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SUBSTITUTED 1-AMINO-CYCLOPENTENES FROM 2,3-DIAMINO-1,3-BUTADIENES AND NITROALKENES

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Abstract—2,3-Diamino-1,3-butadienes (1) reacted with β-nitrostyrene or nitroethene to afford a mixture of isomeric 1,5-diamino-5-methyl-4-nitro-cyclopentenes (3 and 4). The configuration of the main isomers (3) was established by X-ray diffraction analysis which also revealed the great steric crowding of this molecule. The conformation of the cyclopentene ring in 3 in the solid state is also discussed. The enamines (3 and 4) were hydrolyzed to the corresponding aminoketones (5 and 6) which, on reduction, gave the same diaminoketone (7).

The bis-enamine derivatives of α-diketones have received little attention in the past although they are relatively easy to prepare. Only recently has their use as starting materials for the preparation of amino-substituted benzenes and heterocyclic compounds been investigated.[1]

As a potentially useful approach to 6-membered carbon rings bearing amino substituents we planned to use 2,3-diaminobutadienes in Diels–Alder-type reactions.

RESULTS AND DISCUSSION

The enamines (**1a–c**) were easily prepared by a known procedure[1] starting from 2,3-butanedione which was reacted with the appropriate secondary amine and titanium(IV) chloride.

Somewhat surprisingly, compounds **1a–c** showed very low reactivity with several common dienophiles, e.g. maleic anhydride, N-phenylmaleimide and fumaronitrile. No adducts were formed in detectable amounts. In striking contrast, however, *E*-β-nitrostyrene was found to react easily with the diene-diamines (**1a–c**). In tetrahydrofuran at room temperature a complex reaction mixture was formed in a short time.

The mixture obtained from **1a** with β-nitrostyrene (**2a**) afforded on fractional crystallization the cyclopentene enamines **3a** and **4** in a ratio of *ca* 3:1. Two products were also formed starting from **1b** and **1c**; however, in both cases separation by fractional crystallization was ineffective, and extensive decomposition occurred during column chromatography, allowing the isolation of only the main products (**3b** and **3c**, respectively). The reaction of the enamine **1a** with nitroethene was strongly exothermic and afforded the cyclopentene derivative **3d** as the main product.

The structures of compounds **3** and **4** were inferred from analytical and ^{1}H- and ^{13}C-NMR evidence. The expected cyclohexene structure was easily ruled out by the presence of a Me group. The substitution pattern and position of the double bond in the cyclopentene ring was deduced from the presence in both ^{1}H-NMR spectra (Table 1) of an AMX pattern associated with the H atoms on C-2, C-3 and C-4, respectively ($J_{AX} \simeq 0$ Hz).

However, these NMR data did not allow a safe configurational assignment since it is known[2] and confirmed in the present case by molecular models that it is difficult to rely on coupling constant values in flexible cyclopentene structures. Since compound **3a** could be obtained in well formed crystals an X-ray crystallographic study of this molecule was undertaken. This was impossible for the isomer **4** which was unstable when kept in solution for the long times necessary to obtain suitable crystals.

Figure 1 shows the molecular shape and numbering scheme, while details of the geometry are reported in Tables 3–5. The C–H bond lengths vary between 0.90 and 1.08 Å [mean 1.00 Å for the 21 C(sp^3)–H bonds and 0.93 Å for the 6 C(sp^2)–H bonds]. Bond angles involving H atoms are in the usual range.

It is evident from Fig. 1 and from the values of Table 5 that the Me group at C(5), the nitro group at C(4), and the H atom at C(3) all lie on the same side of the plane defined by atoms C(3), C(4) and C(5). As expected, both morpholino rings are in the chair conformation, the ring puckering parameters[3] being $Q = 0.692$, $\theta = 2.0°$ and $\phi = 347.8°$ for the ring including the atom N(1) and $Q = 0.695$, $\theta = 178.3°$ and $\phi = 346.9°$ for the other ring.

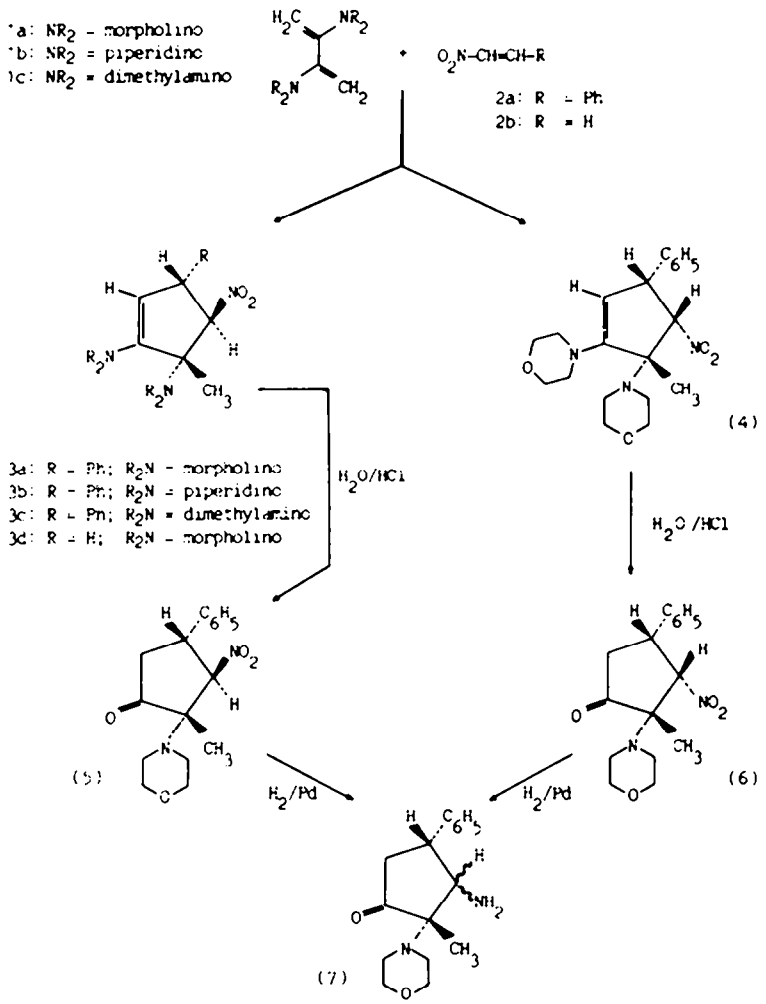
The number and size of the substituents at the cyclopentene ring make the molecule an overcrowded one, as inferred also from the numerous intra-

Table 1. Spectral data of compounds 3–7

Compound no.	IR [cm^{-1}]			^{1}H-NMR [δ]							^{13}C-NMR [δ] [$CDCl_3$]					
	NO_2	C≡CN	CO	Solvent	Me	H-2	H-3	H-4	J_{2-3}	J_{3-4}	Me	C-1	C-2	C-3	C-4	C-5
3a	1535	1620		$CDCl_3$	1.45	4.49	4.58	5.16	2	7	19.0	150.1	99.7	48.0	94.7	73.8
				C_6D_6	1.23	4.10	4.62	5.14	2	7.5						
3b	1540	1620		$CDCl_3$	1.45	4.31	4.54	5.13	1.8	7						
				C_6D_6	1.35	4.17	4.66	5.25	2	7						
3c	1550	1625		C_6D_6	1.35	4.00	4.67	5.05	2	6.5						
3d	1545	1630		C_6D_6	1.21	4.25	2.7*; 2.9	4.95	2.5	4; 8	18.4	149.4	99.7	32.1	86.0	74.2
4	1540	1630		C_6D_6	1.50	4.30	4.73	4.39	1.5	9	25.4	150.5	99.1	45.9	104.7	72.1
5	1550		1750	$CDCl_3$	1.26	3.0*†	4.00	5.41	9; 13	10	14.8	191.2	43.0	40.8	92.4	72.9
6	1540		1745	$CDCl_3$	1.50	*	*	6.30	*	9	11.4	203.9	44.6	42.9	94.2	71.2
7				C_6D_6	0.99	2.3*	3.27	2.5*			13.2	216.1	44.4	46.3	59.5	70.8

* Uncertain owing to overlap by morpholine signals.

† J_{gem} = 17



Scheme 1.

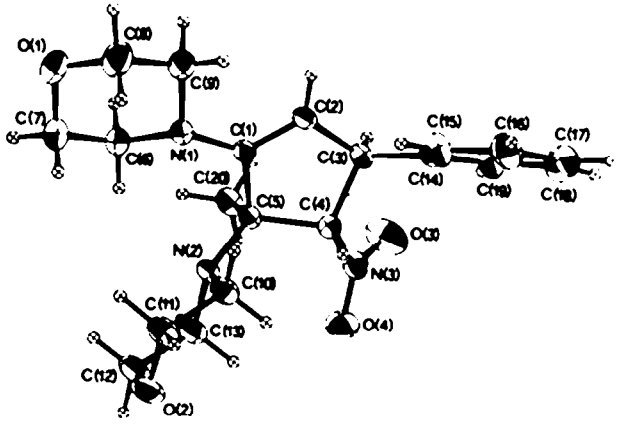


Fig. 1.

molecular contacts less than the sum of van der Waals radii (Table 4). On the other hand, there are no unusually short intermolecular distances and the packing appears to be due only to dispersion forces. Among the molecular deformations that help to relieve the steric hindrance, of particular note are (i) the lengthening of the C(4)–C(5) bond to 1.578(2) Å, to be compared with 1.541(3) Å, the normal $C(sp^3)-C(sp^3)$ bond distance,[4] and with 1.546(35) Å, the value of the corresponding bond length in the unsubstituted cyclopentene molecule;[5] (ii) the considerable twist, ~5°, around the C(1)–C(2) double bond, as measured by the torsion angle N(1)–C(1)–C(2)–C(3); and (iii) the enlargement of

Table 2. Final positional parameters for non-H atoms of 3d with estimated standard deviations in parentheses

Atom	x	y	z
C(1)	0.1904(2)	0.38201(9)	0.61837(7)
C(2)	0.2475(2)	0.44736(10)	0.62425(8)
C(3)	0.4018(2)	0.45781(10)	0.59827(8)
C(4)	0.4499(2)	0.38015(9)	0.59011(7)
C(5)	0.2975(2)	0.33497(10)	0.58380(7)
C(6)	-0.0415(2)	0.30567(11)	0.60940(10)
C(7)	-0.1554(3)	0.27021(12)	0.64604(11)
C(8)	-0.1525(3)	0.36551(13)	0.70612(11)
C(9)	-0.0378(3)	0.40468(11)	0.67122(10)
C(10)	0.3531(3)	0.25608(10)	0.66123(8)
C(11)	0.3037(3)	0.18448(11)	0.68370(9)
C(12)	0.3154(3)	0.13459(10)	0.59781(10)
C(13)	0.3663(3)	0.20437(11)	0.57357(9)
C(14)	0.5181(2)	0.50094(9)	0.63017(8)
C(15)	0.5138(3)	0.50535(11)	0.68584(9)
C(16)	0.6235(3)	0.54362(12)	0.71449(9)
C(17)	0.7401(3)	0.57729(11)	0.68743(10)
C(18)	0.7459(3)	0.57416(12)	0.63219(10)
C(19)	0.6359(3)	0.53674(11)	0.69356(9)
C(20)	0.2449(3)	0.33622(11)	0.52436(8)
N(1)	0.0558(2)	0.35431(8)	0.64084(7)
N(2)	0.3015(2)	0.26244(7)	0.60527(6)
N(3)	0.5588(2)	0.36932(9)	0.54351(7)
O(1)	-0.2485(2)	0.32018(9)	0.67444(8)
O(2)	0.3641(2)	0.12771(7)	0.65242(6)
O(3)	0.5772(2)	0.41596(9)	0.51037(7)
O(4)	0.6231(2)	0.31207(8)	0.54054(7)

Table 3. Selected portion of the molecular geometry of 3a with estimated standard deviations in parentheses

a) Bond lengths (Å)

C(1)-C(2)	1.331(3)	C(1)-N(1)	1.393(2)
C(2)-C(3)	1.497(3)	C(5)-C(20)	1.535(3)
C(3)-C(4)	1.529(2)	C(5)-N(2)	1.461(2)
C(4)-C(5)	1.578(3)	C(4)-N(3)	1.501(2)
C(5)-C(1)	1.539(3)	C(3)-C(14)	1.513(3)

b) Bond angles (°)

C(2)-C(1)-C(5)	111.4(2)	C(4)-C(5)-C(20)	109.6(2)
C(2)-C(1)-N(1)	127.8(2)	C(1)-C(5)-N(2)	110.4(1)
C(5)-C(1)-N(1)	120.8(2)	C(1)-C(5)-C(20)	109.9(2)
C(1)-C(2)-C(3)	114.0(2)	C(20)-C(5)-N(2)	111.6(2)
C(2)-C(3)-C(4)	100.1(2)	C(1)-N(1)-C(6)	120.3(2)
C(2)-C(3)-C(14)	116.3(2)	C(1)-N(1)-C(9)	115.5(2)
C(4)-C(3)-C(14)	113.4(2)	C(3)-C(14)-C(15)	122.2(2)
C(3)-C(4)-C(5)	107.3(1)	C(3)-C(14)-C(19)	120.2(2)
C(3)-C(4)-N(3)	113.7(2)	C(4)-N(3)-O(3)	120.2(2)
C(5)-C(4)-N(3)	112.2(1)	C(4)-N(3)-O(4)	117.1(2)
C(4)-C(5)-C(1)	98.2(1)	C(5)-N(2)-C(10)	115.3(1)
C(4)-C(5)-N(2)	116.4(1)	C(5)-N(2)-C(13)	120.9(2)

c) Torsion angles (°)

C(5)-C(1)-C(2)-C(3)	-2.4(2)	C(2)-C(3)-C(4)-C(5)	28.1(1)
N(1)-C(1)-C(2)-C(3)	175.1(1)	C(2)-C(3)-C(4)-N(3)	152.8(1)
C(2)-C(1)-C(5)-C(4)	19.3(1)	C(14)-C(3)-C(4)-C(5)	152.7(1)
C(2)-C(1)-C(5)-C(20)	-95.0(1)	C(14)-C(3)-C(4)-N(3)	-82.6(1)
C(2)-C(1)-C(5)-N(2)	141.5(1)	C(3)-C(4)-C(5)-C(1)	-29.0(1)
N(1)-C(1)-C(5)-C(4)	-158.4(1)	C(3)-C(4)-C(5)-C(20)	85.6(1)
N(1)-C(1)-C(5)-C(20)	87.3(2)	C(3)-C(4)-C(5)-N(2)	-146.7(1)
N(1)-C(1)-C(5)-N(2)	-36.1(2)	N(3)-C(4)-C(5)-C(1)	-154.6(1)
C(1)-C(2)-C(3)-C(4)	-16.4(2)	N(3)-C(4)-C(5)-C(20)	-39.9(2)
C(1)-C(2)-C(3)-C(14)	-138.9(1)	N(3)-C(4)-C(5)-N(2)	87.8(1)

Table 4. Relevant intramolecular contacts (Å) for 3a. Estimated standard deviations are in parentheses

C(6) ... C(20)	3.300(4)	C(20) ... H(6B)	2.81(2)
C(6) ... N(2)	3.085(3)	C(20) ... H(13A)	2.58(2)
C(6) ... H(20A)	2.74(2)	N(2) ... H(6B)	2.40(2)
C(9) ... H(2)	2.64(2)	O(3) ... H(3)	2.38(2)
C(13) ... C(20)	2.950(3)	O(4) ... H(13B)	2.46(2)
C(13) ... O(4)	3.115(3)	H(2) ... H(9A)	2.19(3)
C(13) ... H(20C)	2.71(2)	H(4) ... H(10B)	2.28(2)
C(19) ... O(3)	3.268(3)	H(6B) ... H(20A)	2.18(3)
C(20) ... N(3)	2.831(4)	H(13A) ... H(20C)	2.15(3)

Table 5. Deviations (Å) from least-squares planes[a] through atoms of the cyclopentene ring in molecule 3a. Atoms marked with an asterisk define the plane; the remaining atoms were omitted from the least-squares calculations

Plane A				Plane B			
C(3)*	0.000	H(3)	-0.94(1)	C(1)*	-0.012(1)	H(3)	0.92(1)
C(4)*	0.000	C(14)	0.637(3)	C(2)*	0.012(1)	C(14)	-0.880(3)
C(5)*	0.000	N(3)	-1.131(4)	C(3)*	-0.007(1)	C(4)	-0.472(2)
C(1)	0.739(4)	H(4)	0.78(1)	C(5)*	0.006(1)	H(4)	-1.43(1)
N(1)	1.391(6)	C(20)	-1.442(3)	N(1)	-0.097(3)	N(3)	-0.007(4)
C(2)	0.695(4)	N(2)	0.718(3)	C(6)	0.660(4)	C(20)	1.447(3)
H(2)	1.00(1)			C(9)	-0.064(4)	N(2)	-0.865(2)
				H(2)	0.09(1)		

Plane A: $-0.21\underline{x} - 2.69\underline{y} + 24.397\underline{z} - 13.28 = 0$

Plane B: $-3.98\underline{x} + 5.70\underline{y} - 20.60\underline{z} + 11.31 = 0$

Dihedral angle (°): A ^ B 30.8(1)

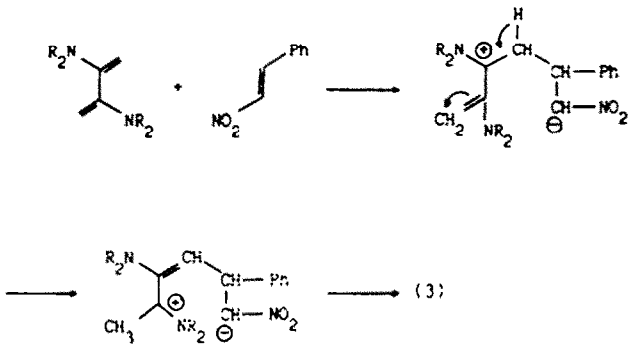
[a] Equations of least-squares planes are in the form: $A\underline{x} + B\underline{y} + C\underline{z} + D = 0$, where $\underline{x}$, $\underline{y}$, $\underline{z}$ are fractional coordinates.

the angles external to the morpholino rings at atoms N(1) and N(2), for which the values here measured, in the range 115.3–120.8°, are significantly larger than those found in other overcrowded molecules containing morpholino groups: for example, in 1-(4-bromobenzoyl)-2,5-dimethyl-4-morpholino-5-phenyl-4,5-dihydroimidazole, values of 112.4(2)° and 111.5(2)° were determined[6] for the corresponding angles.

The conformation of the cyclopentene ring can be defined by the puckering parameters[3] $Q_2 = 0.300$ and $\phi_2 = 175.3$ or, perhaps more efficiently, by the dihedral angle between the planes C(1)–C(2)–C(3)–C(5) and C(3)–C(4)–C(5) (i.e. the planes A and B of Table 5). The value found in the present study, 30.8(1)°, agrees well with that determined by electron diffraction[5] in cyclopentene, 29.0 ± 2.5°. Rather smaller values were found for this angle by far IR spectroscopic measurements [23.3° (Ref. 7) and 22.1° (Ref. 8)] or microwave spectroscopy [22.3° (Ref. 9)], while a large variety of values is reported for X-ray diffraction studies of cyclopentene derivatives. Indeed, lack of stiffness in the 5-membered ring is often encountered in the crystal state for this class of compounds: in 1,2-diphenylcyclopentene, for instance, Bernstein[10] found anomalously high values for the temperature factors on the methylene carbons, a possible indication of partial disorder in the ring, where the pattern of deviations of atoms from the best plane is consistent with approximate C_s symmetry corresponding to the "envelope" conformation, with a dihedral angle of 17.2°. Even a planar conformation was experimentally found[11] for the cyclopentene ring, in 5-vitacid, the 5-membered ring analogue of vitamin-A acid, but this finding, according to the author, "is probably not real but simulated by disorder".

The configurations of 3b and 3c were assigned by analogy and are well consistent with the relative ^{1}H-NMR chemical shifts and coupling constants. For compound 3d the same configuration about the C4–C5 bond was assigned owing to the similarity of the chemical shifts and coupling constants for the Me and $CHNO_2$ groups both in the ^{1}H- and in the ^{13}C-NMR spectra.

For the minor isomer (4) the configuration indicated in the Scheme has been assigned mainly on the



Scheme 2.

basis of the results of the hydrolysis and hydrogenation reactions (see below).

According to their enamine character both **3a** and **4** were readily hydrolized by acid to the corresponding cyclopentanone derivatives **5** and **6**, respectively, in which the configuration of the starting enamine should be retained. By catalytic hydrogenation of **5** and **6** the same amine **7** was formed, as demonstrated by the identity of physical and spectroscopic properties and by the formation of the same methiodide on reaction with excess methyl iodide. This result can be taken as a demonstration of the correctness of the structural assignment for the enamine **4** and the corresponding ketone **6**, since it is known that the hydrogenation of aliphatic nitro compounds occurs through an oxime intermediate[12] and this allows the configurational inversion at C-4, whereas a configurational change at C-3 and C-5 would require a complicated and improbable pathway. The configuration at the $CHNH_2$ group in **7** remains uncertain owing to the interpretation difficulties of the ^{1}H-NMR spectra which are complicated by the overlapping of signals with those of the morpholine residue.

As indicated before, the enamines **1** failed to undergo Diels–Alder cyclo-addition reaction with several dienophiles. Although such reactions are known with butadiene enamines, as for instance, 1-amino-1,3-butadienes,[13] the unsatisfactory reactivity of **1a–c** can very likely be explained by the difficulty of the diene to achieve a *cisoid* conformation because of the severe steric interference between the two bulky amine residues, which is clearly evidenced in molecular models. In turn, this situation should favour the non-concerted addition of the electron-rich enamine to the strongly deficient nitroalkene. The reactions of other enamines with nitroalkenes are well known and fully investigated.[14]

In the present case the dipolar intermediate **8** which is generated by the attack of the enamine carbon to the activated double bond and which is extensively stabilized by resonance undergoes isomerization and cyclization to a cyclopentene ring (Scheme 2). During this process the stereochemistry of the nitroalkene double bond is lost and this leads both to the less hindered **3** and to the more hindered **4** diastereoisomers.

EXPERIMENTAL

M.ps are not corrected. IR spectra were obtained with a Perkin–Elmer 197 instrument. ^{1}H-NMR spectra were recorded on a Varian 360 A spectrometer at 60 MHz; ^{13}C-NMR spectra were recorded on a CFT-20 Varian instrument in $CDCl_3$ solns; all assignments were confirmed by off-resonance experiments. Chemical shifts are given in ppm from Me_4Si. Column chromatography was run on silica gel with the eluent indicated.

1, 5 - *Dimorpholino* - *t* - 5 - *methyl* - *t* - 4 - *nitro* - *r* - 3 - *phenyl* - *cyclopentene* (**3a**) *and* 1, 5 - *dimorpholino* - *t* - 5 - *methyl* - *c* - 4 - *nitro* - *r* - 3 - *phenyl* - *cyclopentene* (**4**). Compound **1a** (8.80 g, 0.04 mol) was dissolved in anhyd THF (60 ml) and a soln of *E*-2-nitrostyrene (5.96 g, 0.04 mol) in anhyd THF (40 ml) was added dropwise with stirring and at room temp. The mixture was stirred at room temp for 24–48 hr. The solvent was evaporated and the crude oily residue was crystallized by addition of diisopropyl ether, yielding a first crop of light yellow powder, which was recrystallized from diisopropyl ether yielding pure **3a**, m.p. 135–137° (7.7 g, 51% yield). (Found: C, 64.6; H, 7.5; N, 11.4. $C_{20}H_{27}N_3O_4$ requires: C, 64.3; H, 7.3; N, 11.25%). MS: *m/z* 373 (M$^+$); 327 (M-NO_2); 240 (M-NO_2-morpholino); 155 (M-NO_2-2-morpholino).

From the mother liquor of **3a**, on standing, a second crop was obtained and purified by recrystallization from diisopropyl ether yielding **4**, m.p. 128–130° (2.3 g, 15% yield). (Found: C, 64.35; H, 7.65; N, 11.35. $C_{20}H_{27}N_3O_4$ requires: C, 64.3; H, 7.3; N, 11.25%). Further standing of the mother liquor yielded another amount of **3a** (0.2 g).

1, 5 - *Dipiperidino* - *t* - 5 - *methyl* - *t* - 4 - *nitro* - *r* - 3 - *phenyl* - *cyclopentene* (**3b**). The enamine **1b** (0.43 g, 2 mmol) was dissolved in anhyd THF (5 ml) and 2-nitrostyrene (0.35 g, 2 mmol) in THF (5 ml) was added. The mixture was stirred for 6 hr at room temp and evaporated. The oily residue contained both **3b** and its isomer (^{1}H-NMR) and was chromatographed on a silica gel column (EtOAc/benzene, 2:3) yielding pure **3b** as an oil which solidified on standing. By adding n-pentane a dark yellow crystalline product was formed, m.p. 89–91° (0.15 g, 20% yield). (Found: C, 71.2; H, 8.15; N, 11.15. $C_{22}H_{31}N_3O_2$ requires: C, 71.5; H, 8.45; N, 11.35%). MS: *m/z* 369 (M$^+$); 323 (M-NO_2); 238 (M-NO_2-piperidino); 155 (M-NO_2-2-piperidino).

1, 5 - *Bis* - *dimethylamino* - *t* - 5 - *methyl* - *t* - 4 - *nitro* - *r* - 3 - *phenyl* - *cyclopentene* (**3c**). A soln of **1c** (1.6 g, 11 mmol) in anhyd THF (12 ml) was mixed with THF (10 ml) soln of β-nitrostyrene (1.7 g, 11 mmol) and stirred at room temp for 24 hr. After evaporation a dark red oil was obtained which was purified by chromatography on a silica gel column (EtOAc/benzene, 1:4) yielding pure **3c** as an orange oil which could not be distilled without decomposition (0.74 g, 32% yield). (Found: C, 66.7; H, 8.25; N, 14.15. $C_{16}H_{23}N_3O_2$ requires: C, 66.4; H, 8.0; N, 14.5%). MS: *m/z* 289 (M$^+$); 243 (M-NO_2); 198 (M-NO_2-Me_2N); 155 (M-NO_2-2Me_2N).

1, 5 - *Dimorpholino* - *c* - 5 - *methyl* - *r* - 4 - *nitro* - *cyclopentene* (**3d**). The enamine **1a** (5 g, 23 mmol) was dissolved in anhyd THF (15 ml) and a THF soln (10 ml) of **2b** (1.66 g, 26 mmol) was slowly added dropwise. The reaction was exothermic and was complete in 30 min at

room temp. The mixture was evaporated and the dark red oily residue was chromatographed on a silica gel column (EtOAc/benzene, 1:4). By evaporation of the main fraction 3d was obtained as a red oil which solidified on addition of n-pentane, m.p. 113–115° dec., (1.3 g, 19% yield). (Found: C, 56.3; H, 7.95; N, 14.2 $C_{16}H_{21}N_3O_4$ requires: C, 56.55; H, 7.75; N, 14.15%).

r - 2 - Methyl - 2 - morpholino - c - 3 - nitro - t - 4 - phenyl-cyclopentanone (5). The enamine 3a (1.0 g, 2.7 mmol) was dissolved in MeOH (10 ml) and 37% HCl was added (0.5 ml). The mixture was stirred at room temp for 48 hr. A solid product separated slowly during this period. Without filtration the mixture was evaporated and the residue was treated with water and extracted several times with $CHCl_3$. After evaporation the residue was recrystallized from diisopropyl ether yielding pure 5, m.p. 111–113° (0.8 g, 97% yield). (Found: C, 63.25; H, 6.9; N, 9.2. $C_{16}H_{20}N_2O_4$ requires: C, 63.15; H, 6.6; N, 9.2%).

r - 2 - Methyl - 2 - morpholino - t - 3 - nitro - t - 4 - phenyl-cyclopentanone (6). The hydrolysis of 4 was performed as described above for 3a, starting from 2 g (5.4 mmol) of 4. After evaporation of the chloroform extract 6 was obtained as a crystalline solid which was recrystallized from diisopropyl ether, m.p. 147–150° (syntherizes around 130°) (0.57 g, 35% yield). (Found: C, 63.45; H, 6.4; N, 8.95. $C_{16}H_{20}N_2O_4$ requires: C, 63.15; H, 6.6; N, 9.2%).

r - 2 - Methyl - 2 - morpholino - 3 - amino - t - 4 - phenyl-cyclopentanone (7). The nitroketone 5 or 6, respectively (1.0 g, 3.3 mmol) was hydrogenated in MeOH soln (20 ml) containing 37% HCl (0.5 ml) with Pd-C (5%) (0.12 g) as catalyst. The reaction was performed at room temp and at normal pressure to consumption of the calculated amount of H_2. The mixure was filtered, evaporated and the oily residue was taken up with NaOH aq (to pH = 8–9) and extracted with diethyl ether. After evaporation the solid residue was recrystallized from diisopropyl ether yielding pure 7, m.p. 107–110° (0.41 g, 48% yield). (Found: C, 74.1; H, 8.35; N, 10.7. $C_{16}H_{22}N_2O$ requires: C, 74.4; H, 8.5; N, 10.85%).

Compound 7 reacted with MeI in acetonitrile yielding a crystalline quaternary ammonium iodide, m.p. 142–144°. (Found: C, 53.0; H, 6.6; N, 6.2. $C_{16}H_{29}IN_2O$ requires: C, 53.25; H, 6.8; N, 6.55%).

X-ray analysis of 3a. Crystals suitable for single crystal X-ray diffraction were obtained by slow evaporation of an isopropanol soln.

Crystal data. For $C_{20}H_{27}N_3O_4$: Mol wt. 373.5; orthorhombic, a = 8.671(2) Å, b = 18.768(3) Å, c = 24.660 (3) Å, V = 4013(1) Å^3, Z = 8, ρ_{obs} = 1.23 g cm^{-3} (flotation in a dilute K_2HgI_4 soln), ρ_{calc} = 1.236 g cm^{-3}, F(000) = 1600; space group *Pbca* (D_{2h}^{15}, No. 61); MoKα radiation (graphite monochromator) λ = 0.71073 Å, μ(MoKα) = 0.812 cm^{-1}; room temp (293 ± 2 K).

Data collection and reduction. A crystal of approximate dimensions 0.28 × 0.27 × 0.15 mm was accurately centered on an Enraf–Nonius CAD-4 diffractometer. The orientation matrix for data collection and the unit cell parameters reported above were obtained from a least squares treatment of the automatically determined setting angles of 25 reflections with 2θ values in the range $19.5 < 2\theta < 23.8$.

The space group *Pbca* was indicated by the absence of reflections $0kl$ with k odd, $h0l$ with l odd and $hk0$ with h odd.

The intensity of all accessible reflections with $2\theta < 50°$ were measured by variable-rate ω-scan technique. The periodic measurement of three standard reflections showed no appreciable trend. Out of 3519 independent reflections measured, 640 having $I < 0$ were assigned zero weight; all other reflections were assigned variances $\sigma^2(I)$ based on counting statistics plus the additional term $(0.025\,S)^2$, where S is the scan count. Diffraction data were corrected for Lorentz and polarization factors but not for absorption.

The structure was solved by direct methods using the program MULTAN[13] and refined by least-squares techniques. The 27 H atoms were located in difference maps during the course of the refinement, which was by minimization of the quantity $\Sigma w(\Delta F)^2$, with weights $w = 4F_o^2/\sigma^2(F_o^2)$ for the 2879 reflections classified as observed. In the final cycles 353 parameters were simultaneously adjusted: coordinates and anisotropic temperature coefficients for 27 heavy atoms, coordinates and isotropic temperature factors for 27 hydrogen atoms, a scale factor, and a secondary extinction coefficient g. The final results are $R = 0.093$ and $R_w = 0.042$ for the 2879 reflections employed in the refinement [$R = 0.034$ and $R_w = 0.035$ on the 1644 reflections with $F^2 > 2\sigma(F^2)$]. The goodness-of-fit, defined as $[\Sigma w(\Delta F)^2/(m-s)]^{1/2}$, where m is the number of observations and s the number of parameters, is 1.23. Atomic scattering factors were from ref. 4. Final atomic parameters are given in Table 2;† the final value of the extinction coefficient g is $1.18(9) \times 10^{-7}$. The values of the molecular geometry relevant to the discussion are reported in Table 3, 4 and 5; the molecule as viewed along the c axis is shown in the Fig.

†Lists of positional and thermal parameters, as well as Tables of structure factors and full molecular geometry have been deposited with Cambridge Crystallografic Data Centre, Lensfield Road, Cambridge CB2 1EW, England.

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