Reactions of (*E*)-3,3,3-trichloro(trifluoro)-1-nitropropenes with enamines derived from cycloalkanones. A new type of ring-chain tautomerism in a series of cyclobutane derivatives and stereochemistry of the products

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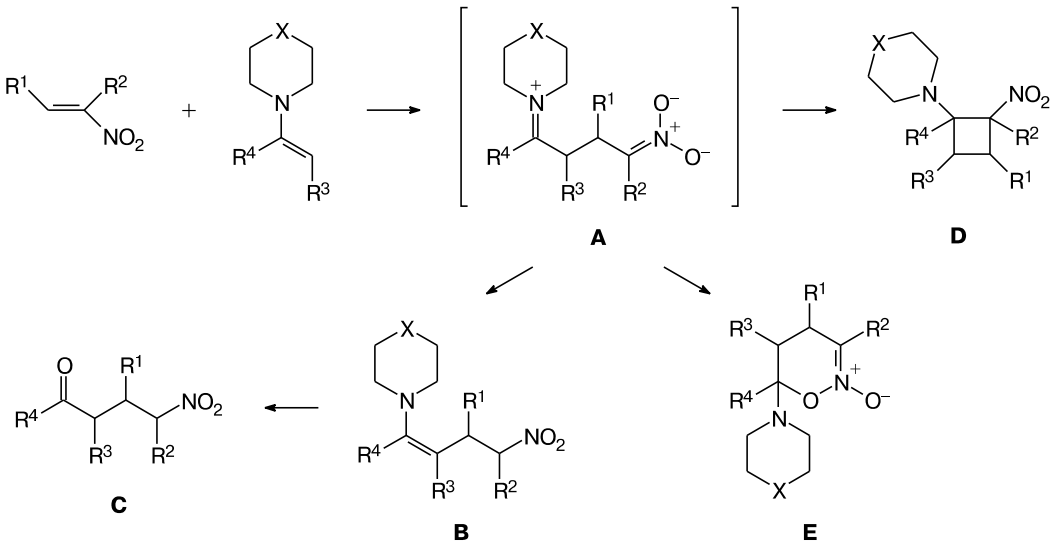
Depending on the reaction conditions, the reactions of (*E*)-3,3,3-trichloro-1-nitropropene with cyclohexanone enamines led to bicyclo[4.2.0]octanes or trisubstituted enamines, which are the ring-chain tautomers capable of reversible transformations. Diastereoselectivity of the reactions of (*E*)-3,3,3-trichloro(trifluoro)-1-nitropropenes with cycloalkanone enamines were studied, a series of hitherto unknown CX_3-containing nitroalkylated enamines and γ-nitro ketones were synthesized, the structures of novel compounds were determined by NMR spectroscopy and X-ray diffraction.

Key words: 3,3,3-trihalo-1-nitropropenes, enamines, cyclobutanes, γ-nitro ketones, organofluorine and organochlorine compounds, X-ray diffraction.

Reactions of ketone enamines with conjugated nitroalkenes proceeds *via* nucleophilic 1,4-cycloaddition, which involved the diastereoselective C—C bond formation and resulted in dipolar intermediate **A**. This intermediate through the proton transfer usually provides nitroalkylated enamine **B**, which is readily hydrolyzed into γ-nitro ketone **C**.[1—3] However, depending on the nature of the reactants and the reaction conditions, the initially formed betaine **A** can give rise to the cyclic products, cyclobutanes **D** ([2+2] carbocyclization)[4—6] and 1,2-oxazine *N*-oxides **E** ([4+2] heterocyclization),[7—9] resulting from intramolecular attack of an iminium carbon atom onto the ambident nitronat anion (Scheme 1). The cycloaddition reactions have been studied in detail on the example of 1(2)-nitropropenes, α(β)-nitrostyrenes, and cycloalkanone enamines;[1—9] in some cases 1,2-oxazine *N*-oxides were isolated. These compounds are highly reactive 1,3-dipole species, which are able to add to

Scheme 1



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the multiple bonds and are readily react with nucleophiles.[10—13]

At the same time, the data on the reactions of polyhaloalkylated nitroolefins with enamines are scares. It is known[14—16] that they react with enamines of cycloalkanones, pinacoline, and acetophenone to give the corresponding nitroalkylated enamines and β-polyhalo-γ-nitro ketones, the promising starting material for the chemo- and stereoselective synthesis of the functionalized R^F- and CCl_3-containing carbinols.[15] Recently,[17] we have demonstrated that the reactions of ethyl 3-morpholinocrotonate with α-(trifluoroethylidene)nitroalkanes give the cyclobutane derivatives resulting from [2+2] carbocyclization, while in the case of α-(trichloroethylidene)nitroalkanes, products of nucleophilic 1,4-addition to the methyl group of enamine are formed.

In the present work, stereochemistry of reaction products of (*E*)-3,3,3-trichloro-1-nitro- and (*E*)-3,3,3-trifluoro-1-nitropropenes **1a**,**b** with enamines **2a**—**d** derived from cycloalkanones (cyclohexanone, cyclopentanone) and cyclic amines (*N*-methylpiperazine, morpholine, piperidine) were studied; a novel type of ring-chain tautomerism in a series of CCl_3-containing bicyclo[4.2.0]-octanes were found (see preliminary communication[18]).

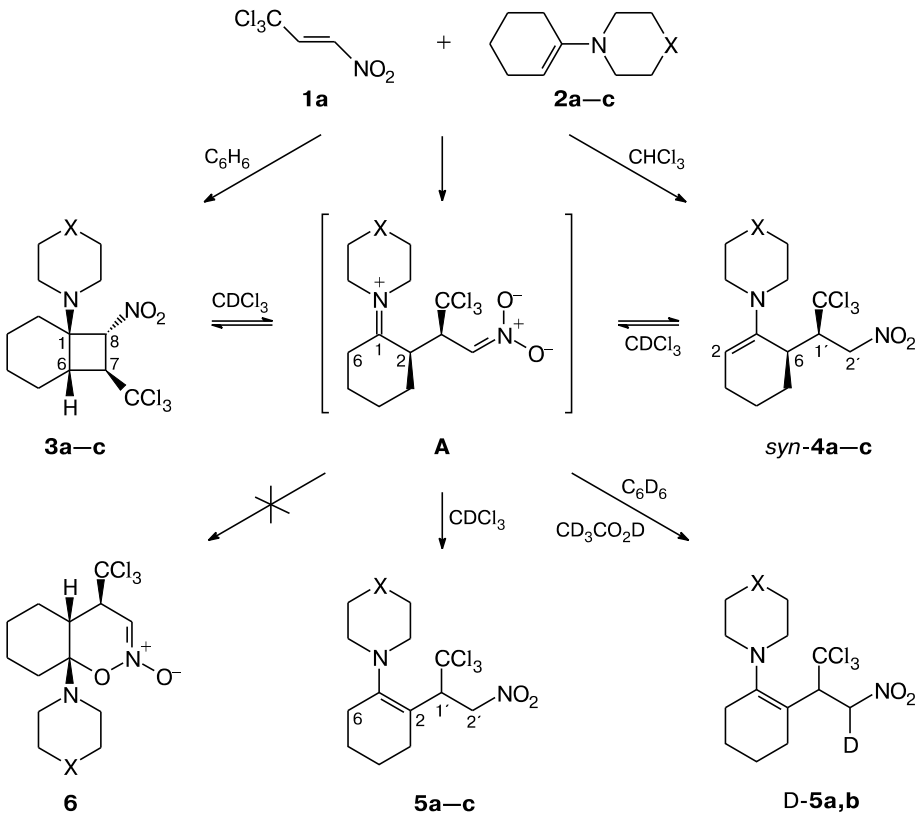
Results and Discussion

The data on the impact of the nature of substituents on ring-chain tautomeric equilibria of the reaction products of conjugated nitroalkenes with enamines are scares. The only known example is the tautomeric equilibrium between 1,2-oxazine *N*-oxides and the corresponding trisubstituted enamines synthesized based on 2-nitro-1-phenylpropene and cyclohexenyl amines.[19,20] It is worthy to note that earlier the ring opening of cyclobutane derivatives to give nitroalkylated enamines was considered irreversible.[4,5,21]

We found that the reaction of CCl_3-containing nitropropene **1a** with cyclohexanone enamines **2a**—**c** in anhydrous hexane at 10—15 °C for 15 min and at ~20 °C for 0.5 h under kinetic control resulted stereoselectively in substituted bicyclo[4.2.0]octanes **3a**—**c** in the yields of 61—76% (Scheme 2).

It should be emphasized that cyclobutanes **3** contain four stereogenic centers, but only one diastereomer was found in the crude product by ^{1}H NMR spectroscopy. Stereochemistry of cyclobutane **3b** was unambiguously confirmed by X-ray diffraction[18] being in good agreement with the known data[22,23] for related molecules. Structures

Scheme 2



X = NMe (**a**), O (**b**), CH_2 (**c**)

of compounds **3a**,**c** were established by comparison of their ^{1}H NMR spectra with that of compound **3b** in C_6D_6, in freshly prepared solution of the latter only signals for the cyclobutane form were found evidencing the relative stability of the obtained products in this solvent. All resonance signals were attributed based on 2D NMR experiments HSQC and HMBC. The characteristic feature of ^{1}H NMR spectra of cyclobutanes **3** are two low field signals of the H(7) (δ 3.76—3.81, dd, J = 9.8 Hz, J = 8.3 Hz) and H(8) protons (δ 4.83—4.90, d, J = 8.3 Hz).

When bicyclo[4.2.0]octanes **3a,b** were kept in the solution in anhydrous chloroform at ~20 °C for 2 h, they underwent ring opening to give trisubstituted *syn*-enamines **4a**,**b** (50—53%), compound **3c** yielded tetrasubstituted enamine **5c** (98%) within 2 days. Compounds **4a**,**b** can be obtained under the same conditions and in the same yields directly from nitroalkene **1a** and enamines **2a**,**b**, however pure trisubstituted enamine **4c** was not isolated due to its low stability. Regardless the synthesis procedure used, enamines **4a**,**b** always formed as one *syn*-diastereomer, which relative configuration (1′*R**,6*R**) was rigorously determined by X-ray diffraction of crystals of **4b**.[18] Morpholine-containing enamine **5b** was synthesized in nearly quantitative yield by keeping cyclobutane **3b** in solution in chloroform at ~20 °C for 2 days. Piperazine derivative **5a** was detected in the reaction mixture only by ^{1}H NMR spectroscopy. Pure tri- and tetrasubstituted enamines **4b** and **5b** were isolated only in one case, when *N*-cyclohexenylmorpholine (**2b**) was used as enamine.

The ^{1}H NMR spectra of compounds **5** exhibit no signals for the vinyl (H(2)) and the methyne (H(6)) protons characteristic of trisubstituted enamines **4**, and the most low field shifted signal of the methyne proton of the side chain (H(1′)) resonates as doublet of doublets at δ 5.9—6.0 with J = 10.5 Hz and J = 3.0 Hz. Unusually strong down field shift of this proton as compared to that of the same proton of trisubstituted enamines **4** (δ 3.6—3.7) can be explained by deshielding effect of the neighboring double bond; the spin-spin coupling constant values indicate in favor of conformations with *trans* and *gauche* arrangement of the hydrogen atoms.

Cyclobutanes **3a**—**c** are relatively stable compounds in the crystalline state and suitable for long term storage in refrigerator at −10 °C. However, in the $CDCl_3$ at room temperature, equilibrium between ring (**3a**—**c**) and chain (**4a**—**c**) tautomers are established. Enamines **4a**,**b** are also stable in the crystalline state, but being dissolved in $CDCl_3$, they spontaneously transform into cyclobutanes **3a**,**b** until thermodynamic equilibrium between cyclic and open forms is established. Since both direct and reverse reactions are diastereoselective and do not lead to the mixtures of stereoisomers, it is possible to suggest that the ring opening of the cyclobutane **3** and its formation from the open form **4** proceed *via* betaine **A**. This process was monitored by the ^{1}H NMR spectroscopy at 25 °C, the ratio of cyclic (**3**) and open (**4** and **5**) forms was determined by integration of well-resolved signals of the H(7) and H(8) ring protons and the H(1′) and H(2′) chain protons (see Scheme 2).

Almost immediately after dissolution of *N*-methylpiperazine derivative **3a** in $CDCl_3$, ^{1}H NMR spectrum exhibits signals of compounds **3a** and **4a** in a 90 : 10 ratio (Fig. 1, *a*). After 40 min, tautomeric mixture contains equal amounts of cyclobutane **3a** and enamine **4a** (Fig. 1, *b*), while after 280 min, the ratio of **3a** : **4b** was equal to 18 : 82 (Fig. 1, *c*) and did not change within 1 day. However, over time, the third product (**5a**) accumulates in the mixture indicating that under conditions used compounds **3a** and **4a** irreversibly isomerize into tetrasubstituted enamine **5a** (4% after 7 days and 7% after 2 weeks) *via* intermediate **A** (Fig. 2). It should be emphasized that tautomeric mixture of the same composition (**4a** : **3a** = 82 : 18) is also formed from pure *syn*-enamine **4a** upon keeping its solution in $CDCl_3$ for 290 min (Fig. 3, *a*—*c*).

In a series of morpholine derivatives, the monitoring of the ring opening of cyclobutane **3b** into trisubstituted enamine **4b** was complicated by formation of tetrasubsti-

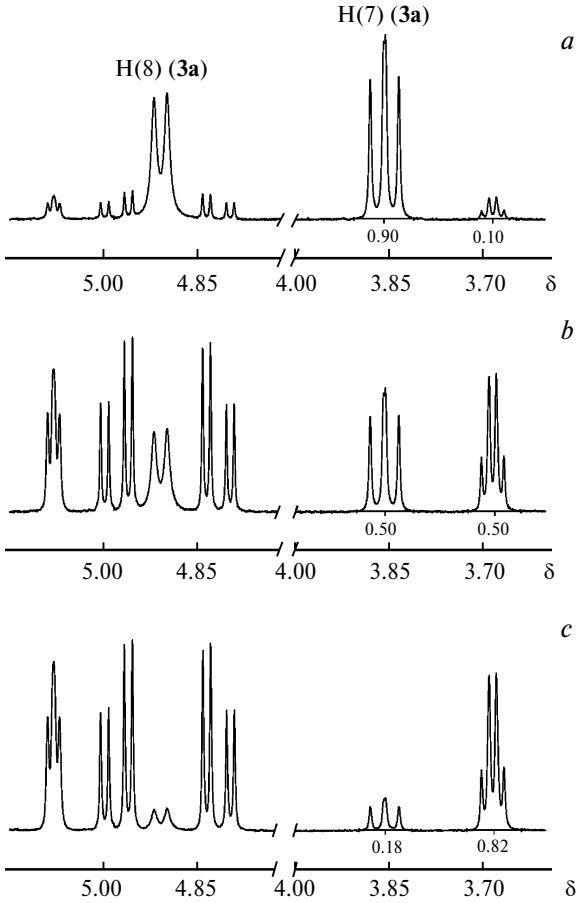


Fig. 1 ^{1}H NMR spectra of a mixture **3a** ⇄ **4a** after 3 (*a*), 40 (*b*), and 280 min (*c*) after dissolution of compound **3a**.

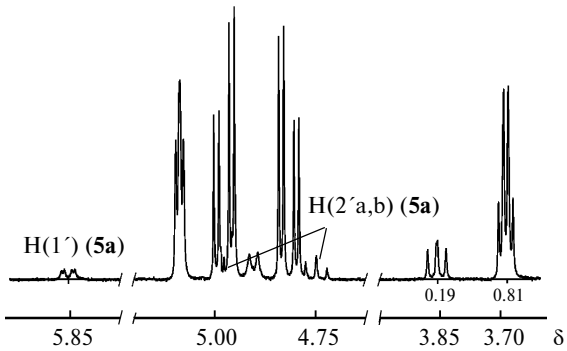


Fig. 2. ^{1}H NMR spectrum of a mixture **3a** ⇄ **4a** after 13 days.

tuted enamine **5b**, which was more rapid than the **3b** ⇄ **4b** equilibration. The third set of the signals (3%) attributed to enamine **5b** was observed 4 h after dissolution of compound **3b** in $CDCl_3$; within 24 h its content increased up to 44% and 48 h after **5b** was the only reaction product. It is occurred possible to establish the composition of the tautomeric equilibrium mixture for morpholine derivatives

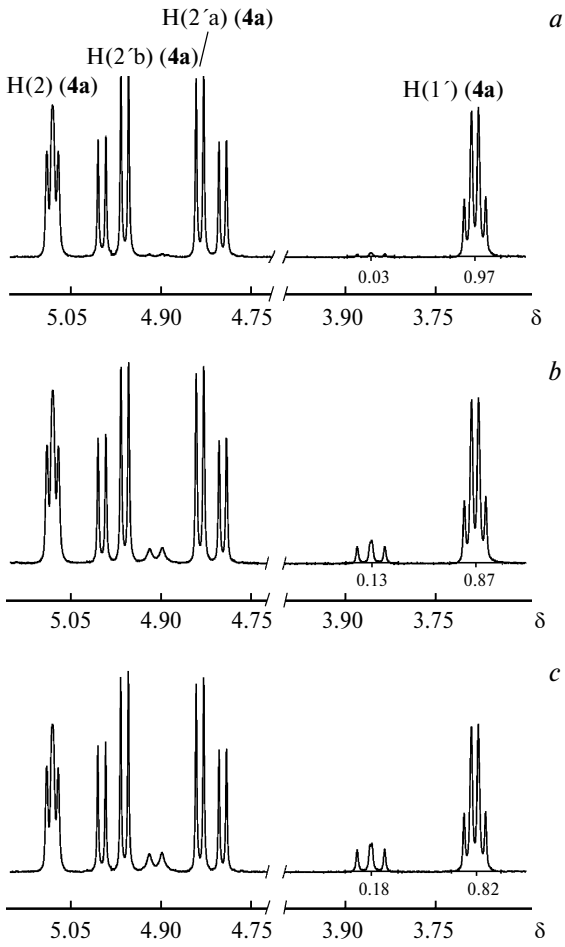


Fig. 3. ^{1}H NMR spectra of a mixture **4a** ⇄ **3a** after 3 (*a*), 60 (*b*), and 290 min (*c*) after dissolution of compound **4a**.

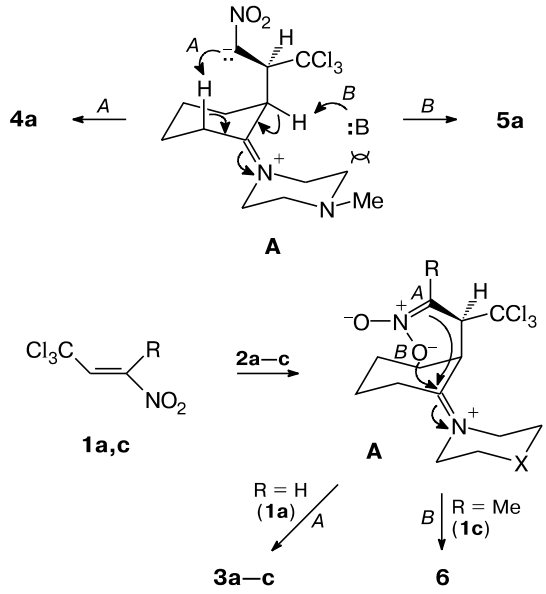
by studying the reverse reaction, namely, the ring closure of enamine **4b** to cyclobutane **3b**. As in the case of *N*-methylpiperazine derivatives, the equilibrium mixture contains **4b** : **3b** = 82 : 18 and equilibrium was achieved in 6 h. In the case of reverse reaction, the transformation of compound **4b** into product **5b** proceeds much slower (a ratio of **4b** : **3b** : **5b** = 64 : 20 : 16 was achieved after 32 h).

In studying the behavior of cyclobutane **3c** in the $CDCl_3$ solution by ^{1}H NMR spectroscopy it was found that the piperidine derivative is less stable and undergoes ring opening to give trisubstituted enamine **4c** more rapidly. The spectrum of cyclobutane **3c** recorded immediately after dissolution of the sample revealed the presence of compounds **3c** and **4c** in a ratio of 38 : 62, after 30 min as in the two previous cases, the ratio was already 18 : 82 and does not change over three next hours. Therefore, the content of more thermodynamically stable tetrasubstituted enamine **5c** increased to 3 and 14%, respectively 1 and 3 h after (see Scheme 2). Thus, the nature of amine has no effect on the ration of cyclic and opened tautomeric forms existing in the dynamic equilibrium, and the vast content of enamine **4** (82% in all three cases) is due to the highest stability of the open form as compared with cyclobutane form. The spectral study of tetrasubstituted enamines **5** in C_6D_6 and $CDCl_3$ indicates that these compounds are relatively stable in anhydrous solvent and do not involved in tautomerism or isomerism of any type.

These results clearly demonstrate a possibility of ring-chain tautomerism in a series of cyclobutane derivatives and are of special interest since no spontaneous formation of a strained cyclobutane system from acyclic precursor was earlier documented. As it was expected, the solvent nature strongly affected the rates of tautomeric equilibration of this type. Thus, equilibrium between compounds **3a** and **4a** is nearly completely shifted to the acyclic form **4a** immediately after dissolution of the sample **3a** in CD_3OD. Meanwhile, in non-polar C_6D_6, we found the mixtures **3a** : **4a** = 73 : 27 (from **3a**) and **4a** : **3a** = 93 : 7 (from **4a**) 24 h after dissolution (in $CDCl_3$, these ratios established within 15 and 30 min, respectively). It is noteworthy that addition of CD_3CO_2D to the solutions of **3a**,**b** in C_6D_6 accelerates their transformation into compounds **5a**,**b**. Thus, a solution of cyclobutane **3b** in C_6D_6 in the presence of CD_3CO_2D after 3 days contained only tetrasubstituted enamine **5b** as a mixture of approximately equal amounts of non-deuterated form **5b** and monodeuterated at the C(2′) of the side chain form D-**5b** (content of dideuterated product was no more than 5%). Interesting that form D-**5b** was represent by only one diastereomer indicating the stereoselectivity of deuteration (only the proton of the CH_2 group resonating in the strong field at δ 4.20 (J = 10.7 Hz) is replaced by deuterium, while the low field proton resonates, as it was expected, as a doublet at δ 4.40 (J = 3.0 Hz)).

Due to slow formation of *N*-methylpiperazine derivative **5a** (7 and 24% after 13 and 41 days, respectively), it was not isolated pure. Apparently, it can be explained by the fact that enamines **4** are formed from betaine **A** with axially oriented substituent[1] as a result of the intramolecular transfer of the axial proton H(6) (route *A*), while the intermolecular cleavage of the equatorial proton H(2) by the external base yielded enamines **5** (route *B*). In this case, *N*-methyl group in the piperazine intermediate **A** may hinder the approach of the base to the H(2) proton thus decreasing the formation rate of enamine **5a** (Scheme 3).

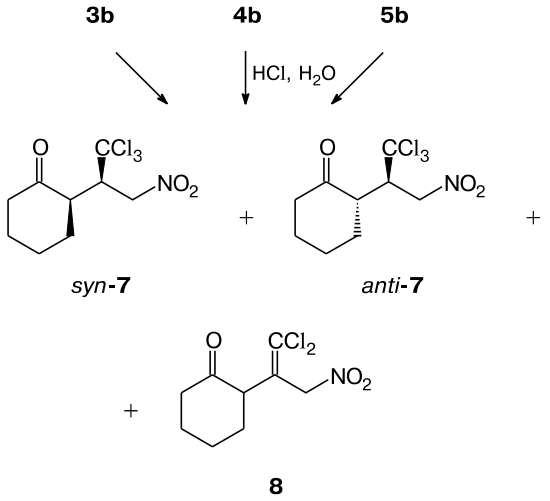
Scheme 3



It is also should be noticed that when cyclohexanone enamines **2** react with (*E*)-3,3,3-trichloro-1-nitropropene (**1a**) to give [2+2] cycloaddition adducts **3** (no cyclic nitronates **6** were found in any cases), their reactions with (*E*)-1,1,1-trichloro-3-nitro-2-butene (**1c**; R = Me) under the similar conditions proceed differently to yield [4+2] cycloaddition adducts, 3-methyl-4-trichloromethyl-1,2-oxazine *N*-oxides **6**.[16] The change in the direction of reaction with nitrobutene **1c** is due apparently to the presence of the methyl group hindering the approach of the carbanion to the iminium carbon atom and favors its attack by the oxygen atom of the ambident nitronate anoin (see Scheme 3).

On the next step of our research, we studied characteristic features of hydrolysis of tri- and tetrasubstituted CCl_3-containing enamines on the example of morpholine derivatives **4b** and **5b**. It was found that treatment of enamine **4b**, whose *syn* structure was determined by X-ray diffraction,[18] with diluted HCl in EtOH at 40 °C for 4 h resulted in *syn*-γ-nitro ketone **7** (yield was 55%) containing 6% of *anti*-γ-nitro ketone **7** as an impurity. Apparently, these conditions are non-epimerization towards the resulting ketone and formation of small amount of *anti*-isomer **7** can be due to relatively fast isomerization of **4b** into **5b**. From the viewpoint of stereoselective ring opening of cyclobutanes **3** into *syn*-enamines **4**, it is not surprising that cyclobutane **3b** is also hydrolyzes to *syn*-ketone **7** ($CHCl_3$, HCl) containing 15% of dichloro ketone **8**. Detecting of the latter among the reaction products is evidenced the readiness of dehydrochlorination of γ-nitro ketones **7**. Indeed, treatment of enamine **5b** with morpholine excess (2 equiv.) in MeOH (40 °C, 40 h) led to pure dichloro ketone **8** in 41% yield (Scheme 4).

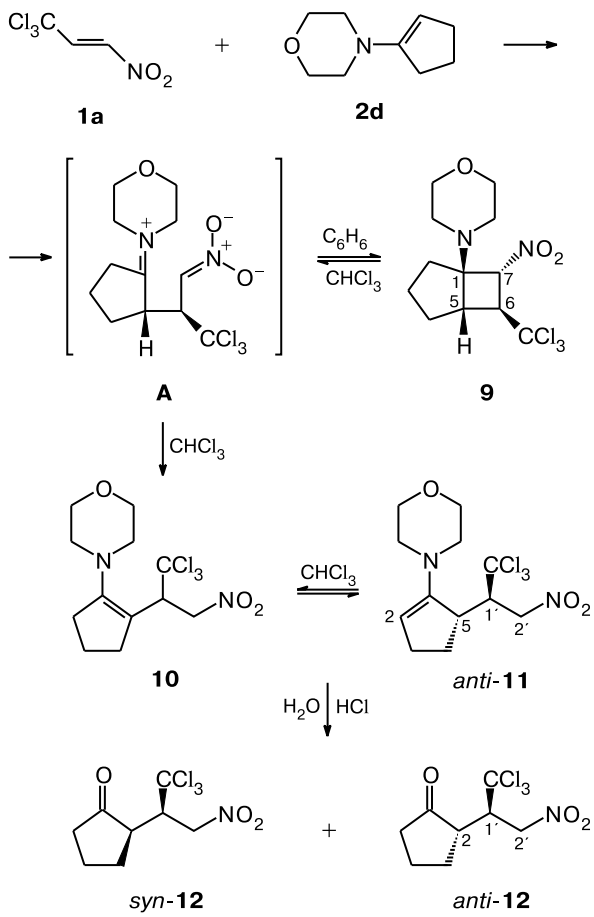
Scheme 4



Discovery of a new type of the ring-chain tautomerism in a series of the products of the reaction between CCl_3-containing nitroalkene **1a** with cyclohexanone enamines **2a—c** motivated us to study the similar reactions involving cyclopentanone morpholine enamine **2d**. It was found that in this case the reaction in anhydrous benzene (10 → 20 °C, 45 min) afforded bicyclo[3.2.0]heptane **9** in 78% yield. Stereochemistry of compound **9** was confirmed by X-ray diffraction (Fig. 4). Cyclobutane **9** is relatively stable in the solid state and in solution in C_6D_6; while in solutions in $CDCl_3$ at 25 °C, it undergoes the ring opening to give a mixture of tri- and tetrasubstituted enamines **10** and *anti*-**11** (Scheme 5). Detailed study of this transformation in the NMR tube revealed that enamine **10** (5%) is appeared first immediately after dissolution of compound **9** in $CDCl_3$. Over time, as cyclobutane **9** is disappeared trisubstituted *anti*-enamine **11** begins to accumulate, along with tetrasubstituted enamine **10** (Table 1). Equilibrium between tri- and tetrasubstituted enamines of cyclopentene series has been observed previously.[24,25]

Initially formed enamine **10** isomerizes only into *anti*-enamine **11** indicating the selective protonation of the double bond in compound **10** and are in agreement with

Scheme 5



published data[8] on non-halogenated analogs. This fact excludes the participation of betaine **A** in isomerization, since in the latter case one can expect formation of *syn*-isomer. It is worthy to note that 1 day after in the studied solution, the product of hydrolysis, *anti*-ketone **12**, begins to accumulate, the content of which after 4 days increases to 7%. As could be expected (see Table 1), the reaction of *N*-cyclopentenylmorpholine (**2d**) with nitroalkene **1a** in chloroform (24 h, ~20 °C) results in a mixture of tetra- and trisubstituted enamines **10** and *anti*-**11** in a 3 : 2 ratio. The acid hydrolysis of this mixture (diluted HCl, 4 h, 50 °C) leads to a mixture of γ-nitro ketones **12** in the ratio of *anti*-**12** : *syn*-**12** = 3 : 1. Hydrolysis of cyclobutane **9** under the same conditions affords a similar mixture (see Scheme 5).

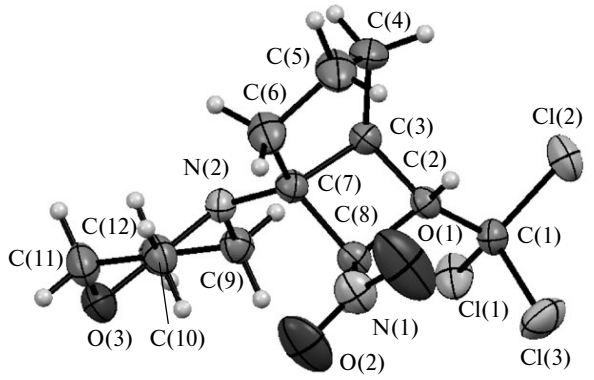


Fig. 4. Molecular structure of bicyclo[3.2.0]heptane **9**.

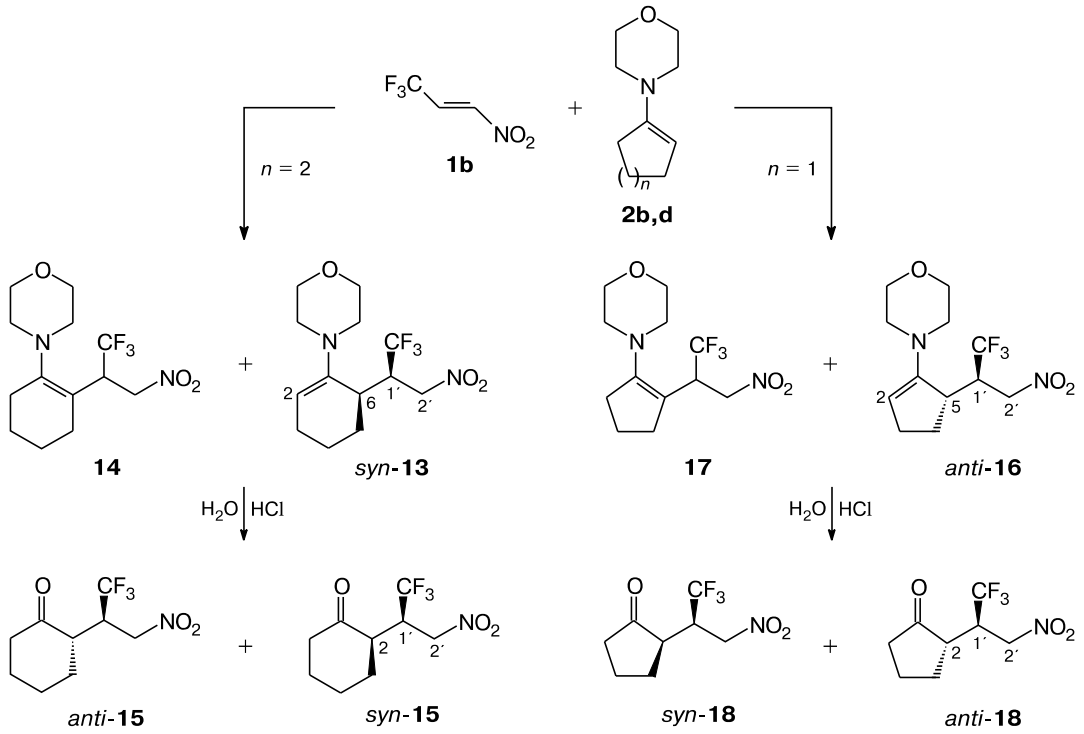
Table 1. Time dependent content of enamines **10**, *anti*-**11**, and *anti*-**12** at the ring opening of cyclobutane **9** in $CDCl_3$ solution (^1H NMR data)

Time	**9**	**10**	*anti*-**11**	*anti*-**12**
		%		
2 min	95	5	0	0
1 h	82	18	0	0
6 h	32	51	17	0
25 h	0	62	35	3
92 h	0	58	35	7

We believe that hydrolysis conditions used are non-epimerization one and formation of isomer *syn*-**12** is due to the presence of enamine **10** in the starting mixture. Hydrolysis of the latter proceeds non-stereoselectively to give ketones *syn*-**12** and *anti*-**12** in approximately equal amounts. Thus, on going from cyclohexenylamines **2a—c** to *N*-cyclopentenylmorpholine (**2d**), several significant changes are observed. First, there is no ring-chain tautomerism between cyclic (**9**) and open (**10** and **11**) forms of enamine. Second, the ring opening of cyclobutane **9** affords initially not tri- but tetrasubstituted enamine **10**, which is in equilibrium with trisubstituted enamine **11**. Third, compound **10** isomerizes stereoselectively into *anti*-enamine **11**, while in the case of cyclohexenyl derivatives trisubstituted *syn*-enamines **4a—c** are observed, which arise from the ring opening of cyclobutanes **3a—c** *via* a dipolar intermediate **A**.

Reaction of more reactive nitropropene **1b** bearing the CF_3 group instead of the CCl_3 group with *N*-cyclohexenylmorpholine (**2b**) (benzene, 2 h, ~20 °C) to give the corresponding cyclobutane derivative failed. In this case, filtration afforded only nitroalkylated *syn*-enamine **13** in 63% yield (this compound have been earlier synthesized from 2-diazo-1,1,1-trifluoro-3-nitropropane[26]) and distillation of the filtrate *in vacuo* furnished a colorless oil being an inseparable mixture containing tetrasubstituted enamine **14** with an admixture of *syn*-isomer **13** (18%) (total yield 26%) (Scheme 6). Note that performing the reaction of nitroalkene **1b** with enamine **2b** without solvent increases the yield of *syn*-**13** up to 86%. Acid hydrolysis of this compound under mild conditions (diluted HCl, 2 h, ~20 °C) is not accompanied by epimerization and afforded *syn*-nitro ketone **15** in 73% yield. The structure of compound **15** is determined by X-ray diffraction (Fig. 5). Epimer *anti*-**15** is detected in the mixture obtained by hydrolysis

Scheme 6



of **14** (diluted HCl, 2 h, 40 °C; *anti*-**15** : *syn*-**15** : **14** = = 46 : 45 : 9). Nitro ketone **15** have been described earlier,[14,26] however its *syn* configuration is first established.

We also performed the reaction of CF_3-containing nitroalkene **1b** with cyclopentanone enamine **2d** in chloroform (10 → 20 °C, 2 h) to obtain quantitatively a mixture of nitroalkylated enamines *anti*-**16** and **17** in a ratio of 3 : 1. Analogously to trichloromethylated compounds **10** and *anti*-**11**, it is possible to suggest initial formation of tetrasubstituted enamine **17**, which exists in equilibrium with trisubstituted enamine *anti*-**16** formed from the latter. Acid hydrolysis of this mixture (diluted HCl, 4 h, 50 °C) is accompanied by partial epimerization to give a mixture of approximately equal amounts of γ-nitro ketones *anti*-**18** and *syn*-**18** in the yield of 68% (see Scheme 6).

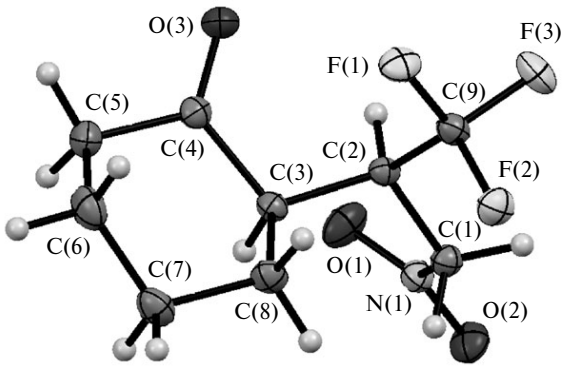
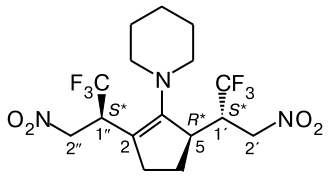


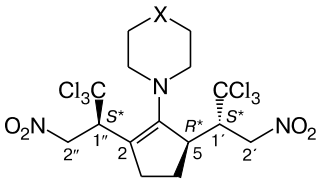
Fig. 5. Molecular structure of *syn*-γ-nitro ketone **15**.

Stereochemistry of the synthesized compounds. As it was mentioned above, for a series of acyclic derivatives synthesized based on cyclohexanone enamines **2a**—**c**, relative *syn* configurations were determined for trisubstituted CCl_3-enamine **4b** and CF_3-nitro ketone **15** using X-ray diffraction. This fact serves for easy determination of stereochemistry of other products of cyclohexanone series by comparing their ^{1}H NMR spectra (Table 2). Nevertheless, we encountered serious problems in establishing the relative configuration of cyclopentane derivatives synthesized from nitroalkenes **1a**,**b** and *N*-cyclopentenylmorpholine (**2d**) as a mixtures of liquid isomers. The situation is further complicated by the fact that bicyclo[3.2.0]-heptane **9**, whose structure was unambiguously determined by X-ray diffraction (see Fig. 4) undergoes the ring opening to give not tri- but tetrasubstituted enamine **10**, which then partially stereoselectively transforms into one of isomers of trisubstituted enamine **11** (*syn*-**11** or *anti*-**11**). Stereochemistry of enamine **11**, the key compound in series of cyclopentane products, is established due to recent important observation.[14] In studying the reaction of nitroalkene **1b** with *N*-cyclopentenylpiperidine, bis-adduct **19a** was isolated as the single diastereomer and by X-ray diffraction its 1′*S**,5*R**,1″*S** configuration was determined.

In attempt at obtaining the crystals suitable for X-ray diffraction of the analogs of compound **19a**, which can serve as a reference in determination of relative configuration of cyclopentane derivatives, we synthesized dialkylated adducts **19b—e**. Compounds **19b**,**c** were synthesized by the reaction of nitroalkene **1a** (2 equiv.) with *N*-cyclopentenylpiperidine and enamine **2d** in anhydrous dichloromethane (reflux, 3 h, yield of 34—49%) and compounds **19d**,**e** were obtained under similar conditions by subsequent addition of first nitroalkene **1a** and either **1c** or **1b** (yields of **19d**,**e** were 41 and 32%, respectively). The relative 1′*S**,5*R**,1″*R**,2″*S** configuration of bis-adduct **19d** was unambiguously established by X-ray diffraction (Fig. 6), which allow further determination of stereochemistry of compounds by comparing their ^{1}H NMR spectra (see Table 2). It was

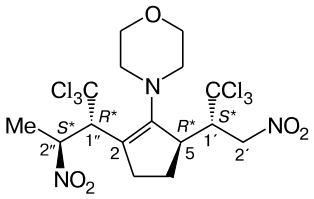


19a

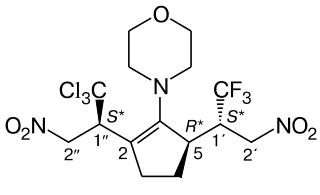


19b,c

X = CH_2 (**b**), O (**c**)



19d



19e

Table 2. Chemical shifts and spin-spin coupling constants for H(1′), H(2′a), and H(2′b) protons in ^{1}H NMR spectra of enamines **4a,b**, **11**, **13**, **16**, **19b—e** and γ-nitro ketones **7**, **12**, **15**, **18**

Compound	Solvent	δ			*J*/Hz		
		H(1′)	H(2′a)	H(2′b)	$J_{2'a,2'b}$	$J_{1',2'b}$	$J_{1',2'a}$
			dd				
syn-**4a**	C_6D_6	3.67 (td)	4.61	4.88	15.0	5.6	4.6
syn-**4a**	$CDCl_3$	3.68 (q)	4.82	4.98	15.2	5.2	5.0
syn-**4b**	C_6D_6	3.62 (dt)	4.57	4.82	15.0	5.6	4.4
syn-**4b**	$CDCl_3$	3.70 (m)	4.84	5.04	15.1	5.5	4.7
syn-**7**	$CDCl_3$	3.77 (ddd)	4.74	5.22	16.0	6.5	3.0
anti-**7**	$CDCl_3$	4.67 (ddd)	4.55	4.92	14.5	4.4	6.5
anti-**11**[a]	C_6D_6	4.07 (dt)	3.94	4.37	15.0	5.9	2.9
anti-**11**	$CDCl_3$	4.07 (dt)	4.36	4.76	15.0	6.0	2.7
anti-**12**	$CDCl_3$	4.19 (ddd)	4.47	5.01	14.0	4.1	7.7
syn-**12**	$CDCl_3$	3.77 (dt)	5.00	5.28	15.1	9.0	3.4
syn-**13**	C_6D_6	3.40 (m)	4.22	4.28	14.5	6.4	6.3
syn-**13**	$CDCl_3$	3.48 (m)	4.67	4.75	14.5	6.1	6.5
syn-**15**	$CDCl_3$	3.60 (m)	4.47	4.83	14.7	6.7	4.4
anti-**15**	$CDCl_3$	4.06 (m)	4.45	4.53	14.1	8.3	4.0
anti-**16**[b]	C_6D_6	4.01 (m)	3.78	4.02	14.3	7.6	3.2
anti-**16**	$CDCl_3$	3.56 (m)	4.31	4.55	14.4	7.9	2.7
anti-**18**	$CDCl_3$	3.88 (m)	4.30	4.62	13.8	7.5	5.5
syn-**18**	$CDCl_3$	3.56 (qq)	4.68	4.97	14.4	6.3	6.2
anti-**19b**[c]	$CDCl_3$	4.14 (dt)	4.18	4.77	15.0	7.3	1.8
anti-**19c**[d]	C_6D_6	4.13 (dt)	3.93	4.39	15.1	6.9	2.2
anti-**19c**	$CDCl_3$	4.16 (dt)	4.19	4.79	15.8	7.7	2.2
anti-**19d**[e]	C_6D_6	4.18 (dt)	4.07	4.46	15.3	7.3	1.2
anti-**19d**	$CDCl_3$	4.14 (m)	4.12	4.73	15.5	7.7	1.5
anti-**19e**[f]	$CDCl_3$	3.59 (qiuntt)	4.30	4.63	14.3	8.8	2.2

[a] H(5): 3.43 m (C_6D_6), 3.75 m ($CDCl_3$).
[b] H(5): 2.97 m (C_6D_6), 3.39 m ($CDCl_3$); ^{19}F NMR ($CDCl_3$), δ: 92.6 (d, CF_3, J = 9.6 Hz).
[c] H(5): 3.87 m ($CDCl_3$).
[d] H(5): 3.37 m (C_6D_6), 3.86 m ($CDCl_3$).
[e] H(5): 3.37 br.t, J = 7.0 (C_6D_6), 3.80 m ($CDCl_3$).
[f] H(5): 3.38 m ($CDCl_3$); ^{19}F NMR ($CDCl_3$), δ: 92.3 (d, CF_3, J = 9.3 Hz).

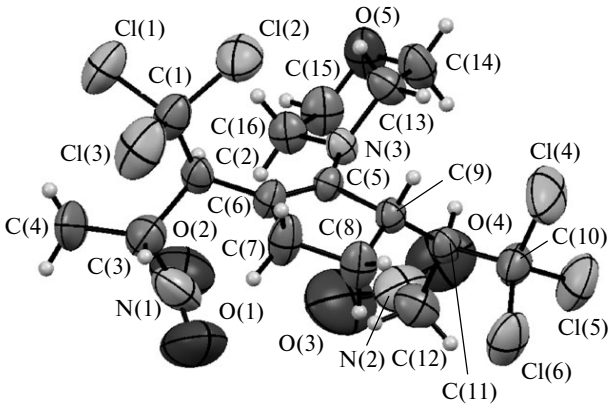


Fig. 6. Molecular structure of dialkylated compound **19d**.

found that stereochemistry of **19b**,**c**,**e** is the same as for trifluoromethylated compound **19a** (1′*S**,5*R**,1″*S**).[14]

A comparison of ^{1}H NMR spectra of compounds **19b**,**c** and **11** recorded in C_6D_6 and $CDCl_3$ reveals very similar chemical shifts for the H(1′), H(2′a), H(2′b), and H(5) and spin-spin coupling constants for the AMX spin system formed by the protons of the side chain at the C(5) atom, thus suggesting that tetrasubstituted CCl_3-enamine **10** is in equilibrium with trisubstituted *anti*-enamine **11**. Similar comparison of NMR spectra of compounds **19e** and **16** in $CDCl_3$ including ^{19}F NMR spectra (δ_{CF_3} 92.3—92.6) also indicates *anti* configuration of enamine **16**, which, apparently, as well as *anti*-**11**, is the product of isomerization of initially formed tetrasubstituted CF_3-enamine **17** (see Schemes 5, 6 and Table 2). Acid hydrolysis of the mixtures of isomeric enamines *anti*-**11** : **10** = 40 : 60 and *anti*-**16** : **17** = 75 : 25 results in the mixtures of diastereomeric γ-nitro ketones *anti*-**12** : *syn*-**12** = 74 : 26 and *anti*-**18** : *syn*-**18** = 56 : 44, respectively. Stereochemistry of these γ-nitro ketones can be determined by comparing their ^{1}H NMR spectra in $CDCl_3$ with the spectra of *syn*- and *anti*-ketones **7** and **15** of the cyclohexane series (*cf.*, for example, *syn*-**7** and *syn*-**12**, Table 2). Regardless of the ring size and the nature of the CX_3 group passing from *syn*- to *anti*-ketones always accompanied by the low field shift of the signal of the H(1′) proton of 0.90—0.32 ppm.

In summary, we first shown that the reactions of (*E*)-3,3,3-trichloro-1-nitropropene with cycloalkanone enamines result in cyclobutanes or enamines of linear structure depending on the reaction conditions. Novel type of ring-chain tautomerism consisting in reversible transformation of the CCl_3-containing cyclobutane derivatives into trisubstituted enamines is found and studied by ^{1}H NMR spectroscopy. Starting from (*E*)-3,3,3-trichloro(trifluoro)-1-nitropropenes, a series of hitherto unknown CX_3-containing nitroalkylated enamines and γ-nitro ketones are diastereoselectively synthesized and their relative configurations are established.

Experimental

IR spectra were recorded on a Perkin—Elmer Spectrum BX-II instrument in the KBr pellets. ^{1}H, ^{19}F, and ^{13}C NMR spectra were run on Bruker DRX-400 (working frequencies of 400, 376, and 100 MHz, respectively) and Bruker Avance II instruments (working frequencies of 500 and 126 MHz) in $CDCl_3$ and C_6D_6 using Me_4Si and C_6F_6 as internal standards. Nitroalkenes **1a**,**b** (see Refs 27, 28) and enamines **2** (see Ref. 29) were synthesized by known procedures.

Synthesis of cyclobutanes 3a—c (general procedure). To a stirred solution of the corresponding enamine **2** (10.0 mmol) in anhydrous hexane (3 mL), a solution of nitropropene **1a** (1.90 g, 10.0 mmol) in anhydrous hexane (3 mL) was added over a period of 15 min at 10—15 °C. The mixture was stirred at ~20 °C for 0.5 h, the precipitate formed was filtered off, washed with hexane, and recrystallized from hexane or hexane—benzene (1 : 2, for **3b**).

(1*R,6*S**,7*S**,8*R**)-1-(4-Methylpiperazino)-8-nitro-7-(trichloromethyl)bicyclo[4.2.0]octane (3a).** Yield 2.26 g (61%), colorless prisms, m.p. 93—94 °C. Found (%): C, 45.48; H, 5.94; N, 11.33. $C_{14}H_{22}Cl_3N_3O_2$. Calculated (%): C, 45.36; H, 5.98; N, 11.34. IR, ν/cm^{-1}: 1537, 1455, 1367. ^{1}H NMR (C_6D_6), δ: 0.80—1.70 (m, 8 H, 4 CH_2); 2.10 (s, 3 H, Me); 2.21 (br.s, 4 H, $N(CH)_2)_2$); 2.35 (t, 1 H, H(6), *J* = 8.0 Hz); 2.42 (dt, 2 H, $N(C\underline{H}H)_2$, *J* = 10.5 Hz, *J* = 4.5 Hz); 2.63 (dt, 2 H, $N(CH\underline{H})_2$, *J* = 10.5 Hz, *J* = 4.5 Hz); 3.79 (dd, 1 H, H(7), *J* = 9.6 Hz, *J* = 8.3 Hz); 4.90 (d, 1 H, H(8), *J* = 8.3 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.20—2.10 (m, 8 H, 4 CH_2); 2.30 (s, 3 H, Me); 2.45 (br.s, 4 H, $N(CH_2)_2$); 2.62 (t, 1 H, H(6), *J* = 8.0 Hz); 2.68 (dt, 2 H, $N(C\underline{H}H)_2$, *J* = 10.5 Hz, *J* = 4.5 Hz); 2.80 (br.s, 2 H, $N(CH\underline{H})_2$); 3.86 (dd, 1 H, H(7), *J* = 9.6 Hz, *J* = 8.5 Hz); 4.91 (d, 1 H, H(8), *J* = 8.5 Hz).

(1*R,6*S**,7*S**,8*R**)-1-Morpholino-8-nitro-7-(trichloromethyl)bicyclo[4.2.0]octane (3b).** Yield 2.58 g (72%), colorless prisms, m.p. 134—135 °C. Found (%): C, 43.65; H, 5.51; N, 7.71. $C_{13}H_{19}Cl_3N_2O_3$. Calculated (%): C, 43.66; H, 5.35; N, 7.83. IR, ν/cm^{-1}: 1540, 1458, 1357. ^{1}H NMR (500 MHz, C_6D_6), δ: 0.80—1.22 (m, 6 H, 3 CH_2); 1.54—1.60 (m, 2 H, CH_2); 2.17—2.22 (m, 2 H, $N(C\underline{H}H)_2$); 2.28 (ddt, 1 H, H(6), *J* = 9.8 Hz, *J* = 6.3 Hz, *J* = 1.7 Hz); 2.38—2.42 (m, 2 H, $N(CH\underline{H})_2$); 3.44 (ddd, 2 H, $O(C\underline{H}H)_2$, *J* = 10.8 Hz, *J* = 5.8 Hz, *J* = 3.3 Hz); 3.47 (ddd, 2 H, $O(CH\underline{H})_2$, *J* = 10.8 Hz, *J* = 5.8 Hz, *J* = 3.3 Hz); 3.76 (dd, 1 H, H(7), *J* = 9.8 Hz, *J* = 8.3 Hz); 4.83 (d, 1 H, H(8), *J* = 8.3 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.20—2.10 (m, 8 H, 4 CH_2); 2.60—2.70 (m, 3 H, $N(C\underline{H}H)_2$, H(6)); 2.74—2.82 (m, 2 H, $N(CH\underline{H})_2$); 3.68—3.75 (m, 4 H, $O(CH_2)_2$); 3.87 (t, 1 H, H(7), *J* = 9.1 Hz); 4.95 (d, 1 H, H(8), *J* = 8.4 Hz). ^{13}C NMR (C_6D_6), δ: 20.5 (C(4)), 21.0 (C(3)), 22.3 (C(2)), 24.3 (C(5)), 36.5 (C(6)), 47.1 (NCH_2), 54.3 (C(7)), 64.1 (C(1)), 67.3 (OCH_2), 83.7 (C(8)), 99.8 (CCl_3).

(1*R,6*S**,7*S**,8*R**)-8-Nitro-1-piperidino-7-(trichloromethyl)bicyclo[4.2.0]octane (3c).** Yield 2.70 g (76%), colorless prisms, m.p. 75—76 °C. Found (%): C, 47.20; H, 5.91; N, 7.95. $C_{14}H_{21}Cl_3N_2O_2$. Calculated (%): C, 47.28; H, 5.95; N, 7.88. IR, ν/cm^{-1}: 1549, 1442, 1367. ^{1}H NMR (C_6D_6), δ: 0.80—1.70 (m, 14 H, 7 CH_2); 2.25 (dt, 2 H, $N(C\underline{H}H)_2$, *J* = 10.6 Hz, *J* = 5.0 Hz); 2.36 (br.t, 1 H, H(6), *J* = 8.0 Hz); 2.48 (dt, 2 H, $N(CH\underline{H})_2$, *J* = 10.6 Hz, *J* = 5.0 Hz); 3.81 (dd, 1 H, H(7), *J* = 9.8 Hz, *J* = 8.4 Hz); 4.90 (d, 1 H, H(8), *J* = 8.4 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.20—2.20 (m, 14 H, 7 CH_2); 2.52—2.64 (m, 3 H, $N(C\underline{H}H)_2$,

H(6)); 2.67 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 10.5 Hz, J = 5.2 Hz); 3.84 (dd, 1 H, H(7), J = 9.8 Hz, J = 8.5 Hz); 4.91 (d, 1 H, H(8), J = 8.5 Hz).

(6*R,1′*R**)-1-(4-Methylpiperazino)-6-[2-nitro-1-(trichloromethyl)ethyl]-1-cyclohexene (*syn*-4a).** A solution of cyclobutane **3a** (0.37 g, 1.0 mmol) in chloroform (1 mL) was kept at ~20 °C for 2 h, the solvent was removed *in vacio*, and the residue was recrystallized from hexane. Yield 0.20 g (53%), colorless prisms, m.p. 126—127 °C. Found (%): 45.24; H, 5.95; N, 11.39. $C_{14}H_{22}Cl_3N_3O_2$. Calculated (%): C, 45.36; H, 5.98; N, 11.34. IR, ν/cm^{-1}: 1652, 1553, 1457, 1375. ^{1}H NMR (C_6D_6), δ: 1.30—1.90 (m, 6 H, 3 CH_2); 2.09 (br.s, 4 H, N(CH_2)$_2$); 2.05 (s, 3 H, Me); 2.25 (br.s, 2 H, N(C<u>H</u>H)$_2$); 2.68 (br.s, 1 H, H(6)); 2.76 (br.s, 2 H, N(CH<u>H</u>)$_2$); 3.67 (td, 1 H, H(1′), J = 5.1 Hz, J = 4.6 Hz); 4.61 (dd, 1 H, H(2′a), J = 15.0 Hz, J = 4.6 Hz); 4.76 (dd, 1 H, H(2), J = 4.1 Hz, J = 3.4 Hz); 4.88 (dd, 1 H, H(2′b), J = 15.0 Hz, J = 5.6 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.50—2.20 (m, 6 H, 3 CH_2); 2.30 (s, 3 H, Me); 2.30—2.60 (m, 6 H, 3 CH_2N); 2.88 (br.s, 1 H, H(6)); 3.08 (br.s, 2 H, CH_2N); 3.68 (q, 1 H, H(1′), J = 4.8); 4.82 (dd, 1 H, H(2′a), J = 15.2 Hz, J = 5.0 Hz); 4.98 (dd, 1 H, H(2′b), J = 15.2 Hz, J = 5.2 Hz); 5.08 (t, 1 H, H(2), J = 3.8 Hz).

(6*R,1′*R**)-1-Morpholino-6-[2-nitro-1-(trichloromethyl)-ethyl]-1-cyclohexene (*syn*-4b)** was synthesized similarly to enamine **4a**, yiled 0.18 g (50%), colorless prisms, m.p. 101—102 °C. Found (%): C, 43.64; H, 5.22; N, 7.79. $C_{13}H_{19}Cl_3N_2O_3$. Calculated (%): C, 43.66; H, 5.35; N, 7.83. IR, ν/cm^{-1}: 1648, 1558, 1383. ^{1}H NMR (500 MHz, C_6D_6), δ: 1.33—1.54 (m, 3 H, H(4a), H(4b), H(5a)); 1.73 (m, 1 H, H(3a)); 1.83—1.90 (m, 2 H, H(3b), H(5b)); 2.06 (ddd, 2 H, N(C<u>H</u>H)$_2$, J = 11.5 Hz, J = 5.8 Hz, J = 3.1 Hz); 2.53—2.60 (m, 3 H, N(CH<u>H</u>)$_2$, H(6)); 3.32—3.42 (m, 4 H, O(CH_2)$_2$); 3.62 (dt, 1 H, H(1′), J = 5.6 Hz, J = 4.4 Hz); 4.57 (dd, 1 H, H(2′a), J = 15.0 Hz, J = 4.4 Hz); 4.67 (dd, 1 H, H(2), J = 4.1 Hz, J = 3.5 Hz); 4.82 (dd, 1 H, H(2′b), J = 15.0 Hz, J = 5.6 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.55—2.20 (m, 6 H, 3 CH_2); 2.51 (dt, 2 H, N(C<u>H</u>H)$_2$, J = 11.7 Hz, J = 5.0 Hz); 2.87 (br.q, 1 H, H(6), J = 3.5 Hz); 3.05 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 11.7 Hz, J = 5.0 Hz); 3.70 (m, 5 H, O(CH_2)$_2$, H(1′)); 4.84 (dd, 1 H, H(2′a), J = 15.1 Hz, J = 4.7 Hz); 5.04 (dd, 1 H, H(2′b), J = 15.1 Hz, J = 5.5 Hz); 5.08 (t, 1 H, H(2), J = 3.7 Hz). ^{13}C NMR (126 MHz, C_6D_6), δ: 17.1 (C(4)), 24.1 (C(3)), 30.5 (C(5)), 34.5 (C(6)), 50.6 (NCH_2), 61.2 (C(1′)), 67.0 (OCH_2), 75.6 (C(2′)), 103.0 (CCl_3), 112.6 (C(2)), 145.9 (C(1)).

1-Morpholino-2-[2-nitro-1-(trichloromethyl)ethyl]-1-cyclohexene (5b). ***A.*** To a solution of enamine **2b** (0.17 g, 1.0 mmol) in chloroform (5 mL), a solution of nitroalkene **1a** in chloroform (5 mL) was added dropwise. A mixture was stirred at ~20 °C for 7 days, the solvent was removed *in vacuo*. Purification of the residue by column chromatography (silica gel, elution with chloroform) afforded 0.36 g (100%) of compound **5b**, yellow oil. Found (%): C, 43.49; H, 5.20; N, 7.77. $C_{13}H_{19}Cl_3N_2O_3$. Calculated (%): C, 43.66; H, 5.35; N, 7.83. IR, ν/cm^{-1}: 1646, 1558, 1378. ^{1}H NMR (C_6D_6), δ: 1.20—2.40 (m, 12 H, 4 CH_2, N(CH_2)$_2$); 3.60—3.73 (m, 4 H, O(CH_2)$_2$); 4.20 (t, 1 H, H(2′a), J = 10.7 Hz); 4.41 (dd, 1 H, H(2′b), J = 11.0 Hz, J = 3.0 Hz); 5.93 (dd, 1 H, H(1′), J = 10.5 Hz, J = 3.0 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.50—2.40 (m, 10 H, 4 CH_2, NCH_2); 2.60—2.70 (m, 2 H, NCH_2); 3.74 (br.s, 4 H, O(CH_2)$_2$); 4.76 (t, 1 H, H(2′a), J = 10.7 Hz); 4.98 (dd, 1 H, H(2′b), J = 10.8 Hz, J = 3.0 Hz); 5.93 (dd, 1 H, H(1′), J = 10.3 Hz, J = 3.0 Hz).

B. A solution of compound **3b** (0.36 g, 1.0 mmol) in chloroform was kept at ~20 °C for 2 days. The solvent was removed *in vacuo*, the product was purified by column chromatography (silica gel, elution with chloroform). Yield 0.23 g (78%).

2-[2-Nitro-1-(trichloromethyl)ethyl]-1-piperidino-1-cyclohexene (5c) was synthesized similarly to enamine **5b** following the procedure ***B***. Yield 0.35 g (98%), white powder, m.p. 54—55 °C. Compound **5c** is unstable at room temperature and within 0.5 h is undergoes spontaneous exothermic decompositions with HCl evolution. IR, ν/cm^{-1}: 1643, 1556, 1378. ^{1}H NMR (C_6D_6), δ: 0.80—2.70 (m, 18 H, 9 CH_2); 4.24 (t, 1 H, H(2′a), J = 10.7 Hz); 4.45 (dd, 1 H, H(2′b), J = 10.9 Hz, J = 3.1 Hz); 6.03 (dd, 1 H, H(1′), J = 10.3 Hz, J = 2.8 Hz).

(2*R,1′*R**)-2-[2-Nitro-1-(trichloromethyl)ethyl]cyclohexanone (*syn*-7).** A suspension of enamine *syn*-**4b** (0.36 g, 1.0 mmol) in 0.5 *M* HCl (2.5 mL) and EtOH (2 mL) was stirred at 40 °C for 4 h, then the mixture was cooled and extracted with dichloromethane (2×1 mL). The organic layer was dried with anhydrous Na_2SO_4, the solvent was removed *in vacuo*. Recrystallization of the residue from pentane afforded ketone *syn*-**7** in a yield of 0.16 g (55%), colorless prisms, m.p. 55—56 °C (content of isomer *anti*-**7** is 6%). Found (%): C, 37.57; H, 4.35; N, 4.76. $C_9H_{12}Cl_3NO_3$. Calculated (%): C, 37.46; H, 4.19; N, 4.85. IR, ν/cm^{-1}: 1709, 1558, 1381. ^{1}H NMR ($CDCl_3$), δ: 1.50—2.50 (m, 8 H, 4 CH_2); 3.25—3.31 (m, 1 H, H(2)); 3.77 (ddd, 1 H, H(1′), J = 6.5 Hz, J = 3.0 Hz, J = 1.8 Hz); 4.74 (dd, 1 H, H(2′a), J = 16.0 Hz, J = 3.0 Hz); 5.22 (dd, 1 H, H(2′b), J = 16.0 Hz, J = 6.5 Hz). Ketone *syn*-**7** was also synthesized from cyclobutane **3b** in chloroform in the presence of diluted HCl (content of 2-(1,1-dichloro-3-nitroprop-1-en-2-yl)cyclohexanone **8** is 15%).

(2*S,1′*R**)-2-[2-Nitro-1-(trichloromethyl)ethyl]cyclohexanone (*anti*-7)** was synthesized as the *anti*-**7** : *syn*-**7** = 62 : 38 (by hydrolysis of *syn*-enamine **4b** with insufficient acid amount) and *anti*-**7** : *syn*-**7** : **8** = 46 : 13 : 41 mixtures (by hydrolysis of enamine **5b** under conditions described for ketone *syn*-**7**). ^{1}H NMR ($CDCl_3$), δ: 1.50—2.60 (m, 8 H, 4 CH_2); 3.23 (ddd, H, H(2), J = 13.2 Hz, J = 5.5 Hz, J = 2.7 Hz); 4.55 (dd, 1 H, H(2′a), J = 14.5 Hz, J = 6.5 Hz); 4.67 (ddd, 1 H, H(1′), J = 6.5 Hz, J = 4.4 Hz, J = 2.7 Hz); 4.92 (dd, 1 H, H(2′b), J = 14.5 Hz, J = 4.4 Hz).

2-(1,1-Dichloro-3-nitroprop-1-en-2-yl)cyclohexanone (8). A solution of enamine **5b** (0.36 g, 1.0 mmol) and morpholine (0.18 g, 2.0 mmol) in MeOH (2 mL) was stirred at 40 °C for 3 days, then water (3 mL) was added and stirring was continued for 1 day. After cooling to ~20 °C, the reaction mixture was extracted with chloroform (3×1 mL), the organic layer was dried with Na_2SO_4, and the solvent was removed *in vacuo*. Column chromatography of the residue (silica gel, elution with chloroform) and subsequent recrystallization afforded compound **8** in the yield of 0.10 g (41%), m.p. 78—79 °C, white powder. Found (%): C, 43.05; H, 4.47; N, 5.42. $C_9H_{11}Cl_2NO_3$. Calculated (%): C, 42.88; H, 4.40; N, 5.56. IR, ν/cm^{-1}: 1701, 1614, 1558, 1378. ^{1}H NMR ($CDCl_3$), δ: 1.60—2.50 (m, 8 H, 4 CH_2); 3.89 (dd, 1 H, H(2), J = 12.8 Hz, J = 5.8 Hz); 4.96 (d, 1 H, H(3′a), J = 15.8 Hz); 5.35 (d, 1 H, H(3′b), J = 15.8 Hz).

(1*R,5*S**,6*S**,7*R**)-1-Morpholino-7-nitro-6-(trichloromethyl)bicyclo[3.2.0]heptane (9).** To a stirred solution of enamine **2d** (1.53 g, 10.0 mmol) in anhydrous benzene (3 mL), a solution of nitropropene **1a** (1.90 g, 10.0 mmol) in anhydrous benzene (3 mL) was added dropwise within 15 min at 10—15 °C. The mixture was stirred at ~20 °C for 0.5 h and diluted with hexane (5 mL). The precipitate formed was filtered off, washed with

hexane and recrystallized from hexane—benzene (1 : 2) to give cyclobutane **9** in the yield of 2.68 g (78%), m.p. 155—156 °C, colorless prisms. Found (%): C, 41.88; H, 5.14; N, 8.00. $C_{12}H_{17}Cl_3N_2O_3$. Calculated (%): C, 41.94; H, 4.99; N, 8.15. IR, ν/cm^{-1}: 1538, 1447, 1368. ^{1}H NMR (C_6D_6), δ: 1.13—1.53 (m, 6 H, 3 CH_2); 1.96 (dt, 2 H, N(C<u>H</u>H)$_2$, J = 11.0 Hz, J = 4.6 Hz); 2.35 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 11.0 Hz, J = 4.6 Hz); 2.35 (t, 1 H, H(5), J = 6.0 Hz); 3.44 (t, 4 H, O(CH_2)$_2$, J = 4.6 Hz); 3.58 (dd, 1 H, H(6), J = 7.5 Hz, J = 6.7 Hz); 5.02 (d, 1 H, H(7), J = 7.5 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.54—2.04 (m, 6 H, 3 CH_2); 2.51 (dt, 2 H, N(C<u>H</u>H)$_2$, J = 11.5 Hz, J = 4.5 Hz); 2.77 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 11.5 Hz, J = 4.5 Hz); 2.83 (t, 1 H, H(5), J = 6.0 Hz); 3.70—3.74 (m, 5 H, O(CH_2)$_2$, H(6)); 5.24 (d, 1 H, H(7), J = 7.5 Hz). ^{13}C NMR (126 MHz, C_6D_6), δ: 25.7 (C(3)), 27.1 (C(2)), 31.3 (C(4)), 42.8 (C(5)), 47.1 (NCH_2), 55.3 (C(6)), 67.0 (OCH_2), 74.2 (C(1)), 83.9 (C(7)), 99.5 (CCl_3).

1-Morpholino-2-[2-nitro-1-(trichloromethyl)ethyl]-1-cyclopentene (10) and **(5*S**,1′*R**)-1-morpholino-5-[2-nitro-1-(trichloromethyl)ethyl]-1-cyclopentene (*anti*-11).** A solution of cyclobutane **9** (0.34 g, 1.0 mmol) in chloroform (2 mL) was kept at ~20 °C for 24 h. Removal of the solvent *in vacuo* quantitatively afforded a mixture of isomers **10** (60%) and *anti*-**11** (40%), yellow oil. The mixture of the same composition was obtained directly from the starting compounds **1a** and **2d** under similar conditions. IR, ν/cm^{-1}: 1659, 1637, 1560, 1378. Found (%): C, 41.75; H, 5.08; N, 7.86. $C_{12}H_{17}Cl_3N_2O_3$. Calculated (%): C, 41.94; H, 4.99; N, 8.15. ^{1}H NMR (C_6D_6), δ: 1.45—2.40 (m, 10 H, 3 CH_2, N(CH_2)$_2$); 3.50—3.55 (m, 4 H, O(CH_2)$_2$); 4.24 (dd, 1 H, H(2′a), J = 11.4 Hz, J = 10.5 Hz); 4.43 (dd, 1 H, H(2′b), J = 11.4 Hz, J = 3.2 Hz); 5.03 (dd, 1 H, H(1′), J = 10.5 Hz, J = 3.2 Hz) (compound **10** (60%)); 1.45—2.40 (m, 6 H, 2 CH_2, N(C<u>H</u>H)$_2$); 2.62—2.68 (m, 2 H, N(CH<u>H</u>)$_2$); 3.40—3.46 (m, 1 H, H(5)); 3.55—3.60 (m, 4 H, O(CH_2)$_2$); 3.94 (dd, 1 H, H(2′a), J = 15.0 Hz, J = 2.9 Hz); 4.07 (dt, 1 H, H(1′), J = 5.9 Hz, J = 2.6 Hz); 4.37 (dd, 1 H, H(2′b), J = 15.0 Hz, J = 5.9 Hz); 4.39 (t, 1 H, H(2), J = 1.8 Hz) (*anti*-**11** (40%)). ^{1}H NMR ($CDCl_3$), δ: 1.78—2.48 (m, 6 H, 3 CH_2); 2.55 (dt, 2 H, N(C<u>H</u>H)$_2$, J = 11.6 Hz, J = 4.6 Hz); 2.70 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 11.6 Hz, J = 4.6 Hz); 3.75 (t, 4 H, O(CH_2)$_2$, J = 4.6 Hz); 4.75 (dd, 1 H, H(2′a), J = 11.7 Hz, J = 10.8 Hz); 5.01 (dd, 1 H, H(2′b), J = 11.7 Hz, J = 3.0 Hz); 5.02 (dd, 1 H, H(1′), J = 10.8 Hz, J = 3.0 Hz) (**10** (62%)); 1.45—2.40 (m, 4 H, 2 CH_2); 2.63—2.70 (m, 2 H, N(C<u>H</u>H)$_2$); 2.95—3.03 (m, 2 H, N(CH<u>H</u>)$_2$); 3.70—3.80 (m, 5 H, O(CH_2)$_2$, H(5)); 4.07 (dt, 1 H, H(1′), J = 6.0 Hz, J = 2.4 Hz); 4.36 (dd, 1 H, H(2′a), J = 15.0 Hz, J = 2.7 Hz); 4.76 (dd, 1 H, H(2′b), J = 15.0 Hz, J = 6.0 Hz); 4.77 (m, 1 H, H(2)) (*anti*-**11** (38%)).

(2*S,1′*R**-** and **2*R**,1′*R**)-2-[2-Nitro-1-(trichloromethyl)ethyl]cyclopentanones (*anti*-12, *syn*-12).** ***A.*** A suspension of cyclobutane **9** (0.34 g, 1.0 mmol) in a mixture of 0.5 *M* HCl (2.5 mL) and EtOH (2 mL) was stirred at 50 °C for 4 h, then the reaction mixture was cooled and extracted with dichloromethane (2×1 mL). The organic layer was dried with anhydrous Na_2SO_4, the solvent was removed *in vacuo*. Column chromatography of the residue (silica gel, elution with dichloromethane) afforded a mixture of *anti*-**12** and *syn*-**12** (3 : 1) in the yield of 0.16 g (60%). IR, ν/cm^{-1}: 1742, 1562, 1379. Found (%): C, 35.12; H, 3.88; N, 5.39. $C_8H_{10}Cl_3NO_3$. Calculated (%): C, 35.00; H, 3.67; N, 5.10. ^{1}H NMR ($CDCl_3$), δ: 1.70—2.50 (m, 6 H, 3 CH_2); 3.00—3.08 (m, 1 H, H(2)); 4.19 (ddd, 1 H, H(1′), J = 7.7 Hz, J = 4.1 Hz, J = 2.0 Hz); 4.47 (dd, 1 H, H(2′a), J = 14.0 Hz, J = 7.7 Hz); 5.01 (dd, 1 H, H(2′b), J = 14.0 Hz, J = 4.1 Hz) (*anti*-**12** (74%)); 1.70—2.50 (m, 6 H, 3 CH_2); 2.58 (m, 1 H, H(2)); 3.77 (dt, 1 H, H(1′), J = 8.9 Hz, J = 3.4 Hz); 5.00 (dd, 1 H, H(2′a), J = 15.1 Hz, J = 3.4 Hz); 5.28 (dd, 1 H, H(2′b), J = 15.1 Hz, J = 9.0 Hz) (*syn*-**12** (26%)).

B. To a stirred solution of enamine **2d** (1.53 g, 10.0 mmol) in chloroform or dichloromethane (3 mL), a solution of nitropropene **1a** (1.90 g, 10.0 mmol) in chloroform or dichloromethane (3 mL) was added dropwise over a period of 15 min at 10—15 °C. The reaction mixture was stirred at ~20 °C for 2 h, the solvent was removed *in vacuo*, and 0.5 *M* HCl (25 mL) was added to the residue. The resulting mixture was stirred at 50 °C for 4 h and extracted with chloroform (3×3 mL), the organic layers were dried with anhydrous Na_2SO_4. Purification by column chromatography (silica gel, elution with dichloromethane) afforded a mixture of *anti*-**12** and *syn*-**12** (3 : 1) in the yield of 1.87 g (68%).

(6*R,1′*R**)-1-Morpholino-6-[2-nitro-1-(trifluoromethyl)ethyl]-1-cyclohexene (*syn*-13).** To a stirred solution of enamine **2b** (1.67 g, 10.0 mmol) in anhydrous benzene (3 mL), a solution of nitropropene **1b** (1.41 g, 10.0 mmol) in anhydrous benzene (3 mL) was added dropwise over a period of 15 min at 10—15 °C. The reaction mixture was stirred at ~20 °C for 2 h and diluted with hexane (10 mL). The precipitate formed was filtered off and recrystallized form hexane to give compound *syn*-**13** in the yield of 1.93 g (63%), m.p. 86—87 °C (*cf.* Ref. 26: m.p. 88—89 °C), colorless prisms. Performing the reaction without solvent for 0.5 h led to the increase in the yield up to 86%. IR, ν/cm^{-1}: 1648, 1557, 1387. ^{1}H NMR (C_6D_6), δ: 1.20—1.90 (m, 6 H, 3 CH_2); 1.97—2.04 (m, 2 H, N(C<u>H</u>H)$_2$); 2.39 (br.q, 1 H, H(6), J = 4.1 Hz); 2.43—2.49 (m, 2 H, N(CH<u>H</u>)$_2$); 3.29—3.48 (m, 5 H, H(1′), O(CH_2)$_2$); 4.22 (dd, 1 H, H(2′a), J = 14.5 Hz, J = 6.3 Hz); 4.28 (dd, 1 H, H(2′b), J = 14.5 Hz, J = 6.4 Hz); 4.61 (t, 1 H, H(2), J = 3.9 Hz). ^{1}H NMR ($CDCl_3$), δ: 1.50—2.20 (m, 6 H, 3 CH_2); 2.44—2.50 (m, 2 H, N(C<u>H</u>H)$_2$); 2.76 (br.q, 1 H, H(6), J = 4.6 Hz); 2.88—2.96 (m, 2 H, N(CH<u>H</u>)$_2$); 3.42—3.54 (m, 1 H, H(1′)); 3.67—3.77 (m, 4 H, O(CH_2)$_2$); 4.67 (dd, 1 H, H(2′a), J = 14.5 Hz, J = 6.5 Hz); 4.75 (dd, 1 H, H(2′b), J = 14.5 Hz, J = 6.1 Hz); 5.04 (t, 1 H, H(2), J = 3.9 Hz). ^{19}F NMR (C_6D_6), δ: 94.5 (d, CF_3, J = 9.8 Hz). ^{19}F NMR ($CDCl_3$), δ: 92.9 (d, CF_3, J = 9.7 Hz).

1-Morpholino-2-[2-nitro-1-(trifluoromethyl)ethyl]-1-cyclohexene (14) was prepared as a colorless oil by distillation of filtrate obtained in the synthesis of *syn*-**13**; the sample contained 18% of the latter (^{19}F NMR data). Yield 0.81 g (26%), b.p. 110—112 °C (2 Torr). Found (%): C, 50.69; H, 6.41; N, 9.37. $C_{13}H_{19}F_3N_2O_3$. Calculated (%): C, 50.65; H, 6.21; N, 9.09. IR, ν/cm^{-1}: 1655, 1562, 1380. ^{1}H NMR ($CDCl_3$), δ: 1.50—2.70 (m, 12 H, 4 CH_2, N(CH_2)$_2$); 3.75 (m, 4 H, O(CH_2)$_2$); 4.62 (dd, 1 H, H(2′a), J = 11.9 Hz, J = 10.4 Hz); 4.68 (dd, 1 H, H(2′b), J = 11.9 Hz, J = 4.7 Hz); 5.48 (quint.d, 1 H, H(1′), J = 10.4 Hz, J = 4.7 Hz). ^{19}F NMR ($CDCl_3$), δ: 95.3 (d, CF_3, J = 10.3 Hz).

(2*R,1′*R**)-2-[2-Nitro-1-(trifluoromethyl)ethyl]cyclohexanone (*syn*-15)** was synthesized by hydrolysis of enamine *syn*-**13** (HCl, H_2O, EtOH, 2 h, 20 °C). Yield 73%, b.p. 121—123 °C (3 Torr), m.p. 43—44 °C (pentane), colorless prisms (*cf.* Ref. 26: b.p. 114—116 °C (2 Torr), m.p. 43 °C). IR, ν/cm^{-1}: 1714, 1564, 1381. ^{1}H NMR ($CDCl_3$), δ: 1.60—2.50 (m, 8 H, 4 CH_2); 2.80 (dtq, 1 H, H(2), J = 12.7 Hz, J = 5.5 Hz, J = 0.8 Hz); 3.54—3.66 (m, 1 H, H(1′)); 4.47 (dd, 1 H, H(2′a), J = 14.7 Hz, J = 4.4 Hz); 4.83 (dd, 1 H, H(2′b), J = 14.7 Hz, J = 6.7 Hz). ^{19}F NMR ($CDCl_3$), δ: 95.5 (dd, CF_3, J = 9.5 Hz, J = 0.8 Hz). On keeping the solution of this isomer in $CDCl_3$ at ~20 °C for 4 days in the

presence of SiO_2, it partially isomerizes to give a mixture of ketones *syn*-**15** (80%) and *anti*-**15** (20%).

(2*S,1′*R**)-2-[2-Nitro-1-(trifluoromethyl)ethyl]cyclohexanone (*anti*-15)** was not isolated in individual state. Hydrolysis of enamine **14** containing 18% of isomer *syn*-**13** (HCl, H_2O, EtOH, 4 h, 40 °C) resulted in a mixture of *anti*-**15**, *syn*-**15**, and **14** in a ratio of 46 : 45 : 9, yellowish oil (yield of 96%, ^{19}F NMR data). ^1H NMR ($CDCl_3$), δ: 1.41 (qd, 1 H, C<u>H</u>H, *J* = 12.9 Hz, *J* = 3.6 Hz); 1.50—2.50 (m, 7 H, CH<u>H</u>, 3 CH_2); 2.89—2.96 (m, 1 H, H(2)); 4.00—4.12 (m, 1 H, H(1′)); 4.45 (dd, 1 H, H(2′a), *J* = 14.1 Hz, *J* = 4.0 Hz); 4.53 (dd, 1 H, H(2′b), *J* = 14.1 Hz, *J* = 8.3 Hz). ^{19}F NMR ($CDCl_3$), δ: 93.3 (d, CF_3, *J* = 9.6 Hz).

(5*S,1′*R**)-1-Morpholino-5-[2-nitro-1-(trifluoromethyl)ethyl]-1-cyclopentene (*anti*-16)** and **1-morpholino-2-[2-nitro-1-(trifluoromethyl)ethyl]-1-cyclopentene (17).** To a stirred solution of enamine **2d** (1.53 g, 10.0 mmol) in anhydrous chloroform (3 mL), a solution of nitropropene **1b** (1.41 g, 10.0 mmol) in anhydrous chloroform (3 mL) was added dropwise over a period of 15 min at 10—15 °C. The reaction mixture was stirred at ~20 °C for 2 h. The removal of the solvent *in vacuo* quantitatively afforded a mixture of *anti*-**16** and **17** in a ratio of 3 : 1, yellow oil. IR, ν/cm^{-1}: 1637, 1564, 1379. ^1H NMR (C_6D_6), δ: 1.20—2.10 (m, 4 H, 2 CH_2); 2.18 (ddd, 2 H, N(C<u>H</u>H)$_2$, *J* = 11.7 Hz, *J* = 6.1 Hz, *J* = 3.4 Hz); 2.41 (ddd, 2 H, N(CH<u>H</u>)$_2$, *J* = 11.7 Hz, *J* = 6.1 Hz, *J* = 3.4 Hz); 2.94—3.00 (m, 1 H, H(5)); 3.37—3.52 (m, 4 H, O(CH_2)$_2$); 3.78 (dd, 1 H, H(2′a), *J* = 14.3 Hz, *J* = 3.2 Hz); 3.97—4.06 (m, 1 H, H(1′)); 4.02 (dd, 1 H, H(2′b), *J* = 14.3 Hz, *J* = 7.6 Hz); 4.30 (dd, 1 H, H(2), *J* = 3.8 Hz, *J* = 2.2 Hz) (*anti*-**16**); 1.20—2.10 (m, 6 H, 3 CH_2); 2.32 (t, 4 H, N(CH_2)$_2$, *J* = 4.6 Hz); 3.35—3.44 (m, 4 H, O(CH_2)$_2$); 3.95 (dd, 1 H, H(2′a), *J* = 12.2 Hz, *J* = 4.8 Hz); 4.03 (dd 1 H, H(2′b), *J* = 12.2 Hz, *J* = 10.2 Hz); 4.52 (quintd, 1 H, H(1′), *J* = 9.9 Hz, *J* = 4.8 Hz) (**17**). ^1H NMR ($CDCl_3$), δ: 1.70—2.70 (m, 6 H, 2 CH_2, N(C<u>H</u>H)$_2$); 2.87—2.94 (m, 2 H, N(CH<u>H</u>)$_2$); 3.36—3.42 (m, 1 H, H(5)); 3.50—3.62 (m, 1 H, H(1′)); 3.68—3.80 (m, 4 H, O(CH_2)$_2$); 4.31 (dd, 1 H, H(2′a), *J* = 14.4 Hz, *J* = 2.7 Hz); 4.55 (dd, 1 H, H(2′b), *J* = 14.4 Hz, *J* = 7.9 Hz); 4.76 (dd, 1 H, H(2), *J* = 3.9 Hz, *J* = 2.3 Hz) (*anti*-**16**). ^{19}F NMR (C_6D_6), δ: 94.1 (d, CF_3, *J* = 9.8 Hz) (*anti*-**16**); 95.5 (d, CF_3, *J* = 9.6 Hz) (**17**). ^{19}F NMR ($CDCl_3$), δ: 92.6 (d, CF_3, *J* = 9.6 Hz) (*anti*-**16**); 94.3 (d, CF_3, *J* = 8.8 Hz) (**17**).

(2*S,1′*R**- and 2*R**,1′*R**)-2-[2-Nitro-1-(trifluoromethyl)ethyl]cyclopentanones (*anti*-18, *syn*-18).** A mixture of diastereomeric ketones were obtained from compounds **2d** and **1b** following the procedure ***B*** described for isomers **12**. Yield 1.53 g (68%), yellowish oil, b.p. 108—110 °C (2 Torr) (*cf.* Ref. 30: b.p. 105—107 °C (3 Torr)). Found (%): C, 42.14; H, 4.48; N, 6.47. $C_8H_{10}F_3NO_3$. Calculated (%): C, 42.67; H, 4.47; N, 6.22. IR, ν/cm^{-1}: 1746, 1565, 1381. ^1H NMR ($CDCl_3$), δ: 1.60—2.50 (m, 6 H, 3 CH_2); 2.62 (ddd, 1 H, H(2), *J* = 11.3 Hz, *J* = 8.3 Hz, *J* = 2.7 Hz); 3.83—3.94 (m, 1 H, H(1′)); 4.30 (dd, 1 H, H(2′a), *J* = 13.8 Hz, *J* = 5.5 Hz); 4.62 (dd, 1 H, H(2′b), *J* = 13.8 Hz, *J* = 7.5 Hz) (*anti*-**18** (54%)); 1.60—2.50 (m, 7 H, 3 CH_2, H(2)); 3.56 (qq, 1 H, H(1′), *J* = 8.8 Hz, *J* = 6.3 Hz); 4.68 (dd, 1 H, H(2′a), *J* = 14.4 Hz, *J* = 6.2 Hz); 4.97 (dd, 1 H, H(2′b), *J* = 14.4 Hz, *J* = 6.3 Hz) (*syn*-**18** (46%)). ^{19}F NMR ($CDCl_3$), δ: 92.7 (d, CF_3, *J* = 9.2 Hz) (*anti*-**18** (54%)); 94.5 (d, CF_3, *J* = 8.8 Hz) (*syn*-**18** (46%)).

(1′*S,5*R**,1″*S**)-1-{2,5-Bis[2-nitro-1-(trichloromethyl)ethyl]cyclopenten-1-yl}piperidine (19b).** To a stirred solution of *N*-cyclopentenylpiperidine (0.76 g, 5.0 mmol) in anhydrous dichloromethane (5 mL), a solution of nitroalkene **1a** (1.90 g, 10.0 mmol) in anhydrous dichloromethane (5 mL) was added dropwise over a period of 15 min at ~20 °C. The reaction mixture was refluxed with stirring for 3 h and the solvent was removed *in vacuo*. The brown oily residue was dissolved in benzene (5 mL) and hexane (2 mL) was added. The precipitate formed was filtered off and recrystallized from dichloromethane—hexane (1 : 2) to give compound **19b** in the yield of 0.92 g (34%), m.p. 100—111 °C, white powder. Found (%): C, 36.10; H, 3.84; N, 7.83. $C_{16}H_{21}Cl_6N_3O_4$. Calculated (%): C, 36.12; H, 3.98; N, 7.90. IR, ν/cm^{-1}: 1625, 1573, 1563, 1453, 1417, 1375. ^1H NMR ($CDCl_3$), δ: 1.54—1.72 (m, 6 H, 3 CH_2); 1.72—1.82 (m, 1 H, C<u>H</u>H); 2.12—2.23 (m, 1 H, CH<u>H</u>); 2.40—2.51 (m, 1 H, C<u>H</u>H); 2.72—2.80 (m, 1 H, CH<u>H</u>); 2.80—2.88 (m, 2 H, N(C<u>H</u>H)$_2$); 3.14—3.23 (m, 2 H, N(CH<u>H</u>)$_2$); 3.87 (m, 1 H, H(5)); 4.14 (dt, 1 H, H(1′), *J* = 7.3 Hz, *J* = 1.8 Hz); 4.18 (dd, 1 H, H(2′a), *J* = 15.0 Hz, *J* = 1.8 Hz); 4.76 (dd, 1 H, H(1″), *J* = 10.3 Hz, *J* = 3.3 Hz); 4.77 (dd, 1 H, H(2′b), *J* = 15.0 Hz, *J* = 7.3 Hz); 4.86 (dd, 1 H, H(2″a), *J* = 11.8 Hz, *J* = 10.3 Hz); 5.09 (dd, 1 H, H(2″b), *J* = 11.8 Hz, *J* = 3.3 Hz).

(1′*S,5*R**,1″*S**)-4-{2,5-Bis[2-nitro-1-(trichloromethyl)ethyl]cyclopenten-1-yl}morpholine (19c)** was synthesized similarly to compound **19b** starting from nitroalkene **1a** and enamine **2d**. Yield 1.33 g (49%), m.p. 137—138 °C, white powder. Found (%): C, 33.68; H, 3.47; N, 7.65. $C_{15}H_{19}Cl_6N_3O_5$. Calculated (%): C, 33.74; H, 3.59; N, 7.87. IR, ν/cm^{-1}: 1625, 1578, 1558, 1456, 1443, 1424, 1378. ^1H NMR ($CDCl_3$), δ: 1.83 (ddd, 1 H, H(3a), *J* = 14.6 Hz, *J* = 9.7 Hz, *J* = 4.9 Hz); 2.20 (dtd, 1 H, H(4a), *J* = 15.6 Hz, *J* = 9.7 Hz, *J* = 5.8 Hz); 2.48 (dddd, 1 H, H(4b), *J* = 15.6 Hz, *J* = 9.7 Hz, *J* = 5.8 Hz, *J* = 2.6 Hz); 2.82 (ddd, 1 H, H(3b), *J* = 14.6 Hz, *J* = 9.7 Hz, *J* = 4.9 Hz); 2.93 (ddd, 2 H, N(C<u>H</u>H)$_2$, *J* = 11.2 Hz, *J* = 5.8 Hz, *J* = 3.5 Hz); 3.28 (ddd, 2 H, N(CH<u>H</u>)$_2$, *J* = 11.2 Hz, *J* = 5.8 Hz, *J* = 3.5 Hz); 3.74—3.85 (m, 4 H, O(CH_2)$_2$); 3.86 (m, 1 H, H(5)); 4.16 (dt, 1 H, H(1′), *J* = 7.7 Hz, *J* = 2.0 Hz); 4.19 (dd, 1 H, H(2′a), *J* = 15.8 Hz, *J* = 2.2 Hz); 4.75 (dd, 1 H, H(1″), *J* = 10.4 Hz, *J* = 3.3 Hz); 4.79 (dd, 1 H, H(2′b), *J* = 15.8 Hz, *J* = 7.7 Hz); 4.87 (dd, 1 H, H(2″a), *J* = 12.1 Hz, *J* = 10.4 Hz); 5.10 (dd, 1 H, H(2″b), *J* = 12.1 Hz, *J* = 3.3 Hz). ^1H NMR (C_6D_6), δ: 1.24—1.32 (m, 1 H, H(3a)); 1.56 (dtd, 1 H, H(4a), *J* = 15.6 Hz, *J* = 9.8 Hz, *J* = 5.9 Hz); 1.97 (dddd, 1 H, H(4b), *J* = 15.6 Hz, *J* = 9.8 Hz, *J* = 5.9 Hz, *J* = 2.6 Hz); 2.32 (ddd, 1 H, H(3b), *J* = 14.6 Hz, *J* = 9.8 Hz, *J* = 4.7 Hz); 2.65 (ddd, 2 H, N(C<u>H</u>H)$_2$, *J* = 11.4 Hz, *J* = 5.8 Hz, *J* = 3.5 Hz); 2.93 (ddd, 2 H, N(CH<u>H</u>)$_2$, *J* = 11.4 Hz, *J* = 5.8 Hz, *J* = 3.5 Hz); 3.37 (m, 1 H, H(5)); 3.47—3.56 (m, 4 H, O(CH_2)$_2$); 3.93 (dd, 1 H, H(2′a), *J* = 15.1 Hz, *J* = 2.2 Hz); 4.13 (dt, 1 H, H(1′), *J* = 6.9 Hz, *J* = 2.2 Hz); 4.24 (dd, 1 H, H(2″a), *J* = 12.4 Hz, *J* = 10.3 Hz); 4.39 (dd, 1 H, H(2′b), *J* = 15.1 Hz, *J* = 6.9 Hz); 4.40 (dd, 1 H, H(2″b), *J* = 12.4 Hz, *J* = 3.6 Hz); 4.58 (dd, 1 H, H(1″), *J* = 10.3 Hz, *J* = 3.6 Hz).

(1′*S,5*R**,1″*R**,2′*S*)-4-{2-[2-Nitro-1-(trichloromethyl)propyl]-5-[2-nitro-1-(trichloromethyl)ethyl]cyclopenten-1-yl}morpholine (19d).** To a stirred solution of enamine **2d** (0.77 g, 5.0 mmol) in anhydrous dichloromethane (5 mL), a solution of nitroalkene **1a** (0.95 g, 5.0 mmol) in anhydrous dichloromethane (5 mL) was added dropwise over a period of 15 min at ~20 °C. The mixture was stirred for 30 min followed by dropwise addition of a solution of nitroalkene **1c** (1.02 g, 5.0 mmol) in anhydrous dichloromethane (5 mL) within 15 min at ~20 °C. The reaction mixture was refluxed for 3 h and the solvent was removed *in vacuo*. Ethanol (5 mL) was added to the brown oily residue;

the precipitate fromed was filtered off, and washed with hexane. Yield 1.13 g (41%), m.p. 163—164 °C, colorless prisms. Found (%): C, 35.05; H, 3.95; N, 7.84. $C_{16}H_{21}Cl_6N_3O_5$. Calculated (%): C, 35.06; H, 3.86; N, 7.67. IR, ν/cm^{-1}: 1632, 1554, 1454, 1420, 1381, 1359. ^{1}H NMR ($CDCl_3$), δ: 1.62—1.72 (m, 1 H, C<u>H</u>H); 1.93 (d, 3 H, Me, J = 6.7 Hz); 2.17 (dtd, 1 H, CH<u>H</u>, J = 14.3 Hz, J = 9.5 Hz, J = 4.7 Hz); 2.50—2.70 (m, 2 H, CH_2); 2.98 (ddd, 2 H, N(C<u>H</u>H)$_2$, J = 11.2 Hz, J = 6.0 Hz, J = 3.0 Hz); 3.22 (ddd, 2 H, N(CH<u>H</u>)$_2$, J = 11.2 Hz, J = 5.8 Hz, J = 3.2 Hz); 3.74—3.85 (m, 5 H, O(CH_2)$_2$, H(5)); 4.12 (dd, 1 H, H(2a′), J = 15.5 Hz, J = 1.5 Hz); 4.14 (m, 1 H, H(1′)); 4.59 (d, 1 H, H(1″), J = 9.6 Hz); 4.73 (dd, 1 H, H(2b′), J = 15.5 Hz, J = 7.7 Hz); 5.24 (dq, 1 H, H(2″), J = 9.6 Hz, J = 6.7 Hz). ^{1}H NMR (C_6D_6), δ: 1.22—1.35 (m, 1 H, C<u>H</u>H); 1.33 (d, 3 H, Me, J = 6.7 Hz); 1.64 (dtd, 1 H, CH<u>H</u>, J = 14.6 Hz, J = 9.5 Hz, J = 5.0 Hz); 2.20—2.37 (m, 2 H, CH_2); 2.76 (dt, 2 H, N(C<u>H</u>H)$_2$, J = 11.7 Hz, J = 4.5 Hz); 2.93 (dt, 2 H, N(CH<u>H</u>)$_2$, J = 11.7 Hz, J = 4.5 Hz); 3.37 (br.t, 1 H, H(5), J = 7.0 Hz); 3.56 (t, 4 H, O(CH_2)$_2$, J = 4.5 Hz); 4.07 (dd, 1 H, H(2a′), J = 15.3 Hz, J = 1.2 Hz); 4.18 (dt, 1 H, H(1′), J = 7.3 Hz, J = 1.2 Hz); 4.46 (dd, 1 H, H(2b′), J = 15.3 Hz, J = 7.3 Hz); 4.47 (d, 1 H, H(1″), J = 9.4 Hz); 4.79 (dq, 1 H, H(2″), J = 9.4 Hz, J = 6.7 Hz).

(1′*S,5*R**,1″*S**)-4-{2-[2-Nitro-1-(trichloromethyl)ethyl]-5-[2-nitro-1-(trifluoromethyl)ethyl]cyclopenten-1-yl}morpholine (19e)** was synthesized similarly to compound **19d** with addition of nitroalkene **1b** (0.71 g, 5.0 mmol) on the second step. Yield 1.56 g (32%), m.p. 173—174 °C, white powder. Found (%): C, 37.20; H, 3.80; N, 8.62. $C_{15}H_{19}Cl_3F_3N_3O_5$. Calculated (%): C, 37.17; H, 3.95; N, 8.67. IR, ν/cm^{-1}: 1635, 1566, 1558, 1434, 1380. ^{1}H NMR ($CDCl_3$), δ: 1.68—2.10 (m, 2 H, CH_2); 2.42—2.62 (m, 2 H, CH_2); 2.97 (ddd, 2 H, N(C<u>H</u>H)$_2$, J = 11.2 Hz, J = 5.8 Hz, J = 3.2 Hz); 3.20 (ddd, 2 H, N(CH<u>H</u>)$_2$, J = 11.2 Hz, J = 5.8 Hz, J = 3.2 Hz); 3.38 (m, 1 H, H(5)); 3.59 (quintt, 1 H, H(1′), J = 9.1 Hz, J = 2.5 Hz); 3.68—3.80 (m, 4 H, O(CH_2)$_2$); 4.30 (dd, 1 H, H(2′a), J = 14.3 Hz, J = 2.2 Hz); 4.63 (dd, 1 H, H(2′b), J = 14.3 Hz, J = 8.8 Hz); 4.73 (dd, 1 H, H(2″a), J = 11.3 Hz, J = 10.3 Hz); 4.92 (dd, 1 H, H(1″), J = 10.3 Hz, J = 3.1 Hz); 4.98 (dd, 1 H, H(2″b), J = 11.3 Hz, J = 3.1 Hz). ^{19}F NMR ($CDCl_3$), δ: 92.3 (d, CF_3, J = 9.3 Hz).

X-ray diffraction analyses of compounds 9, *syn*-15 and 19d were performed on a single crystal automatized Xcalibur 3 diffractometer equipped with CCD detector following the standard procedure (T = 295(2) K for compounds **9**, **19d** and 120(2) K for compound *syn*-**15**), Mo-Kα irradiation, graphite monochromator, ω scanning mode, scanning step of 1°). The structures were solved by direct method using the SHELX97 program package.[31] All non-hydrogen atoms were positioned independently by anisotropic approximation, the hydrogen atoms were placed

Table 3. Crystallographic data and X-ray diffraction experiment parameters for compounds **9**, *syn*-**15**, and **19d**

Parameter	**9**	*syn*-**15**	**19d**
Crystal system	Monoclinic	Triclinic	Triclinic
Space group	$P2_1/c$	$P\bar{1}$	$P\bar{1}$
a/Å	7.6720(3)	5.6773(6)	11.7494(17)
b/Å	26.3710(7)	9.3221(16)	14.8139(13)
c/Å	7.7406	10.8453(10)	14.870(2)
α/deg	90	65.899(13)	87.897(12)
β/deg	109.149(3)	81.626(8)	67.026(12)
γ/deg	90	82.085(11)	80.397(10)
V/Å^3	1479.41(8)	516.41(11)	2348.3(5)
Z	4	2	4
d_{calc}/g cm^{-3}	1.543	1.538	1.550
μ/mm^{-1}	0.627	0.148	0.764
F(000)	712	248	1120
Scanning rang on θ/deg	2.89—28.28	3.64—30.51	2.84—26.37
h, k, l Indices	$-7 < h < 10$, $-35 < k < 33$, $-10 < l < 10$	$-8 < h < 7$, $-13 < k < 13$, $-13 < l < 15$	$-14 < h < 14$, $-18 < k < 16$, $-18 < l < 17$
Number of measured reflections	7869	3546	10948
Number of independent reflections	3542 (R_{int} = 0.0533)	3071 (R_{int} = 0.0133)	9333 (R_{int} = 0.0418)
Reflections with $I > 2\sigma(I)$	2587	2105	3015
Completeness of data collection (%)	96.4 (θ = 26.00°)	97.3 (θ = 26.00°)	97.2 (θ = 26.37°)
S on F^2	1.003	1.007	1.002
R Factors ($I > 2\sigma(I)$)			
R_1	0.0439	0.0324	0.0541
wR_2	0.1153	0.0791	0.0990
R Factors (on all reflections)			
R_1	0.0574	0.0518	0.1738
wR_2	0.1196	0.0823	0.1077
$\Delta\rho_e$ (max/min)/e Å^{-3}	0.393/−0.446	0.391/−0.247	0.467/−0.294

in geometrically calculated positions and refined in the riding model with fixed thermal parameters. The main parameters of X-ray diffraction experiments are given in Table 3. In structure **19d**, the morpholine cycle of one of the crystallographically independent molecule are in the chair conformation. The cycle of the second independent molecule are disordered in two positions with population of 0.5, in which the substituent at the morpholine nitrogen adopts pseudo-axial and pseudo-equatorial positions. The details of X-ray experiments for compounds **9**, *syn*-**15**, and **19d** were deposited with the Cambridge Crystallographic Data Center (CCDC 860867, 860866, 863734, respectively).

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