 (4.43)
14	CyH[a]	214 (4.03)	249 (3.90)	280 (4.01)	451 (4.35)[b]

[a] CyH, Cyclohexane; [b]fine structure (vibrationally resolved).

Mechanism of the reactions

The isolation of the products in the reactions of the cyclic electrophiles **3** and **5** with Fischer's base, under kinetically controlled conditions, allows a mechanism to be postulated. In accordance with the topological rule of Seebach and Golinski,[21] although the enamine β-carbon atom is not prochiral, the approach of the reactants is likely to occur as depicted in Figure 4. The resulting zwitterion intermediate **15** in its chair–chair conformation, **15´** would abstract either diastereomeric proton generating the carbon–carbon double bond in the *E-* configuration. Then the nitronic acid carbon atom in **16** would be protonated from the less hindered side of the ring, giving rise to the *cis-* diastereoisomer **8** (or **11**) having the nitro group in the axial orientation.
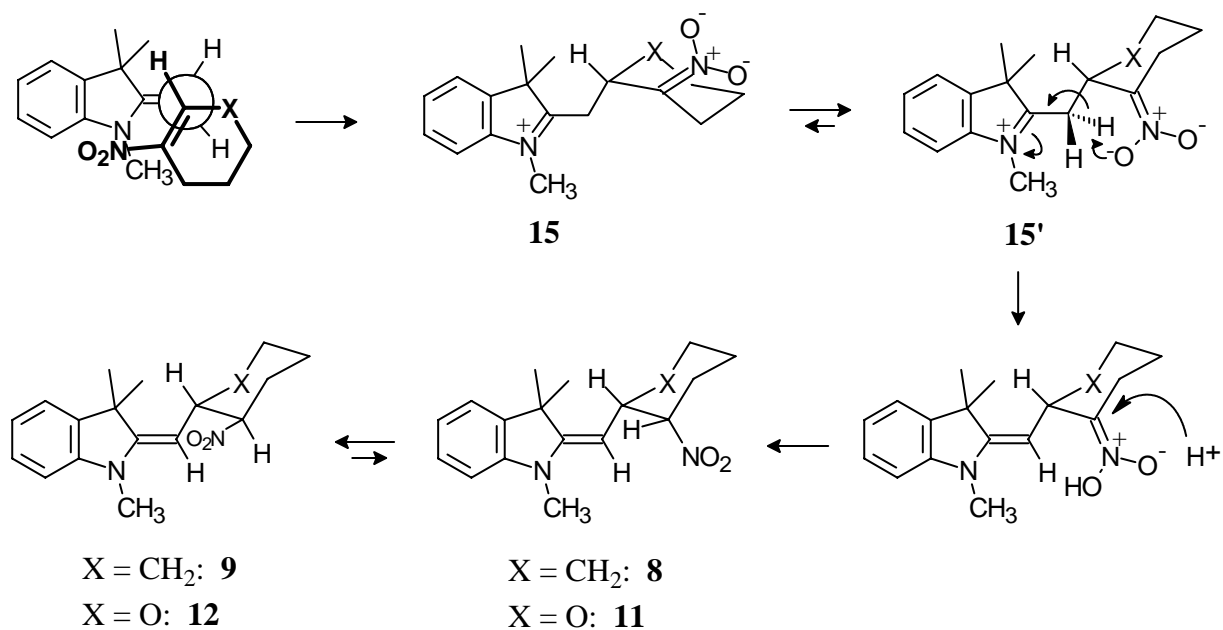
15   **15'**

X = CH$_2$: **9**   X = CH$_2$: **8**
X = O: **12**   X = O: **11**

Figure 4

Conclusions

The reactions between Fischer's base and the nitro-olefins and, maybe more interestingly, with the nitrovinyl ethers, give the corresponding Michael-type adducts as oily products which present some curious physical properties, such as that of climbing up the walls of glass vessels by forming strongly adherent films. However, the simple nitroalkylated compounds are not very stable. When left in the air for some period they decompose, probably under the action of oxygen, as happens with the Fischer's base itself, which is easily oxidized to the corresponding oxindole derivative.[22] In only one case was the desired *spiro* compound formed and this is probably related to the type and steric demand of the substituents at the electrophilic double bond. In contrast, the nitrodiene derivatives proved very stable, and could be stored for months in the air without any modification in their structure.

Experimental Section

General Procedures. Melting points were determined with a Büchi 510 apparatus and are uncorrected. Column chromatography was performed on silica gel (Merck 60, 70–230 mesh). TLC was performed on Polygram® Sil G/UV$_{254}$ silica gel pre-coated plastic sheets (eluent: light petroleum–ethyl acetate). NMR spectra were recorded on a Jeol 400 (9.4 Tesla, 400.13 MHz for ^{1}H, 100.62 MHz for ^{13}C) spectrometer. Chemical shifts (δ in ppm) are given from internal

CHCl$_3$ (7.26) for ^{1}H- and ^{13}CDCl$_3$ (77.0) for ^{13}C- NMR. Coupling constants (*J,* Hz) are accurate to ± 0.2 Hz for ^{1}H. Mass spectra (MS) at 70 eV using the electron-impact mode was performed on a VG 7070 spectrometer by. "Laboratorio di Spettrometria di Massa, Università di Trieste." IR spectra were run on a Thermo Nicolet 320 FT-IR spectrometer for CHCl$_3$ solutions or neat; the absorption values are given in cm^{-1}. Absorption spectra were obtained with a Shimadzu UV-2501PC spectrometer in solvents of Merck Uvasol grades at room temperature.

Reactants. The Fischer's base was purchased from Aldrich, the nitro-olefins were prepared in accordance with literature procedures, as follows: nitro-ethene (**2a**),[23] 2-nitropropene (**2b**),[23] 1-nitrocyclohexene (**3**),[24] 2-ethoxy-1-nitro-ethene (**4a**),[20] ethyl 3-ethoxy-2-nitro-acrylate (**4c**),[25] 3,4-dihydro-5-nitro-2H-pyran (**5**).[26]

1-Ethoxy-2-nitropropene (4b). Reaction of 1-ethoxypropene with a mixture of acetic anhydride and nitric acid at –33°C furnished the intermediate product as a 1:1 diastereomeric mixture, which was pure enough to be used as such. 1-Acetoxy-1-ethoxy-2-nitropropane: NMR data: δ_H (CDCl$_3$) 6.15 (1 H, t, O-CH-O), 4.62 (1 H, 2dq, CHNO$_2$), 3.77 (1 H, m, OC*H*$_2$CH$_3$), 3.62 (1 H, m, OC*H*$_2$CH$_3$), 2.08 (1.5 H, s, CH$_3$CO), 2.05 (1.5 H, s, CH$_3$CO), 1.57 (1.5 H, d, CH$_3$), 1.51 (1.5 H, d, CH$_3$), 1.15 (1.5H, t, OCH$_2$C*H*$_3$), 1.13 (1.5H, t, OCH$_2$C*H*$_3$). δ_C (CDCl$_3$) 170.1 (s), 170.0 (s), 95.2 (d), 95.1 (d), 83.6 (d), 83.1 (d), 66.6 (t), 66.5 (t), 20.71 (q), 20.68 (q), 14.7 (q), 14.6 (q), 13.9 (q), 13.6 (q). Elimination of acetic acid by means of triethylamine gave an oil, which was freed from volatile substances under argon for a few hours. After this treatment the product was practically pure and no distillation was necessary. 1-Ethoxy-2-nitropropene (**4b**): IR, 3072 1664, 1557, 1498, 1218, 991, 861. NMR, δ_H (CDCl$_3$) 8.03 (1 H, s, vinyl-H), 4.17 (2 H, q, OC*H*$_2$CH$_3$), 2.04 (3 H, s, CH$_3$), 1.38 (3 H, t, OCH$_2$C*H*$_3$). δ_C (CDCl$_3$) 157.1 (d), 131.9 (s), 72.0 (t), 15.3 (q), 10.2 (q).

General procedure for the reactions between Fischer's base and nitro-olefins

To a solution of Fischer's base (0.173 g, 1.0 mmol) in diethyl ether (2 mL) the appropriate nitro-olefin (1.0 mmol) in the same solvent (1 mL) was slowly added, keeping the temperature between –15°C and –5°C (the reaction with nitro-ethene **2a** was carried out in the presence of hydroquinone (1 eq.) to prevent polymerization of the nitro-olefin. The reaction mixture was kept in the refrigerator for 12 h. In the reaction of compound **1** with 2-nitropropene **2b**, the spiro[1,2]oxazine N-oxide **4b** precipitated from the ethereal solution, and was filtered off. In the other cases the resulting products **7a** and **8, 9** were purified by flash chromatography (eluent, light petroleum–ethyl acetate, 95%). The products **13a,b,c** and **14** were formed from their respective parent compounds **10a–c** and **11, 12** at room temperature without addition of any catalyst. The products were purified by flash chromatography (eluent, light petroleum–ethyl acetate, gradient).

Spiro[1,3-dihydro-1,3,3-trimethyl-2*H*-indole-2,6´-(5´,6´-dihydro-3´-methyl-4´*H*-[1,2]oxazine 2´-oxide] (6b). m.p. 65–66 °C. IR data, 1623 (C=N$^+$), 1604, 1491 (Ar). NMR, δ_H (CDCl$_3$, –20°C) 7.11 (1 H, t, H-6), 7.01 (1 H, d, H-4), 6.79 (1 H, t, H-5), 6.50 (1 H, d, H-7), 2.92 (3 H, s,

NCH$_3$), 2.66 (2 H, t, CH$_2$C=N), 2.30 (2 H, bt, CH_2CH$_2$C=N), 2.08 (3H, s, CH$_3$), 1.31 (6 H, very broad s, *gem*- CH$_3$). δ_C (CDCl$_3$, –20°C) 147.4 (s, C-7a), 135.6 (s, C-3a), 127.5 (d, C-6), 121.0 (d, C-4), 120.1 (s, C=N-O$^-$), 119.1 (d, C-5), 108.9 (s, C-2), 106.7 (d, C-7), 49.6 (s, C-3), 28.0 (q, NCH$_3$), 28.7 (t, CH_2C=N), 21.4 (t, CH_2CH$_2$C=N), 18.1 (q, CH$_3$). The signals for the *gem*-dimethyl carbon atoms were too broad to be detected. MS (70 eV), 260 (M$^{+•}$, 3), 186 (6), 175 (56), 160 (100), 132 (18), 117 (12), 84 (14), 77 (10).

2,3-Dihydro-2-[(3-nitro)propylidene]-1,3,3-trimethyl-1H-indole (7a). IR, 1650, 1554, 1366, 1600, 1495, 738. NMR, δ_H (CDCl$_3$) 7.12 (1 H, t, H-6), 7.04 (1 H, d, H-4), 6.74 (1 H, t, H-5), 6.47 (1 H, d, H-7), 4.42 (2 H, t, CH$_2$NO$_2$), 4.08 (1 H, t, H-1´), 3.06 (2 H, q, CH_2CH$_2$NO$_2$), 2.95 (3 H, s, NCH$_3$), 1.50 (6 H, s, *gem*- CH$_3$). δ_C (CDCl$_3$) 156.4 (s, C-2), 145.8 (s, C-7a), 137.5 (s, C-3a), 127.6 (d, C-6), 121.2 (d, C-4), 118.2 (d, C-5), 104.6 (d, C-7), 86.2 (d, H-1´), 75.8 (t, CH$_2$NO$_2$), 44.3 (s, C-3), 29.8 (t, CH_2CH$_2$NO$_2$), 28.7 (q, NCH$_3$), 27.6 (2q, *gem*- CH$_3$).

2,3-Dihydro-2-[(3-nitro)butylidene]-1,3,3-trimethyl-1H-indole (7b). IR, 1655, 1551, 1363, 1606, 1495, 738. NMR, δ_H (CDCl$_3$) 7.10 (1 H, t, H-6), 7.04 (1 H, d, H-4), 6.73 (1 H, t, H-5), 6.47 (1 H, d, H-7), 4.58 (1 H, sext., J = 6.6 Hz, CHNO$_2$), 4.06 (1 H, d, J = 7.7 Hz, H-1´), 3.22 (3 H, s, NCH$_3$), 3.03 (1 H, m, CHCHNO$_2$), 2.80 (1 H, m, CHCHNO$_2$), 1.60 (3 H, d, J = 6.6 Hz, CH$_3$), 1.48 (6 H, s, *gem*- CH$_3$). δ_C (CDCl$_3$) 156.4 (s, C-2), 145.8 (s, C-7a), 137.7 (s, C-4a), 127.6 (d, C-6), 121.3 (d, C-4), 118.2 (d, C-5), 104.7 (d, C-7), 86.2 (d, C-1´), 84.8 (d, CHNO$_2$), 44.3 (s, C-3), 32.5 (t, CH_2CHNO$_2$), 28.9 (q, NCH$_3$), 27.9 (2q, *gem*- CH$_3$), 18.5 (q, CH$_3$). MS (70 eV): 260 (M$^{+•}$, 12), 214 (8), 198 (13), 186 (37), 175 (37), 171 (15), 160 (100), 145 (13), 144 (17), 132 (16), 126 (17), 117 (12), 77 (13), 74 (25).

***cis*-2,3-Dihydro-2-[(2-nitrocyclohexyl)methylidene]-1,3,3-trimethyl-1H-indole (8), and *trans*-2,3-dihydro-2-[(2-nitrocyclohexyl)methylidene]-1,3,3-trimethyl-1H-indole (9).**
Chromatography (light petroleum–ethyl acetate 95:5) of the two diastereomers furnished the pure *trans*- isomer **9**, and a 1:4 mixture of **8** and **9**.
Compound 8. NMR, δ_H (CDCl$_3$) 7.08 (1 H, t, H-6), 7.01 (1 H, d, H-4), 6.71 (1 H, t, H-5), 6.45 (1 H, d, H-7), 4.76 (1H, dt, J$_1$ = J$_2$ = 4.8 Hz, J$_3$ = 9.5 Hz, W$_H$ = 16.5 Hz, CHNO$_2$), 4.34 (1H, d, J = 11.4 Hz, H-1´), 3.51 (1H, m, W$_H$ = 21.5 Hz, CHCHNO$_2$), 2.95 (3H, s, NCH$_3$), 2.26 (1H, m, ring H), 2.0 (3 H, m, ring H), 1.78 (1 H, m, ring H), 1.45 (3H, s, CH$_3$ at C-3), 1.41 (3H, s, CH$_3$ at C-3), 1.40 (1 H, m, ring H), 1.20 (1 H, m, ring H). δ_C (CDCl$_3$) 155.7 (s, C-2), 145.9 (s, C-7a), 137.9 (s, C-3a), 127.6 (d, C-6), 121.2 (d, C-4), 118.1 (d, C-5), 104.6 (d, C-7), 89.4 (d, C-1´), 87.6 (d, CHNO$_2$), 44.5 (s, C-3), 36.1 (d, CHCHNO$_2$), 32.3 (t, CH$_2$), 29.0 (q, NCH$_3$), 28.5 (q, CH$_3$ at C-3), 28.4 (q, CH$_3$ at C-3), 26.0 (t, CH$_2$), 22.8 (t, CH$_2$), 21.3 (t, CH$_2$).
Compound 9. IR, 3052, 3028, 1658, 1606, 1546, 1496, 1372, 911, 736. NMR, δ_H (CDCl$_3$) 7.07 (1 H, t, H-6), 7.01 (1 H, d, H-4), 6.70 (1 H, t, H-5), 6.43 (1 H, d, H-7), 4.25 (1H, ddd, J$_1$ = 11.7 Hz, J$_2$ = 10.6 Hz, J$_3$ = 3.7 Hz, W$_H$ = 27.5 Hz, CHNO$_2$), 4.05 (1H, d, J = 10.6 Hz, H-1´), 3.05 (1 H, dq, J$_1$ = J$_2$ = J$_3$ = 10.6 Hz, J$_4$ = 10.6 Hz, J$_3$ = 3.7 Hz, CHCHNO$_2$), 2.92 (3H, s, NCH$_3$), 2.26 (1 H, m, ring H), 2.01 (1H, dq, ring H), 1.96 (3 H, m, ring H), 1.76 (2H, m, ring H), 1.50 (1 H, m, ring H), 1.46 (4 H, s + m, CH$_3$ at C-3, ring H), 1.42 (3H, s, CH$_3$ at C-3). δ_C (CDCl$_3$) 155.5 (s, C-2), 145.9 (s, C-7a), 138.0 (s, C-3a), 127.7 (d, C-6), 121.3 (d, C-4), 118.0 (d, C-5), 104.7 (d, C-7),

94.3 (d, C-1´), 92.4 (d, CHNO$_2$), 44.6 (s, C-3), 40.3 (d, *C*HCHNO$_2$), 34.9 (t, CH$_2$), 31.2 (t, CH$_2$), 29.0 (q, NCH$_3$), 28.65 (q, CH$_3$ at C-3), 28.58 (q, CH$_3$ at C-3), 24.9 (t, CH$_2$), 24.3 (t, CH$_2$). MS (70 eV): 300 (M$^{+\bullet}$, 50), 285 (9), 254 (38), 238 (15), 212 (28), 188 (21), 184 (14), 182 (13), 175 (17), 172 (23), 160 (100), 158 (31), 145 (16), 144 (15), 86 (18), 84 (31), 77 (8).

2,3-Dihydro-2-[(2-ethoxy-3-nitro)propylidene]-1,3,3-trimethyl-1*H*-indole (10a). IR, 3066, 3034, 1642, 1630, 1500, 1125, 996, 790, 775. NMR, δ_H (CDCl$_3$) 7.14 (1 H, t, H-6), 7.09 (1 H, d, H-4), 6.80 (1 H, t, H-5), 6.54 (1 H, d, H-7), 5.18 (1 H, ddd, J$_1$ = 10.2 Hz, J$_2$ = 9.9 Hz, J$_3$ = 3.6 Hz, CH-O), 4.52 (1 H, dd, J$_1$ = 12.0 Hz, J$_2$ = 9.9 Hz, CHNO$_2$), 4.34 (1 H, dd, J$_1$ = 12.0 Hz, J$_2$ = 3.6 Hz, CHNO$_2$), 4.06 (1 H, d, J = 10.2 Hz, H-1´), 3.68 (1 H, m, OC*H*$_2$CH$_3$), 3.42 (1 H, m, OC*H*$_2$CH$_3$), 3.01 (3 H, s, NCH$_3$), 1.37 (3 H, s, CH$_3$ at C-3), 1.35 (3 H, s, CH$_3$ at C-3), 1.18 (3 H, t, OCH$_2$C*H*$_3$). δ_C (CDCl$_3$) 169.4 (s, C-2), 143.5 (s, C-7a), 139.5 (s, C-3a), 138.5 (d, C-6), 127.6 (d, C-4), 121.4 (d, C-5), 105.2 (d, C-7) 88.9 (d, C-1´), 80.6 (t, CH$_2$NO$_2$), 72.4 (d, CHO), 63.5 (t, OC*H*$_2$CH$_3$), 47.1 (s, C-3), 30.3 (q, NCH$_3$), 28.5, 27.8 (2q, *gem*- CH$_3$), 15.8 (q, OCH$_2$C*H*$_3$).

cis- and *trans*- **2-(2,3-Dihydro-1,3,3-trimethyl-1*H*-indolylidene)methyl-3-nitro-tetrahydro-2*H*-pyran, (11) and (12).** Although it was not possible to separate the two diastereomers, their spectroscopic data are given separately for the sake of clarity.

Compound 11. NMR, δ_H (CDCl$_3$) 7.12 (1 H, t, H-6), 7.05 (1 H, d, H-4), 6.84 (1 H, t, H-5), 6.52 (1 H, d, H-7), 5.03 (1H, dd, J$_1$ = 10.2 Hz, J$_2$ = 4.0 Hz, CH-O), 4.72 (1H, m, W$_H$ = 12.0 Hz, CHNO$_2$), 4.39 (1H, d, J = 10.2 Hz, H-1´), 4.02 (1H, m, H$_{eq}$ of OCH$_2$ grouping) 3.61 (1H, m, H$_{ax}$ of OCH$_2$ grouping), 2.98 (3 H, s, NCH$_3$), 2.44 (1H, m, ring CH), 2.27 (1H, m, ring CH), 2.12 (1H, m, ring CH), 1.83 (1H, m, ring CH), 1.53 (3 H, s, CH$_3$ at C-3), 1.47 (3 H, s, CH$_3$ at C-3). δ_C (CDCl$_3$) 160.2 (s, C-2), 145.4 (s, C-7a), 138.0 (s, C-3a), 127.8 (d, C-6), 121.8 (d, C-4), 119.0 (d, C-5), 105.9 (d, C-7) 85.6 (d, C-1´), 82.0 (d, CHNO$_2$), 71.3 (d, CHO), 64.2 (t, OCH$_2$), 45.0 (s, C-3), 29.9 (q, NCH$_3$), 29.0, 29.8 (2q, *gem*- CH$_3$), 25.0 (t, CH$_2$), 22.0 (t, CH$_2$).

Compound 12. NMR, δ_H (CDCl$_3$) 7.12 (1 H, t, H-6), 7.06 (1 H, d, H-4), 6.78 (1 H, t, H-5), 6.53 (1 H, d, H-7), 4.65 (1H, t, J = 9.5 Hz, CH-O), 4.45 (1H, ddd, J$_1$ = 9.9 Hz, J$_2$ = 9.5 Hz, J$_3$ = 4.0 Hz, W$_H$ = 26.0 Hz, CHNO$_2$), 4.28 (1H, d, J = 9.9 Hz, H-1´), 4.02 (1H, m, H$_{eq}$ of OCH$_2$ grouping) 3.61 (1H, m, H$_{ax}$ of OCH$_2$ grouping), 2.98 (3 H, s, NCH$_3$), 2.44 (1H, m, ring CH), 1.83 (1H, m, ring CH), 1.63 (2H, m, ring CH$_2$), 1.51 (3 H, s, CH$_3$ at C-3), 1.46 (3 H, s, CH$_3$ at C-3). δ_C (CDCl$_3$) 161.5 (s, C-2), 145.3 (s, C-7a), 138.3 (s, C-3a), 127.7 (d, C-6), 121.3 (d, C-4), 119.1 (d, C-5), 105.4 (d, C-7) 88.3 (d, C-1´), 84.0 (d, CHNO$_2$), 75.2 (d, CHO), 67.2 (t, OCH$_2$), 45.2 (s, C-3), 29.8 (q, NCH$_3$), 29.4 (t, CH$_2$), 28.9, 28.8 (2q, *gem*- CH$_3$), 24.5 (t, CH$_2$).

2,3-Dihydro-2-[(3-nitro)propenylidene]-1,3,3-trimethyl-1*H*-indole (13a). m.p. 161–162°C. IR, 1577, 1561, 1460, 1376, 1276, 926, 798, 756, 722. NMR, δ_H (CDCl$_3$) 8.38 (1 H, dd, J$_1$ = 13.2 Hz, J$_1$ = 12.1 Hz H-2´), 7.27 (2 H, t + d, H-6 and H-4), 7.10 (1H, d, J = 12.1 Hz H-3´), 7.06 (1 H, t, H-5), 6.85 (1 H, d, H-7), 5.46 (1 H, d, J = 13.2 Hz, N-C=CH), 3.30 (3 H, s, NCH$_3$), 1.64 (6 H, s, *gem*- CH$_3$). δ_C (CDCl$_3$) 169.4 (s, C-2), 143.2 (s, C-7a), 139.5 (s, C-3a), 138.6 (d, C-2´), 129.2 (d, C-3´), 128.1 (d, C-6), 122.5 (d, C-5), 121.8 (d, C-4), 107.9 (d, C-7), 89.6 (d, N-C=CH), 47.4 (s, C-3), 29.7 (q, NCH$_3$), 28.6 (2q, *gem*- CH$_3$). MS (70 eV): 244 (M$^{+\bullet}$, 4), 200 (4), 186 (5), 175 (33), 160 (100), 159 (8), 158 (12), 146 (11), 132 (16), 117 (11), 91 (7), 77 (8).

2,3-Dihydro-2-[(3-nitro)-2-butenylidene]-1,3,3-trimethyl-1*H*-indole (13b). m.p. 191–192°C; IR, 1618, 1597, 1563, 1462, 1262, 928, 816, 796, 758, 721. NMR, δ_H (CDCl$_3$) 8.50 (1 H, d, J = 13.2 Hz, H-2´), 7.27 (1 H, t, H-6), 7.24 (1 H, d, H-4), 7.03 (1 H, t, H-5), 6.84 (1 H, d, H-7), 5.30 (1 H, d, J = 13.2 Hz, H-1´), 3.32 (3 H, s, NCH$_3$), 2.25 (3H, s, CH$_3$), 1.64 (6 H, s, *gem-* CH$_3$). δ_C (CDCl$_3$) 167.6 (s, C-2), 143.6 (s, C-7a), 139.4 (s, C-3a), 136.0 (s, H-3´), 133.7 (d, C-2´), 128.0 (d, C-6), 122.1 (d, C-4), 121.8 (d, C-5), 107.6 (d, C-7), 90.3 (d, C-1´), 47.1 (s, C-3), 29.6 (q, NCH$_3$), 28.6 (2q, *gem-* CH$_3$), 11.9 (q, CH$_3$). MS (70 eV): 258 (M$^{+\bullet}$, 62), 212 (15), 198 (39), 197 (47), 182 (37), 181 (22), 180 (23), 175 (24), 167 (25), 160 (79), 159 (76), 158 (100), 145 (16), 144 (33), 132 (12), 116 (12), 77 (18).

***Cis-* and *trans* Ethyl 4-(2,3-dihydro-1,3,3-trimethyl-1*H*-indolylidene)-2-nitro-2-butenoate (13c).** IR, 1713, 1617, 1568, 1488, 1480, 1362, 1360, 1358, 930, 805, 749. NMR data for the major component, δ_H (CDCl$_3$) 8.72 (1 H, d, J = 14.3 Hz, H-2'), 7.33, 7.30 (2 H, t + d, H-6, H-4), 7.15 (1 H, t, H-5), 6.96 (1 H, d, H-7), 6.34 (1 H, d, J = 14.3 Hz, H-1´), 4.38 (2 H, q, OCH$_2$), 3.43 (3 H, s, NCH$_3$), 1.67 (6 H, s, *gem-* CH$_3$), 1.39 (3H, t, CH$_3$). δ_C (CDCl$_3$) 173.8 (s, CO), 162.2 (s, C-2), 142.8 (s, C-7a), 140.1 (s, C-3a), 139.4 (d, C-2´), 129.2 (s, C-3´), 128.32 (d, C-6), 123.32 (d, C-4), 122.0 (d, C-5), 109.0 (d, C-7), 92.2 (d, C-1´), 61.2 (t, OCH$_2$), 48.2 (s, C-3), 30.3 (q, NCH$_3$), 28.7 (2q, *gem-* CH$_3$), 14.30 (q, CH$_3$). NMR data for the minor component, δ_H (CDCl$_3$) 8.23 (1 H, d, J = 13.6 Hz, H-2´), 7.33, 7.30 (2 H, t + d, H-6, H-4), 7.15 (1 H, t, H-5), 6.96 (1 H, d, H-7), 6.51 (1 H, d, J = 13.6 Hz, H-1´), 4.31 (2 H, q, OCH$_2$), 3.43 (3 H, s, NCH$_3$), 1.67 (6 H, s, *gem-* CH$_3$), 1.36 (3H, t, CH$_3$). δ_C (CDCl$_3$) 173.9 (s, CO), 162.6 (s, C-2), 142.9 (s, C-7a), 142.4 (d, C-2´), 140.0 (s, C-3a), 128.35 (d, C-6), 127.8 (s, C-3´), 123.87 (d, C-4), 121.9 (d, C-5), 109.1 (d, C-7), 92.8 (d, C-1´), 61.1 (t, OCH$_2$), 48.2 (s, C-3), 30.4 (q, NCH$_3$), 28.6 (2q, *gem-* CH$_3$), 14.26 (q, CH$_3$). MS data: 316 (M$^{+\bullet}$, 25), 300 (7), 271 (13), 270 (13), 269 (20), 197 (17), 182 (28), 175 (36), 172 (16), 168 (19), 167 (22), 160 (85), 159 (100), 158 (57), 144 (24), 132 (27), 117 (20), 116 (34), 91 (42), 90 (26), 89 (43), 77 (30).

2,3-Dihydro-2-[(6-hydroxy-3-nitro)hexylidene]-1,3,3-trimethyl-1*H*-indole (14). IR, 3431, 3056, 1619, 1579, 1490, 1469, 1356, 1262, 1246, 1287, 929, 799, 746. NMR, δ_H (CDCl$_3$) 8.54 (1 H, d, J = 13.5 Hz, H-2´), 7.27 (1 H, t, H-6), 7.25 (1 H, d, H-4), 7.04 (1 H, t, H-5), 7.84 (1 H, d, H-7), 5.46 (1 H, d, J = 13.5 Hz, H-1´), 3.67 (2 H, t, C*H$_2$*OH), 3.32 (3 H, s, NCH$_3$), 2.85 (2H, t, C*H$_2$*CH$_2$CH$_2$OH), 1.95 (1 H, bs, OH), 1.85 (2 H, quintet, C*H$_2$*CH$_2$OH), 1.65 (6 H, s, *gem-* CH$_3$). δ_C (CDCl$_3$) 168.4 (s, C-2), 143.6 (s, C-7a), 139.5 (s, C-3a), 139.1 (s, C-3´), 134.8 (d, C-2´), 128.0 (d, C-6), 122.3 (d, C-4), 121.8 (d, C-5), 107.7 (d, C-7), 90.3 (d, C-1´), 61.3 (t, CH$_2$OH), 47.3 (s, C-3), 30.4 (t, C-5´), 29.6 (q, NCH$_3$), 28.5 (2q, *gem-* CH$_3$), 21.9 (t, C-4´). MS data: 302 (M$^{+\bullet}$, 58), 285 (8), 258 (22), 256 (16), 240 (22), 211 (28), 197 (56), 194 (22), 186 (23), 182 (23), 181 (30), 180 (23), 175 (38), 172 (32), 168 (19), 167 (21), 160 (90), 158 (100), 145 (22), 144 (39), 132 (17), 116 (15), 91 (11), 77 (17).

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