Synthesis of 3-Aminotropones from *N*-Boc-Protected Furan-2-amine (= *tert*-Butyl Furan-2-ylcarbamate; Boc = (*tert*-Butoxy)carbonyl) by Cycloaddition Reactions and Subsequent Rearrangement

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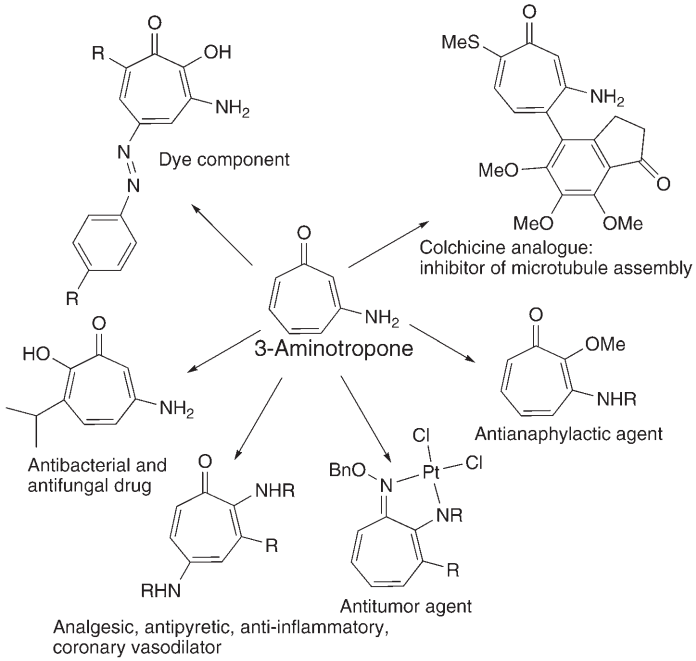
In memoriam Professor *Xavier Solans*

The 3-aminotropones (= 3-aminocyclohepta-2,4,6-trien-1-ones) **4** were prepared in two steps by *i*) a [4 + 3] cycloaddition reaction between a conveniently substituted α,α'-dihalo ketone **1** and a furan-2-amine derivative **2** functionalized at C(2) by a protected amino group (→ **3**), and *ii*) a base-induced molecular rearrangement of the cycloadduct **3** *via* cleavage of the O-bridge. A mechanism for the formation of 3-aminotropones is proposed on the basis of the initial deprotonation of the [(*tert*-butoxy)carbonyl]amino (BocNH) group of **3**, followed by O-bridge opening, an acid–base equilibrium, and finally an alkoxyaluminate elimination to afford the conjugated stable troponoid system (*Scheme 7*).

1. Introduction. – The tropone framework is present in many natural and synthetic products with biological activity, ranging from simple monocyclic systems [1] to more complex nor-diterpenoids [2] and alkaloids [3] (*Scheme 1*) such as colchicine [4]. On the other hand, particularly, it has been found that aminotropones can act as analgesic [5], anti-inflammatory [5][6], antianaphylactic [7], or antitumor [8] agents. The activity of some aminotropone derivatives as coronary vasodilators and their effects on blood pressure and on respiration have also been studied and confirmed [9]. In addition, aminotropone oximes could coordinate to Pt to form *cis*-diamminedichloroplatinum complexes that are used as drugs for clinical cancer chemotherapy [10]. For this application, it is worth to mention the important activity of 3-aminotropone derivatives, analogues of colchicine, which act as inhibitors of microtubule assembly during cell mitosis. These compounds find use as anticancer and antirheumatic drugs [11]. Also, hinokitiol derivatives, having the 3-aminotropone framework, have antibacterial, antifungal, and antileptospiral activities [12].

Scheme 1. *Occurrence of the 3-Aminotropone Ring System in Natural and Synthetic Products with Application and Uses in Different Fields*



In the field of homogeneous catalysis, aminotropone derivatives have been used as bidentate ligands of metal complexes to design new catalysts. Thus, they have been used to catalyze quite different reactions such as hydroamination/cyclization [13] and enantioselective conjugate addition of *Grignard* reagents to enones [14]. Moreover, it is worth noting the reactivity of aminotropones with diketenes [15].

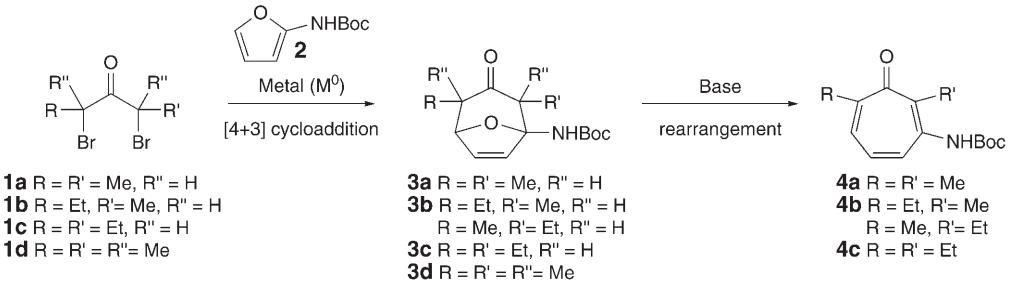
On the other hand, the mesogenic properties exhibited by troponoids and, especially, the thermal stability of aminotropone derivatives explain the use of these compounds in the preparation of liquid crystals [16]. In addition, nitro and diazo derivatives of 3-aminotropones have interesting properties as dyes and find application as components in hair dyes and textile industries [17].

The broad range of biological, catalytic, and physical properties [18] of these compounds has stimulated a number of synthetic efforts in order to develop methodologies to prepare the tropone system.

Several approaches to the synthesis of the tropone ring have evolved, based on cycloaddition reactions [19] and on six-membered ring expansions [20] as the key steps. However, appropriately substituted tropones are still difficult to synthesize because the selective introduction of substituents at certain positions is hard to achieve. Thus, only three syntheses of 3-aminotropones have been published [21][22][23d], and two of these reported 3-aminotropones are not substituted. Hence, the development of new, versatile, and short routes to conveniently substituted 3-aminotropones is desirable.

2. Results and Discussion. – Here, a versatile and short synthesis of 2- and/or 7-substituted 3-aminotropones **4** is reported. Our synthetic methodology consists of only two steps: *i*) a [4 + 3] cycloaddition reaction between an α,α'-dihalo ketone **1** and a furan derivative **2**, functionalized at C(2) by a protected amino group, and *ii*) a rearrangement of the cycloadduct **3**, *via* cleavage of the O-bridge, under basic conditions (*Scheme 2*) [23].

Scheme 2. *Pathway for the Synthesis of 3-Aminotropones* **4a**–**c**. For the relative configuration of compounds **3a**–**d**, see *Table 2*.



1a R = R' = Me, R'' = H
1b R = Et, R'= Me, R'' = H
1c R = R' = Et, R'' = H
1d R = R' = R''= Me

3a R = R' = Me, R'' = H
3b R = Et, R'= Me, R'' = H
R = Me, R'= Et, R'' = H
3c R = R' = Et, R'' = H
3d R = R' = R''= Me

4a R = R' = Me
4b R = Et, R'= Me
R = Me, R'= Et
4c R = R' = Et

2.1. *[4 + 3] Cycloaddition Reaction*. The cycloadducts **3a**–**d** were obtained by a [4 + 3] cycloaddition reaction [24] between *N*-[(*tert*-butoxy)carbonyl]-protected furan-2-amine **2** and an oxyallyl cation, generated *in situ* from α,α'-dibromo ketones **1a**–**d** and a reducing metal (M^0) [25]. The halo ketones **1a**–**d** were prepared in one step and in moderate to good yields from the corresponding commercial ketones, by bromination under PBr_3 catalysis [24a][25a]. Aminated furan **2** was easily obtained in excellent yield from furan-2-carbonyl chloride and sodium azide in *tert*-butyl alcohol *via* a *Curtius* rearrangement [26]. The oxabicycles **3a**–**d** were readily available in diastereoisomerically pure form from **1a**–**d** and **2** after flash column chromatography [27].

2.1.1. *[4 + 3] Cycloaddition Reaction Optimization.* The [4 + 3] cycloaddition reaction between **1a** and **2** (*Scheme 3*) was broadly studied to optimize the reaction conditions and to improve the yield, the workup, and the isolation and purification processes of the products (see *Table 1*). Thus, it turned out that for the evaluated substrates, the highest yield was obtained by using $[Fe_2(CO)_9]$ as reducing agent in anhydrous MeCN (*Entry 12*). The reduction of α,α'-dihalo ketones with $[Fe_2(CO)_9]$ generates highly electrophilic oxyallyl cations due to the more or less covalent nature of the O–Fe bond (of the iron enolatoiron moiety). Since the bonding electron pair of the enolato O-atom is mostly localized in the covalent O–Fe bond, its contribution to the resonance stabilization of the positive charge of the oxyallyl cation is low, making it more electrophilic (reactive) for the capture by an electron-rich diene [24d]. When using a reducing metal or a metallic pair, except for $[Fe_2(CO)_9]$, the presence of NaI improved the reaction yields, due to the intermediate generation of diiodo ketones, which are formed *in situ* from dibromo ketones and NaI, and which are more reactive than dibromo ketones, considering that I-atoms are better leaving groups than Br-atoms [23] (see *Entries 2*, *4*, and *8 vs. Entries 1*, *3*, and *7*, resp.).

Scheme 3. *Synthesis of* **3a** *by a [4+3] Cycloaddition Reaction between* **1a** *and* **2**

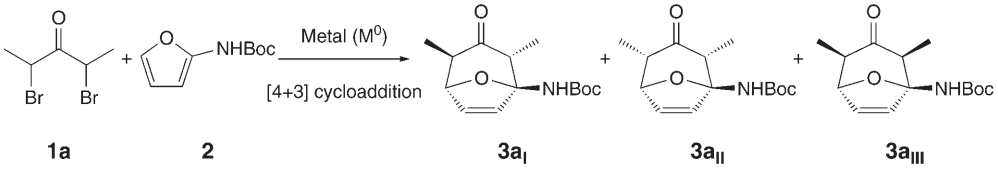


Table 1. *Study of Parameters for the Optimization of the [4+3] Cycloaddition Reaction between* **1a** *and* **2**

Entry	Metal	Molar ratio metal/**2**	Solvent (anh.)	*T* [°]	Reaction time [h]	Yield [%][a])	Ratio of diastereoisomers **3a**$_I$/**3a**$_{II}$/**3a**$_{III}$[b])
1	Cu	4/1	MeCN	−10 to r.t.	4.5	33	2 : 52 : 46
2	Cu/NaI	4+8/1	MeCN	−10 to r.t.	4.5	47	0 : 51 : 49
3	Zn	4/1	MeCN	−10 to r.t.	22	15	30 : 58 : 12
4	Zn/NaI	4+8/1	MeCN	−10 to r.t.	22	62	25 : 42 : 33
5	Zn/Me_3SiCl	4+1.2/1	MeCN	−10 to r.t.	4.5	0	–
6	Zn/Cu	97.7[c])	MeCN	−10 to 0	4.75	18	28 : 61 : 11
7	Zn/Cu	97.7[c])	MeCN	−10 to r.t.	4.75	33	38 : 55 : 7
8	Zn/Cu + NaI	97.7[c])	MeCN	−10 to r.t.	4.5	37	8 : 46 : 46
9	$[Fe_2(CO)_9]$	1.75/1	benzene	−10 to reflux	5.5	0	–
10	$[Fe_2(CO)_9]$	1.75/1	benzene	−10 to 50	5	5	44 : 50 : 6
11	$[Fe_2(CO)_9]$	1.75/1	benzene	−10 to r.t.	5	10	50 : 45 : 5
12	$[Fe_2(CO)_9]$	1.75/1	MeCN	−10 to r.t.	6.5	76	55 : 40 : 5

[a]) Yield after column chromatography. [b]) See *Table 2* for relative configurations. [c]) mg of metal/mmol of diene.

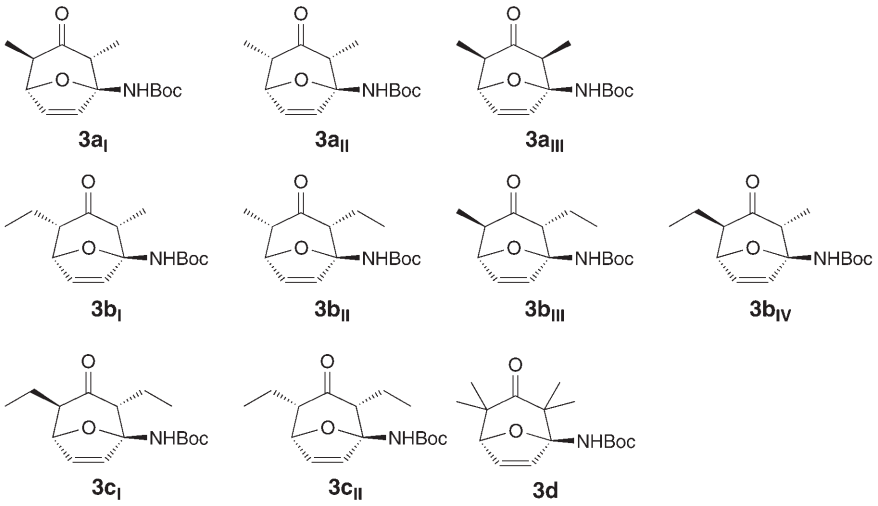
The [4+3] cycloadditions of the halo ketones **1a**–**d** were carried out under the optimized conditions (see *Table 1*, *Entry 12*), with $[Fe_2(CO)_9]$ as the reducing agent and anhydrous MeCN as solvent (*Table 2*). In all cases, the reaction was run at room temperature after the dropwise addition of the dibromo ketone at −10°. All diastereoisomeric products obtained were separated and purified by column chromatography and physically and spectroscopically characterized. The results suggest that, in general, the yield of cycloadducts **3** decreases with increasing bulkiness of the halo ketone side chain. Thus, comparing *Entries 1*, *3*, and *4* (*Table 2*), one observes that the yield in *Entry 4* drops to less than a quarter with respect to *Entry 1*, due to the presence of two extra Me groups in α- and α′-position of halo ketone **1d**, which exert an important steric repulsion among them and also with the BocNH group. This steric hindrance makes the approach of the reactant species in the cycloaddition step very difficult.

2.1.2. *Diastereoselectivity.* When symmetric α,α′-dihalo ketones such as **1a** are used, symmetrically substituted oxyallyl cations are generated. In this particular case, the formation of up to four diastereoisomeric cycloadducts – depending on the relative spatial arrangement of the substituents at C(2) and C(4) in the bicyclic system – is theoretically possible, of which three were observed (*Scheme 3*). To explain this

Table 2. *Results of the [4+3] Cycloaddition Reaction between* **1a–d** *and* **2**

Entry	Substrate	Reaction time [h]	Yield [%][a])	Products[b])	Diastereoisomer ratio
1	**1a**	6.5	76	**3a$_I$**, **3a$_{II}$**, **3a$_{III}$**	55 : 40 : 5
2	**1b**	7	55	**3b$_I$**, **3b$_{II}$**, **3b$_{III}$**, **3b$_{IV}$**	30 : 24 : 25 : 21
3	**1c**	7	60	**3c$_I$**, **3c$_{II}$**	52 : 48
4	**1d**	4	16	**3d**	–

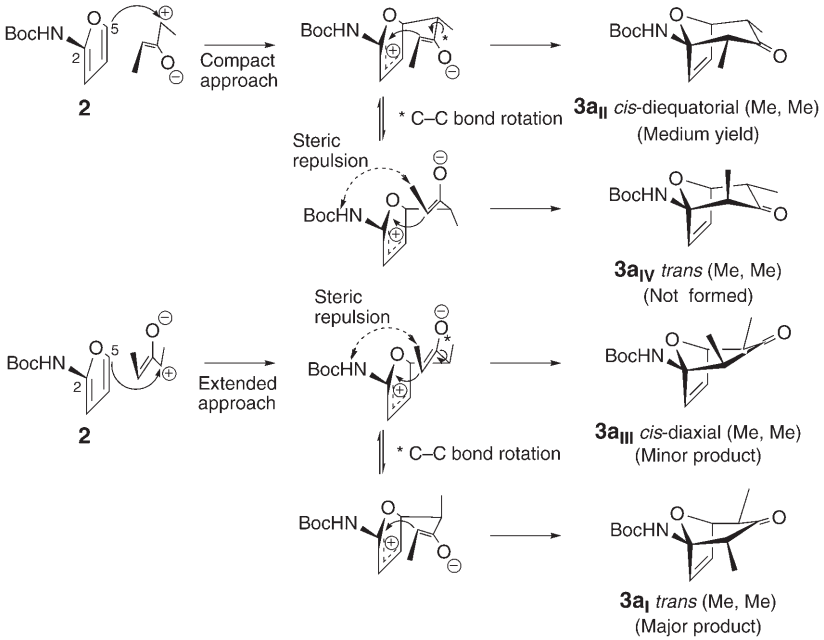
[a]) Yield after column chromatography. [b]) Relative configurations:



stereochemical outcome, a stepwise mechanism is proposed (*Scheme 4*). Accordingly, furan **2** can be attacked by the oxyallyl cation mainly at C(5) rather than at C(2) since C(5) is a more electron-rich C-atom and, on the other hand, since the resulting intermediate carbocation is stabilized by charge delocalization, assisted by the lone electron pair of the N-atom. Once the oxyallyl substructure is linked to the furan, the resulting enolate attacks the intermediate carbocation at the former C(2) position to generate the bicyclic cycloadducts. In this approach, Me groups attached to the initial oxyallyl cation and carbamate group have to sterically fit in order to minimize possible repulsive interactions. Thus, a C–C bond rotation (at the stage of the oxyallyl enolate) can take place to move these two groups far apart, generating *trans* (Me, Me) diastereoisomers as major products (*Scheme 4*).

The diastereoselectivity could be modified to some extent by the nature of the reducing metal (see *Table 1*). Thus, **3a$_{II}$** was obtained as the major product by using Cu in the presence of NaI (*Entry 2*), whereas **3a$_I$** was obtained as the major diastereoisomer when using $[Fe_2(CO)_9]$ as reducing agent (*Entry 12*). This stereochemical outcome is conditioned by the electrophilicity of the reactant oxyallyl cation. As mentioned above, $[Fe_2(CO)_9]$ as a reducing agent generates a highly electrophilic oxyallyl cation which adds to the furan diene by a stepwise mechanism by both the compact- or extended-approach modes (*Scheme 4*). In both cases, the intermediate is

Scheme 4. *Explanation of the Observed Diastereoselectivity in the [4+3] Cycloaddition Reaction of* **1a** *and* **2** *on the Basis of Electron Assistance and Steric Repulsion Effects*



sufficiently long-lived to undergo a C–C bond rotation to reduce the steric repulsion between the Me and BocNH groups, affording $\mathbf{3a_I}$ as the major diastereoisomer but no sterically hindered diastereoisomer $\mathbf{3a_{IV}}$ (*Fig. 1*).

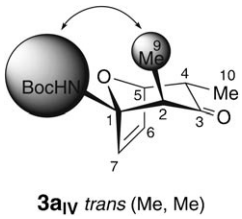


Fig. 1. *Destabilizing steric repulsion in the structure of* $\mathbf{3a_{IV}}$

The use of Cu, Zn, or Zn/Cu in the presence of NaI generates a less electrophilic cation because the ionic character of the O–Zn or O–Cu bond in the oxyallyl enolate allows the bonding electron pair of the O-atom to be available to assist the positive charge of oxyallyl cation and to stabilize it. This oxyallyl cation is less reactive, and it mainly reacts *via* a concerted compact-approach mode affording the *cis*-diequatorial diastereoisomer $\mathbf{3a_{II}}$ as the major product. Moreover, diastereoisomer $\mathbf{3a_{II}}$ is quite stable because the 8-oxabicyclo[3.2.1]oct-6-en-3-one structure adopts a chair-like conformation in the tetrahydro-4*H*-pyran-4-one ring, placing its substituents apart from each other, which considerably decreases the steric strain within the molecule.

The formation, in an important proportion, of the *cis*-diaxial cycloadduct **3a$_{III}$** under these reaction conditions is mechanistically significant and suggests that the cycloaddition reaction proceeds, to a certain extent, *via* an extended concerted mode, concomitant with the compact approach. The missing of the *trans* diastereoisomer **3a$_{IV}$** in these cycloaddition reactions could again be explained by the steric repulsion between the BocNH and Me group at C(2) in the transition state leading to **3a$_{IV}$** (*cf. Scheme 4* and *Fig. 1*).

When furan **2** and the symmetric α,α'-dibromo ketone **1c** were submitted to the cycloaddition reaction in the presence of $[Fe_2(CO)_9]$, only diastereoisomers **3c$_I$** and **3c$_{II}$** were obtained (*Table 2*), in agreement with the above reasoning.

When an oxyallyl cation generated from the nonsymmetric α,α'-dibromo ketone **1b** reacts with **2**, up to eight isomeric cycloadducts can theoretically be formed (*Fig. 2*). With $[Fe_2(CO)_9]$ as reducing agent, only four of these eight possible products were obtained (*Table 2*) the two *trans* products **3b$_{III}$** and **3b$_{IV}$** and the two *cis*-diequatorial products **3b$_I$** and **3b$_{II}$**. It is worth noting that none of the products **3b$_I'$**, **3b$_{II}'$**, **3b$_{III}'$**, and **3b$_{IV}'$**, having a Me or Et group at C(2) in *cis* relation with respect to the BocNH group, was formed (see also *Fig. 1*).

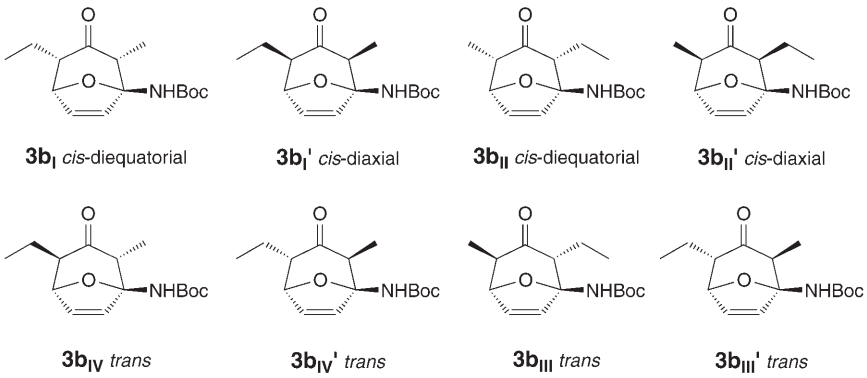


Fig. 2. *Possible formation of eight different isomeric cycloadducts, according to the proposed mechanism, from nonsymmetric α,α'-dihalo ketone* **1b**

2.1.3. *Assignment of the Relative Configuration of the Cycloadducts: NMR Correlation Studies.* The aforementioned isomeric cycloadducts were isolated from the crude product mixture, purified by column chromatography, and physically and spectroscopically characterized. The relative configuration of the isomers was established by the following protocol: *a*) Unequivocal assignment of the ^{1}H- and ^{13}C-NMR signals by 1D and 2D experiments (DEPT, COSY, HETCOR, and NOESY). *b*) Conformational analysis by MM2, MOPAC, and GAUSSIAN computational methods to find the minimum-energy conformations for each diastereoisomer. *c*) Comparative study of the NMR data of all diastereoisomers; analysis of significant differences and correlation studies. *d*) Study of the configuration-dependent stereoelectronic effects responsible for significant and diagnostic ΔJ (Hz) and $\Delta\delta$ (ppm) variations among diastereoisomers in their minimum-energy conformations. *e*) Assignment of the relative configuration that should be consistent with all data and

observations from previous studies. *f*) Confirmation of the validity of the previous assignments of configuration by X-ray diffraction analysis of single crystals of certain key products.

The correlation study is exemplified for the assignment model applied to diastereoisomers **3a$_I$**, **3a$_{II}$**, and **3a$_{III}$**. The establishment of the relative *cis*/*trans* configuration was possible by the analysis of the influence exerted on the chemical shifts (*Table 3*) by the stereoelectronic effects (electric field, shielding and deshielding effects) among the substituents of the oxabicycle. The observation of these phenomena was facilitated by the lack of conformational freedom of the bicyclic system. As shown in *Fig. 3*, there are different conformational possibilities for the tetrahydro-4*H*-pyran-4-one ring of the bicyclic system, depending on the different spatial position of the Me groups at C(2) and C(4). In the diastereoisomers **3a$_I$** and **3a$_{III}$**, the observed coupling constant ^3J(4,5) between H–C(4) and H–C(5) was 0 Hz; thus, according to the *Karplus* equation, the dihedral angle H–C(4)–C(5)–H is 90°, pointing to a boat-like conformation of the tetrahydro-4*H*-pyran-4-one ring. This type of conformation is adopted to reduce the 1,3-*cis*-diaxial steric interactions [28] between Me groups attached to C(2) and C(4) in **3a$_{III}$** or the steric repulsion between Me–C(2) and the BocNH group in **3a$_I$**.

Me–C(4) in **3a$_I$** and **3a$_{III}$** and Me–C(2) in **3a$_{III}$** are oriented towards the oxa bridge, and they are in a certain spatial proximity to it. For this reason, these Me groups exhibit a 1,3-dipolar deshielding interaction (by an electric field effect) [29], and they appear at lower field than the Me groups in **3a$_{II}$** (see *Table 3*). On the other hand, Me–C(2) in **3a$_I$** is *endo*-oriented and close to C(6)=C(7) with its shielding anisotropy cone. In **3a$_{II}$**,

Table 3. *^{1}H-NMR Data* ($CDCl_3$) *of* **3a$_I$**, **3a$_{II}$**, *and* **3a$_{III}$**[a]). δ in ppm, J in Hz.

	3a$_I$	**3a$_{II}$**	**3a$_{III}$**	$\Delta\delta$ (**3a$_I$** – **3a$_{II}$**)	$\Delta\delta$ (**3a$_I$** – **3a$_{III}$**)	$\Delta\delta$ (**3a$_{II}$** – **3a$_{III}$**)
Me–C(4)	1.35 (*d*, ^3J(Me,4) = 7.6)	0.97 (*d*, ^3J(Me,4) = 7.0)	1.33 (*d*, ^3J(Me,4) = 7.6)	0.38	0.02	– 0.36
Me–C(2)	1.08 (*d*, ^3J(Me,2) = 7.0)	1.08 (*d*, ^3J(Me,2) = 7.0)	1.29 (*d*, ^3J(Me,2) = 7.6)	0.00	– 0.21	– 0.21
H–C(7)	6.28 (*s*)	6.29 (*s*)	6.38 (*d*, ^3J(7,6) = 6.1)	– 0.01	– 0.10	– 0.09
H–C(6)	6.28 (*s*)	6.29 (*s*)	6.21 (*ddd*, ^3J(6,7) = 6.1, ^3J(6,5) = 2.0, ^3J(6,4) = 0.5)	– 0.01	0.07	0.08
H–C(5)	4.74 (*s*)	4.91 (*dd*, ^3J(5,4) = 4.6, ^3J(5,6) = 1.2)	4.73 (*d*, ^3J(5,6) = 2.0)	– 0.17	0.01	0.18
H–C(4)	2.31 (*q*, ^3J(4,Me) = 7.6)	2.79 (*dq*, ^3J(4,Me) = 7.0, ^3J(4,5) = 4.6)	2.28 (*q*, ^3J(4,Me) = 7.6)	– 0.48	0.03	0.51
H–C(2)	3.00 (*q*, ^3J(2,Me) = 7.0)	3.02 (*q*, ^3J(2,Me) = 7.0)	2.65 (*q*, ^3J(2,Me) = 7.6)	– 0.02	0.35	0.37

[a]) For numbering of the C-atoms, see *Fig. 1*.

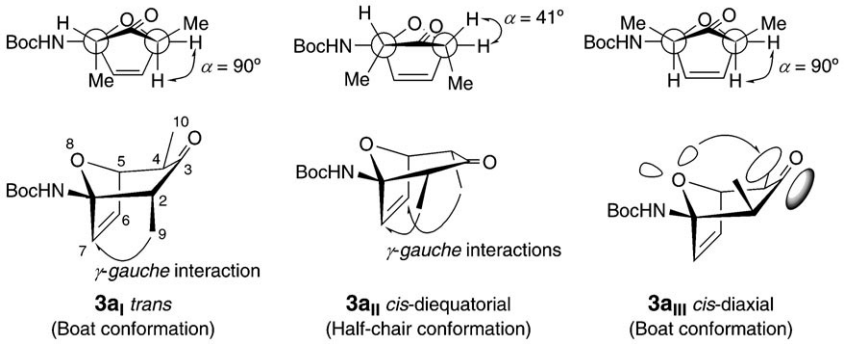


Fig. 3. *Different conformations of the bicyclic system in cycloadducts* **3a**$_{\mathbf{I}}$, **3a**$_{\mathbf{II}}$, *and* **3a**$_{\mathbf{III}}$ *depending on the configuration at C(2) and C(4)*

^3J(4,5) amounts to 4.6 Hz, and the dihedral angle H–C(4)–C(5)–H calculated according to the *Karplus* equation is 41° (see *Fig. 3*). In this particular conformation, the tetrahydro-4*H*-pyran-4-one ring adopts a half-chair conformation placing the Me groups in *quasi*-equatorial position and directing H–C(2) and H–C(4) towards the bridging O-atom, which results in a deshielding effect on both H-atoms in comparison to **3a**$_{\mathbf{III}}$ (or with respect to **3a**$_{\mathbf{I}}$ in the case of H–C(4)).

The comparative study of ^{13}C-NMR data (*Table 4*) was consistent with the assignments of the relative configuration established by the ^{1}H-NMR correlations. The main differences of δ(C) among the diastereoisomers were observed for C(3), C(9), and C(10). Thus, the signal of C(10) (= *Me*–C(4) of **3a**$_{\mathbf{I}}$ and **3a**$_{\mathbf{III}}$ appeared at lower field than that of the same C-atom of **3a**$_{\mathbf{II}}$ (see *Table 4*), owing to a *γ-gauche* shielding interaction [30] between Me–C(4) and H–C(6) in **3a**$_{\mathbf{II}}$ in which Me–C(4) is *endo* oriented. On the other hand, C(9) (= *Me*–C(2)) of **3a**$_{\mathbf{I}}$ and **3a**$_{\mathbf{II}}$ appeared at higher field with respect to that of the same C-atom of **3a**$_{\mathbf{III}}$, due to a *γ-gauche* shielding interaction between Me–C(2) and H–C(7) in **3a**$_{\mathbf{I}}$ and **3a**$_{\mathbf{II}}$ in which Me–C(2) adopts an *endo* position. Moreover, δ (*Me*–C(4)) > δ (*Me*–C(2)) in all diastereoisomers because of the *γ-gauche* shielding effect exerted by the BocNH group on Me–C(2).

Table 4. *^{13}C-NMR Data* ($CDCl_3$) *of* **3a**$_{\mathbf{I}}$, **3a**$_{\mathbf{II}}$, *and* **3a**$_{\mathbf{III}}$. δ in ppm.

	3a$_{\mathbf{I}}$	**3a**$_{\mathbf{II}}$	**3a**$_{\mathbf{III}}$	$\Delta\delta$ (**3a**$_{\mathbf{I}}$ – **3a**$_{\mathbf{II}}$)	$\Delta\delta$ (**3a**$_{\mathbf{I}}$ – **3a**$_{\mathbf{III}}$)	$\Delta\delta$ (**3a**$_{\mathbf{II}}$ – **3a**$_{\mathbf{II}}$)
C(10) (= *Me*–C(4))	16.4	10.6	17.8	5.8	–1.4	–7.2
C(9) (= *Me*–C(2))	9.8	10.0	13.8	–0.2	–4.0	–3.8
C(3)	210.7	208.0	213.0	2.7	–2.3	–5.0

Furthermore, the signal of C(3) of **3a**$_{\mathbf{I}}$ and **3a**$_{\mathbf{III}}$ appears at lower field than that of **3a**$_{\mathbf{II}}$. This fact could be interpreted on the basis of the destabilizing repulsive interaction between the nonshared electron pairs of the bridging O-atom and the π-electrons of the carbonyl group. In the structures of **3a**$_{\mathbf{I}}$ and **3a**$_{\mathbf{III}}$, owing to the close proximity of such orbitals, the electron density of the π-orbital of the carbonyl group is pushed towards its O-atom, leaving the carbonyl C-atom deshielded [30]. This effect would not be

observed or it would be present to a lesser extent in diastereoisomer $\mathbf{3a_{II}}$, in which the tetrahydro-4*H*-pyran-4-one ring adopts a half-chair conformation.

The structure of these compounds was confirmed by an X-ray diffraction analysis of the single crystals of $\mathbf{3a_{II}}$ and $\mathbf{3c_I}$ (see *Figs. 4* and *5*, and *Tables 5* and *6*).

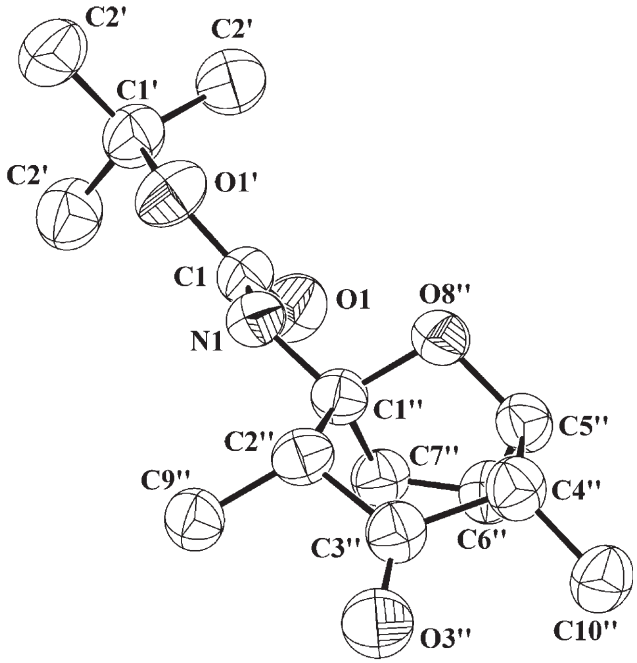


Fig. 4. *ORTEP Representation of* $\mathbf{3a_{II}}$ *by X-ray diffraction analysis.* Arbitrary atom numbering.

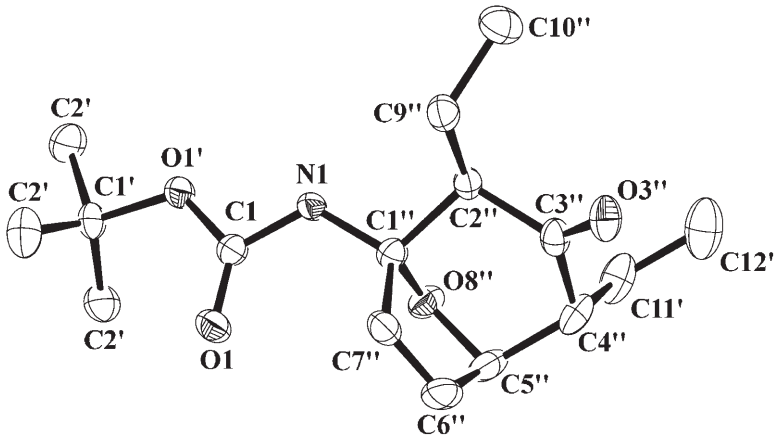


Fig. 5. *ORTEP Representation of* $\mathbf{3c_I}$ *by X-ray diffraction analysis.* Arbitrary atom numbering.

Table 5. *Crystal-Data Refinement for* $\mathbf{3a_{II}}$ *and* $\mathbf{3c_I}$

	$\mathbf{3a_{II}}$	$\mathbf{3c_I}$
Empirical formula	$C_{14}H_{21}NO_4$	$C_{16}H_{25}NO_4$
Crystal size	$0.1 \times 0.1 \times 0.2$ mm	$0.3 \times 0.2 \times 0.15$ mm
Temperature	293(2) K	150(2) K
Wavelength	0.71073 Å	0.71073 Å
Crystal system	monoclinic	triclinic
Space group	$P2_1/n$	$P1$
Unit cell dimensions	$a = 16.194(7)$ Å	$a = 11.0050(2)$ Å
	$b = 11.221(3)$ Å	$b = 12.3000(2)$ Å
	$c = 24.729(8)$ Å	$c = 12.7750(2)$ Å
	$\alpha = 90°$	$\alpha = 100.406(1)°$
	$\beta = 90.95(2)°$	$\beta = 90.228(1)°$
	$\gamma = 90°$	$\gamma = 98.545(1)°$
Volume	4493(3) Å^3	1681.08(5)Å^3
Z	12	4
Calculated density	1.186 Mg/m^3	1.167 Mg/m^3
Absorption coefficient	0.086 mm^{-1}	0.083 mm^{-1}
$F(000)$	1728	640
θ Range for data collection	1.49 – 30.00°	3.35 – 27.51°
Limiting indices	$-22 \le h \le 22$, $0 \le k \le 15$, $0 \le l \le 34$	$-14 \le h \le 14$, $-15 \le k \le 15$, $-16 \le l \le 16$
Reflections collected	12114	29572
Independent reflections	12114 (R(int) = 0.0812)	7653 (R(int) = 0.1019)
Completeness to θ	30.00; 92.6%	27.51; 99.2%
Refinement method	Full-matrix least-squares on F^2	Full-matrix least-squares on F^2
Data, restraints, parameters	12114, 17, 524	7653, 0, 394
Goodness-of-fit on F^2[a])	0.980	1.021
Final R indices ($I > 2\sigma(I)$)	R_1[b]) = 0.0501, wR_2[c]) = 0.1561	R_1[b]) = 0.0543, wR_2[c]) = 0.1049
R indices (all data)	$R_1 = 0.0890$, $wR_2 = 0.1856$	$R_1 = 0.0983$, $wR_2 = 0.1183$
Extinction coefficient[d])	0.0025(7)	0.016(2)
Largest diff. peak and hole	0.354 and −0.395 e Å^{-3}	0.412 and −0.454 e A^{-3}

[a]) G.o.f. $= S = \{\Sigma[w(F_o^2 - F_c^2)^2]/(n-p)\}^{1/2}$. [b]) $R_1 = \Sigma\,||F_o| - |F_c||/\Sigma\,|F_o|$. [c]) $wR_2 = \{\Sigma[w(F_o^2 - F_c^2)^2]/\Sigma[w(F_o^2)^2]\}^{1/2}$. [d]) $F_c^* = k\,F_c\,[1 + 0.001F_c^2\lambda^3/\sin(2\theta)]^{-1/4}$.

2.2. *Rearrangement of the Cycloadducts.* When pure diastereoisomeric oxabicycles **3a**–**c** were allowed to react with a base, they underwent a molecular rearrangement to generate, in one step, 3-aminotropones **4a**–**c** (*cf. Scheme 5* and *Tables 7* and *8*). All 3-aminotropones **4a**–**c** were isolated and purified by column chromatography on silica gel and physically and spectroscopically characterized. Pure diastereoisomeric bicycles $\mathbf{3a_I}$ and $\mathbf{3a_{II}}$ afforded, under identical reaction conditions, the same troponoid **4a**; similarly, both $\mathbf{3c_I}$ and $\mathbf{3c_{II}}$ generated product **4c** independently (*Scheme 5*). Thus, the formation of 3-aminotropones is general for differently substituted oxabicyclic substrates, giving rise to the same 3-aminotropones and with similar yields, regardless of the configuration at C(2) or C(4) of the substrates.

2.2.1. *Rearrangement-Reaction Optimization.* The reaction conditions elaborated with **3a** and the results of the optimization experiments are listed in *Table 7*. The variable parameters were: *a*) type of base (NaOH, $NaNH_2$, ^{t}BuOK, or lithium tri(*tert*-

Table 6. *Selected Bond Lengths* [Å] *and Bond Angles* [°] *for* **3a$_{II}$** *and* **3c$_{I}$**

	3a$_{II}$	**3c$_{I}$**
C(1″)–C(2″)	1.556	1.551
N(1)–C(1″)–C(2″)	109.60	109.74
C(2″)–C(9″)	1.515	1.524
C(1″)–C(2″)–C(9″)	113.26	114.93
C(2″)–C(3″)	1.517	1.531
C(9″)–C(2″)–C(3″)	111.32	111.39
C(3″)–C(4″)	1.540	1.517
C(2″)–C(3″)–O(3″)	121.37	120.51
C(4″)–C(5″)	1.539	1.532
O(3″)–C(3″)–C(4″)	121.17	120.75
C(5″)–C(6″)	1.495	1.508
C(4″)–C(5″)–C(6″)	110.61	109.64
C(6″)–C(7″)	1.326	1.320
C(5″)–C(6″)–C(7″)	108.18	108.72
C(7″)–C(1″)	1.506	1.509
C(6″)–C(7″)–C(1″)	108.24	107.93
O(8″)–C(1″)	1.452	1.440
C(4″)–C(5″)–O(8″)	107.68	107.52
O(8″)–C(5″)	1.440	1.439
O(8″)–C(1″)–N(1)	109.29	109.71
C(1″)–N(1)	1.429	1.427
C(3″)–C(4″)–C(10″)	112.63	–
C(4″)–C(10″)	1.510	–
C(10″)–C(4″)–C(5″)	113.27	–
C(4″)–C(11″)	–	1.536
C(3″)–C(4″)–C(11″)	–	110.76
C(11″)–C(4″)–C(5″)	–	112.51

Scheme 5. *Formation of 3-Aminotropones* **4a** *or* **4c** *from Oxabicycles* **3a$_{I–II}$** *or* **3c$_{I–II}$**, *Respectively, is Independent of the Configuration at C(2) and C(4) of the Precursor Cycloadducts*

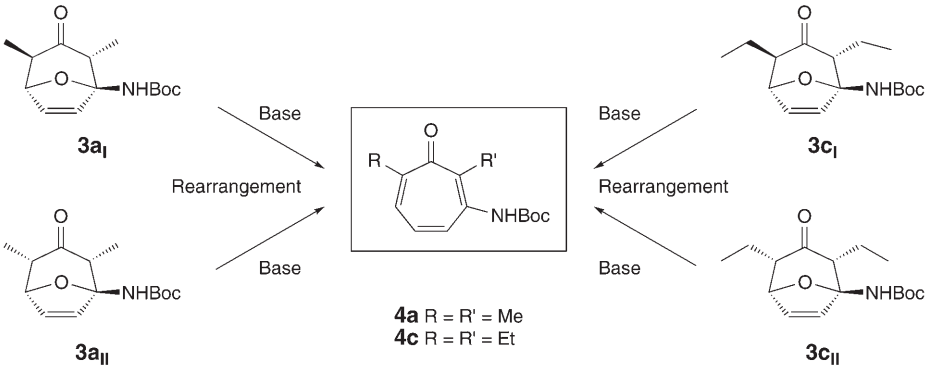


Table 7. *Reaction-Conditions Optimization in the Rearrangement Process of* **3a** *to* **4a** [23d]

Entry	Substrate	Base	Molar ratio base/substrate	Solvent (anh.)	Reaction time [h]	Observations	Yield of **4a** [%][a])
1	$\mathbf{3a_I}$	NaOH	2	MeOH	168	–	30
2	$\mathbf{3a_I}$	TTBAL-H	4	EtOH	72	–	70
3	$\mathbf{3a_{II}}$	NaOH	2	MeOH	168	–	30
4	$\mathbf{3a_{II}}$	$NaNH_2$	2	THF	6	–	21
5	$\mathbf{3a_{II}}$	$NaNH_2$	4	THF	21		30
6	$\mathbf{3a_{II}}$	^{t}BuOK	4	THF	2	formation of **5** in 30% yield	54
7	$\mathbf{3a_{II}}$	TTBAL-H	4	THF	7	ketone reduction	0
8	$\mathbf{3a_{II}}$	TTBAL-H	4	MeOH	48	–	0
9	$\mathbf{3a_{II}}$	TTBAL-H	4	EtOH	48	–	41
10	$\mathbf{3a_{II}}$	TTBAL-H	10	EtOH	25	–	40
11	$\mathbf{3a_{II}}$	TTBAL-H	4	EtOH	4	ultrasound	70

[a]) Calculated on the basis of the ^{1}H-NMR of the residue after workup.

Table 8. *Reaction Conditions of the Rearrangement of* **3b – c** *to* **4b – c** [23d]

Entry	Substrate	Molar ratio base/substrate	Solvent[a])	Reaction time [h]	Observations	Product	Yield [%][b])
1	$\mathbf{3c_{II}}$	5	EtOH	4	ultrasound	**4c**	61
2	$\mathbf{3c_I}$	5	EtOH	4	ultrasound	**4c**	60
3	$\mathbf{3b_{III}} + \mathbf{3b_{IV}}$	5	EtOH	4	ultrasound	**4b**	69

[a]) In all cases, anhydrous solvent and TTBAL-H as the base were used. [b]) Calculated on the basis of ^{1}H-NMR of the residue after workup.

butoxy)aluminium hydride (TTBAL-H)], *b*) molar ratio of reagents, *c*) type of solvent (protic or aprotic), and *d*) reaction time.

The use of NaOH or $NaNH_2$ (*Entries 1* and *3–5* of *Table 7*) afforded the same product **4a** from $\mathbf{3a_I}$ or $\mathbf{3a_{II}}$, than in the case of ^{t}BuOK or TTBAL-H as base, but in lower yield and after a longer reaction time. When NaOH was used as a base, the long reaction time necessary for the total conversion of substrate gave rise to side reactions, and the yield decreased. When the reaction was carried out with ^{t}BuOK as a base, it was possible to isolate and to characterize an interesting intermediate, cycloheptadienone **5** (30%; very useful for the proposal of a mechanism of this reaction), which was not detected in the reactions with TTBAL-H (see below).

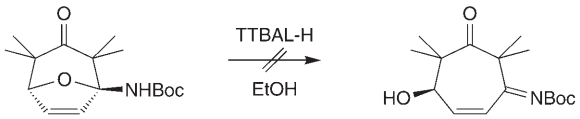
In the presence of TTBAL-H (*Entries 9–11* of *Table 7*), it was observed that the higher the base concentration, the faster the reaction, but the yield dropped. When performing the reaction at a substrate/base molar ratio of 1:1, no conversion was observed after a long reaction time. It is worth noting that performing this reaction under ultrasound sonication (*Entry 11*), the yield was considerably improved and the reaction time was reduced.

In reactions with TTBAL-H, the choice of solvent was very important as reflected by the noted results. Thus, in an aprotic solvent (THF), the reduction of the keto group

was observed; however, when using absolute EtOH as protic solvent, the reaction afforded the product in moderate to good yield. On the other hand, when MeOH was used, a complex reaction mixture was formed.

2.2.2. *Study of the Reaction Mechanism.* The molecular rearrangement of the cycloadducts to afford 3-aminotropones is postulated to involve, as the first step, the removal of a proton by the base. There are three slightly acidic H-atoms in the substrates: the two H-atoms in α-position to the carbonyl group, H–C(2) and H–C(4), and the H-atom attached to the N-atom of the BocNH group. Several experiments were carried out to establish whether deprotonation in α-position to the carbonyl group was necessary to initiate the rearrangement or not. Thus, substrate **3d** (without H-atoms in α-position to the carbonyl group) was synthesized and allowed to react with TTBAL-H under the reaction conditions optimized for the other substrates, but no reaction at all was observed (*Scheme 6*).

Scheme 6. *Attempt to Obtain a Monocyclic Intermediate by Deprotonation of the BocNH Group*

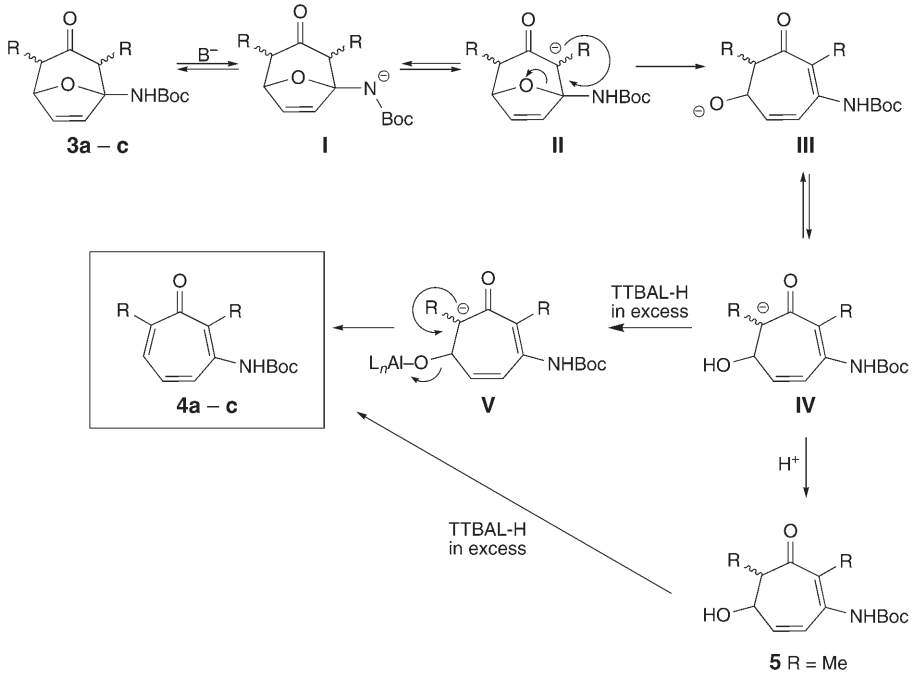


Since the substrate **3d** was recovered unchanged, it is postulated that enolate formation involving C(2) is required to open the cyclic ether, thus, the initiating key step in the reaction should be the removal of the proton in α-position to the carbonyl group. Since the H-atom attached to the N-atom in the BocNH group is more acidic (pK_a *ca.* 11; calculated by [31]) than the H-atom next to the carbonyl group (pK_a *ca.* 19–20), it is reasonable to think of the initial formation of intermediate amide anion **I**, which should be involved in an acid–base equilibrium with intermediate **II**, the initiator of the O-bridge cleavage (*Scheme 7*).

There is some influence of the substitution pattern in α-position of the ketone in substrates **3a**–**c** on the yield of 3-aminotropones (see *Tables 7* and *8*); thus, the Me,Me-substitution pattern of **3a** affords slightly higher yields (70%) than the Me,Et-substitution pattern of **3b** (69%) and, finally, than the Et,Et-substitution pattern of **3c** (60–61%). This difference could be ascribed to the changing accessibility of the base to the H-atoms in α-position to the ketone group in **3a**–**c**, depending on the different steric hindrance exerted by the aforementioned substituents.

To evaluate the importance of the C(6)=C(7) bond in the oxabicyclic substrates on the rearrangement process, $\mathbf{3a_{II}}$ was hydrogenated to $\mathbf{3e_{II}}$ in excellent yield. The product $\mathbf{3e_{II}}$ without C=C bond was treated with TTBAL-H under the optimized reaction conditions to give a 3:1 epimer mixture $\mathbf{3e_{II}}/\mathbf{3e_{I}}$, but no 3-aminotropones were detected (*Scheme 8*). Hence, the following conclusions can be drawn: *a*) The epimerization process demonstrated that in the case of $\mathbf{3e_{II}}$, the ketone was deprotonated in α-position by the base. The new product $\mathbf{3e_{I}}$ was independently synthesized, in quantitative yield, by catalytic hydrogenation of $\mathbf{3a_{I}}$, and the product was identical to $\mathbf{3e_{I}}$ obtained by epimerization of $\mathbf{3e_{II}}$. *b*) The presence of the C(6)=C(7) bond in the bicyclic structure of substrates **3a**–**c** is necessary to obtain 3-aminotropones, because an

Scheme 7. *Proposed Reaction Mechanism for the Rearrangement of Oxabicycles* **3a**–**c** *under Basic Conditions*



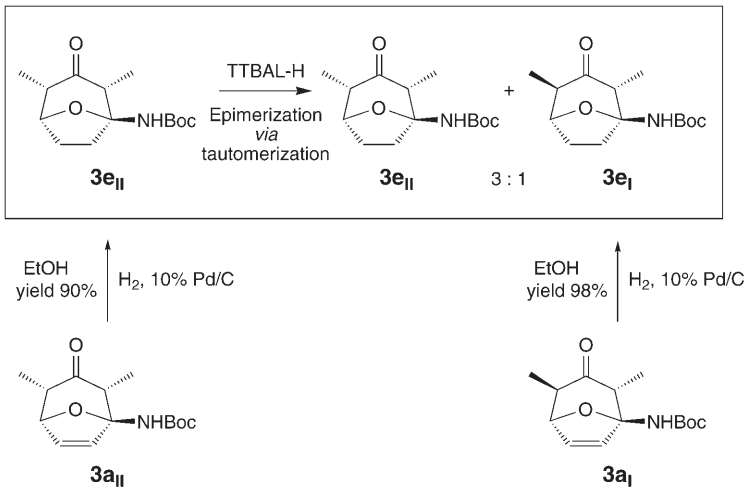
extended conjugation in the monocyclic intermediate **III** (*Scheme 7*) facilitates the O-bridge opening and the subsequent elimination of the resulting alkoxide O-atom to form 3-aminotropones. Furthermore, the presence of a C(6)=C(7) bond increases the ring strain of the molecules of **3a**–**c** in such a way that the O-bridge cleavage is thermodynamically driven to release the strain energy of the substrate molecules.

The formation of intermediate **5** beside **4a** after rearrangement of **3a** in the presence of ^{t}BuOK (*Table 7*, *Entry 6*, and *Scheme 7*) was an interesting finding in that it confirmed some aspects of the proposed reaction mechanism. Cycloheptadienone **5** was transformed into 3-aminotropone **4a** with an excess of TTBAL-H.

The necessity of an excess of TTBAL-H (4 : 1 or 5 : 1 with respect to the substrate) to promote the rearrangement reactions is in accord with a transformation of the OH group of intermediate **IV**, resulting from the cleavage of the O-bridge, into an aluminate L_nAlO, which is a better leaving group than the OH group. The elimination of this aluminate group affords the conjugated stable troponoid system of **4a**–**c**.

3. Conclusions. – In summary, the [4 + 3] cycloaddition of *N*-[(*tert*-butoxy)carbonyl]-protected furan-2-amine **2** and α,α'-dibromo ketones **1a**–**d** afforded oxabicycles **3a**–**d** in moderate to good yield. Best results were obtained by using $[Fe_2(CO)_9]$ as reducing agent in anhydrous MeCN. Furthermore, cycloadducts **3a**–**c** were rearranged by reaction with a base (preferably TTBAL-H) in EtOH under sonication to afford 3-aminotropones **4a**–**c** in moderate to good yield. A mechanism for the formation of 3-

Scheme 8. *Assays to Evaluate the Implication of the Double Bond in the Bicycle Opening*



aminotropones is proposed on the basis of the BocNH group acting as an *Achilles*' heel to promote the O-bridge opening by α-deprotonation and finally an alkoxyaluminate elimination to afford the conjugated stable troponoid system.

Experimental Part

1. *General*. Unless otherwise noted, all reactions were conducted under dry N_2 or Ar in oven-dried glassware. Raw materials were obtained from commercial suppliers and used as received. All solvents were purified by standard techniques before use: Et_2O, THF, hexane, and pentane were distilled under N_2 from sodium/benzophenone. MeCN was distilled under N_2 from CaH_2. Dibromo ketones **1** and *tert*-butyl furan-2-ylcarbamate (**2**) were obtained as reported in [23] and [24], respectively. CC = Column chromatography. GC: *HP-8790* gas chromatograph, *Hewlett-Packard* crosslinked MePhe-silicone capillary column ($l = 25$ m, $\Phi = 0.2$ mm, $\delta = 2.5$ μm); He as carrier gas; FID detector (T 250°, $P_{hydrogen} = 4.2$ psi, $P_{air} = 2.1$ psi); retention time t_R in min. IR Spectra: *FT-IR-Nicolet-510* spectrophotometer; films on NaCl plates; in cm^{-1}. NMR Spectra: *Gemini-200*, *Mercury-400*, and/or *Unity-500* spectrometers; ^1H at 400, ^{13}C at 100 MHz; $CDCl_3$ solns; δ in ppm rel. to $SiMe_4$ as internal standard (^1H) or to the solvent (^{13}C; $CHCl_3$ at δ 77.0), J in Hz; when necessary, assignments were established by DEPT, COSY, and ^{13}C,^1H-correlation experiments. MS: *Hewlett-Packard-5890* mass spectrometer; chemical-ionization technique; in m/z (rel. %).

2. *X-Ray Diffraction Analysis*. Suitable crystals of **3a$_{II}$** and **3c$_{I}$** were selected and mounted, respectively, on a *MAR345* apparatus with image-plate detector and on a *Nonius-Kappa-CCD* equipped with a low-temperature device; graphite-monochromated Mo$K\alpha$ radiation (λ 0.71070 Å) was used. Unit-cell parameters were determined by automatic centering of reflections and refined by the least-squares method. *Lorentz*-polarization corrections were applied.

The structures were solved by direct methods and refined by the full-matrix least-squares method with the SHELXS-97/2 [32] or SIR-97 [33] computer programs, on the basis of the nonequivalent reflections by symmetry (very negative intensities were not assumed). The function minimized was: $\Sigma w\,[(F_o)^2 - (F_c)^2]^2$, where $w = [\sigma^2(I) + (0.0745\,P)^2 + 0.4463\,P)^{-1}$, and $P = [(F_o)^2 + 2\,(F_c)^2]/3$; f, f', and f'' were taken from the International Tables of X-Ray Crystallography [34]. All the H-atoms were computed and refined with a riding model, with isotropic temperature factors equal to 1.2 times the equivalent

temperature factor of the atom to which they are linked. The final R (on F) factors and goodness-of-fit are shown in *Table 5*. The number of refined parameters was 127. Max. shift/e.s.d. = 0.00; mean shift/e.s.d. = 0.00. Refinement of F^2 was done against all reflections. The weighted R-factor wR and goodness-of-fit S were based on F^2, conventional R-factors R were based on F, with F set to zero for negative F^2. The threshold expression of $F^2 > 2\sigma(F^2)$ was used only for calculating R-factors (gt) and was not relevant to the choice of reflections for refinement. R-Factors based on F^2 are statistically about twice as large as those based on F, and R-factors based on all data will be even larger. All e.s.d.s. (except the e.s.d. in the dihedral angle between two l.s. planes) were estimated by using the full covariance matrix. The cell e.s.d.s. were taken into account individually in the estimation of e.s.d.s. in distances, angles, and torsion angles; correlations between e.s.d.s. in cell parameters were only used when they were defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.s. was used for estimating e.s.d.s. involving l.s. planes. The molecular illustrations were made by using the ORTEP-3 program [35].

The main X-ray data are given in *Table 5*. Also a selection of most significant bond lengths and bond angles for **3a$_{II}$** and **3c$_{I}$** are included in *Table 6*. On the other hand, H-atom coordinates as well as anisotropic thermal parameters and detailed information about the crystal-structure determination of **3a$_{II}$** and **3c$_{I}$** is given as supporting information which has been deposited with the *Cambridge Crystallographic Data Centre*[1]).

3. *Cycloaddition Reaction of* **1** *and* **2**. *General Procedure.* To **2** under Ar inside an *AtmosBag*® filled with Ar, the pyrophoric nonacarbonyldiiron (molar ratio [$Fe_2(CO)_9$]/**2** 1.5 : 1) was added as a bright yellow solid in the reactor. Then, anh. MeCN (ratio MeCN/[$Fe^2(CO)_9$] 0.82 ml : 1 mol) was added, and the mixture was stirred for 5 min. The dibromo ketones **1** (molar ratio **1/2** 1.2 : 1), freshly filtered through neutral alumina, was added dropwise at 0°. The mixture was stirred at r.t. for 6 h. The mixture was concentrated, and the residue was dissolved in acetone. Cerium(IV) ammonium nitrate (CAN) (molar ratio CAN/[$Fe_2(CO)_9$] 1 : 1) was added, and the soln. was stirred for 5 min. Then, the solvent was evaporated and the residue filtered through a short path of silica gel, and then submitted to a flash CC (silica gel, hexane/Et_2O of increasing polarity): **3**.

tert-*Butyl* rel-*[(1*R*,2*S*,4*S*,5*S*)-2,4-Dimethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3a$_{I}$**): Colorless oil. GC (T_i 100°, t_i 1 min, r = 10°/min, T_f 250°, t_f 20 min): t_R 9.57. IR (film): 3341*s* (N–H), 2977, 2936, 1709*s* (C=O), 1503 (N–H), 1460, 1369, 1331, 1246 (^{t}Bu), 1167*s* (C–O–C), 1055*s* (C–O–C, asym.). ^{1}H-NMR ($CDCl_3$): 1.08 (*d*, *J* = 7, Me–C(2)); 1.35 (*d*, *J* = 7.6, Me–C(4)); 1.46 (*s*, ^{t}Bu); 2.31 (*q*, *J* = 7.6, H–C(4)); 3.01 (*q*, *J* = 7, H–C(2)); 4.74 (*s*, H–C(5)); 5.19 (*s*, NH); 6.28 (*s*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 9.8 (*Me*–C(2)); 16.4 (*Me*–C(4)); 28.4 (*Me*$_3$C); 48.2 (C(4)); 52.9 (C(2)); 80.9 (Me$_3$*C*); 81.3 (C(5)); 95.3 (C(1)); 132.8 (C(6)); 134.1 (C(7)); 153.9 (^{t}Bu*C*=O); 210.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 285 (13, [*M* + NH_4]$^+$), 268 (100, [*M* + H]$^+$), 212 (22, [*M* + 2 – ^{t}Bu]$^+$), 167 (36, [*M* + H – COO^{t}Bu]$^+$). Anal. calc. for $C_{14}H_{21}NO_4$ (267.32): C 62.90, H 7.92, N 5.24; found: C 62.85, H 7.80, N 5.27.

tert-*Butyl* rel-*[(1*R*,2*S*,4*R*,5*S*)-2,4-Dimethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3a$_{II}$**): Colorless oil. GC (T_i 100°, t_i 1 min, r = 10°/min, T_f 250°, t_f 20 min): t_R 9.87. IR (film): 3347*s* (N–H), 2979, 2936, 1715*s* (C=O), 1522 (N–H), 1456, 1368, 1348, 1250 (^{t}Bu), 1157*s* (C–O–C), 1038*s* (C–O–C, asym.). ^{1}H-NMR ($CDCl_3$): 0.97 (*d*, *J* = 7, Me–C(4)); 1.08 (*d*, *J* = 7, Me–C(2)); 1.46 (*s*, ^{t}Bu); 2.79 (*dq*, *J* = 7, 4.6, H–C(4)); 3.02 (*q*, *J* = 7, H–C(2)); 4.91 (*dd*, *J* = 4.6, 1.2, H–C(5)); 5.27(*s*, NH); 6.29 (*s*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 10.0 (*Me*–C(2)); 10.6 (*Me*–C(4)); 28.5 (*Me*$_3$C); 48.9 (C(4)); 54.2 (C(2)); 80.9 (C(5)); 80.9 (Me$_3$*C*); 95.7 (C(1)); 132.8 (C(6)); 134.1 (C(7)); 154.0 (^{t}BuO*C*O); 208.0 (C(3)). CI-MS (NH_3, 70 eV, 150°): 285 (13, [*M* + NH_4]$^+$), 268 (100, [*M* + H]$^+$), 212 (22, [*M* + 2 – ^{t}Bu]$^+$), 167 (36, [*M* + H – COO^{t}Bu]$^+$). Anal. calc. for $C_{14}H_{21}NO_4$ (267.32): C 62.90, H 7.92, N 5.24; found: C 62.94, H 7.88, N 5.30.

tert-*Butyl* rel-*[(1*R*,2*R*,4*S*,5*S*)-2,4-Dimethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3a$_{III}$**): Colorless oil. GC (T_i 100°, t_i 1 min, r = 10°/min, T_f 250°, t_f 20 min): t_R 9.20. IR (film): 3341*s* (N–H), 2977, 2936, 1709*s* (C=O), 1503 (N–H), 1460, 1369, 1331, 1246 (^{t}Bu), 1167*s* (C–O–C), 1055*s*

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[1]) CCDC-629240 and -629241 contain the supplementary crystallographic data for **3a$_{II}$** and **3c$_{I}$**, respectively. These data can be obtained free of charge *via* http://www.ccdc.cam.ac.uk/data_request/cif.

(C–O–C asym.). ^{1}H-NMR ($CDCl_3$): 1.29 (*d*, *J* = 7.6, Me–C(2)); 1.33 (*d*, *J* = 7.6, Me–C(4)); 1.46 (*s*, ^{t}Bu); 2.28 (*q*, *J* = 7.6, H–C(4)); 2.65 (*q*, *J* = 7.6, H–C(2)); 4.73 (*d*, *J* = 2, H–C(5)); 5.17 (*s*, NH); 6.21 (*ddd*, *J* = 6.1, 2, 0.5, H–C(6)); 6.38 (*d*, *J* = 6.1, H–C(7)). ^{13}C-NMR ($CDCl_3$): 13.8 (*Me*–C(2)); 17.8 (*Me*–C(4)); 28.5 (Me_3C); 48.6 (C(4)); 53.0 (C(2)); 80.9 (Me_3C); 81.1 (C(5)); 95.3 (C(1)); 132.2 (C(6)); 135.4 (C(7)); 153.9 (^{t}BuO*C*O); 213.0 (C(3)). CI-MS (NH_3, 70 eV, 150°): 285 (13, $[M+NH_4]^+$), 268 (100, $[M+H]^+$), 212 (22, $[M+2-{}^t\text{Bu}]^+$), 167 (36, $[M+H-\text{COO}^t\text{Bu}]^+$). Anal. calc. for $C_{14}H_{21}NO_4$ (267.32): C 62.90, H 7.92, N 5.24; found: C 62.97, H 8.01, N 5.19.

tert-*Butyl* rel-*[(1*R,*2*S,*4*R,*5*S*)-4-Ethyl-2-methyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3b$_{\mathbf{I}}$**): Colorless oil. IR (film): 3331, 2975, 2932, 1710, 1522, 1456, 1366, 1249, 1167, 1075, 1055. ^{1}H-NMR ($CDCl_3$): 0.98–1.01 (*m*, *Me*CH_2–C(4), 1 H of MeCH_2–C(4)); 1.07 (*d*, *J* = 6.8, Me–C(2)); 1.46 (*s*, ^{t}Bu); 1.82–1.90 (*m*, 1 H of MeCH_2–C(4)); 2.57–2.62 (*m*, H–C(4)); 3.01 (*q*, *J* = 6.8, H–C(2)); 5.01 (*dd*, *J* = 1.2, 4.8, H–C(5)); 5.26 (br. *s*, NH); 6.24–6.29 (br. *s*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 10.0 (*Me*C(2)); 12.1 (*Me*CH_2–C(4)); 19.1 (MeCH_2–C(4)); 28.4 (Me_3C); 53.9 (C(2)); 55.7 (C(4)); 79.3 (C(5)); 80.9 (Me_3C); 95.7 (C(1)); 133.8 (C(7)); 133.8 (C(6)); 154.0 (^{t}BuO*C*O); 207.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 282 ($[M+1]^+$), 226 ($[M-C_4H_8]^+$), 182 ($[M-C_5H_8O_2]^+$). Anal. calc. for $C_{15}H_{23}NO_4$ (281.35): C 64.03, H 8.24, N 4.98; found: C 64.15, H 8.28, N 5.01.

tert-*Butyl* rel-*[(1*R,*2*S,*4*R,*5*S*)-2-Ethyl-4-methyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3b$_{\mathbf{II}}$**): Colorless oil. IR (film): 3339, 2975, 1708, 1522, 1456, 1367, 1350, 1248, 1165, 1049, 1016. ^{1}H-NMR ($CDCl_3$): 0.96 (*d*, *J* = 7.2, Me–C(4)); 1.04 (*dd*, *J* = 7.2, *Me*CH_2–C(2)); 1.46 (*s*, ^{t}Bu, 1 H of MeCH_2–C(2)); 1.64–1.75 (*m*, 1 H of MeCH_2–C(2)); 2.76 (*dq*, *J* = 5.0, 7.2, H–C(4)); 2.85 (*dd*, *J* = 3.2, 8.0, H–C(2)); 4.88 (*dd*, *J* = 5.0, 0.8, H–C(5)); 5.30 (br. *s*, NH); 6.24–6.28 (*m*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 10.0 (*Me*–C(4)); 14.0 (*Me*CH_2–C(2)); 18.6 (MeCH_2–C(2)); 28.5 (Me_3C); 48.8 (C(4)); 61.2 (C(2)); 80.9 (C(5)); 95.8 (Me_3C); 132.0 (C(7)); 134.0 (C(6)); 154.0 (^{t}BuO*C*O); 207.9 (C(3)). CI-MS (NH_3, 70 eV, 150°): 282 ($[M+1]^+$), 226 ($[M-C_4H_8]^+$), 182 ($[M-C_5H_8O_2]^+$). Anal. calc. for $C_{15}H_{23}NO_4$ (281.35): C 64.03, H 8.24, N 4.98; found: C 64.08, H 8.19, N 4.95.

tert-*Butyl rel-[(1*R,*2*S,*4*S,*5*S*)-2-Ethyl-4-methyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3b$_{\mathbf{III}}$**): Colorless oil. IR (film): 3330, 2975, 2934, 1709, 1522, 1456, 1367, 1249, 1166, 1076, 1055, 1011. ^{1}H-NMR ($CDCl_3$): 1.05 (*dd*, *J* = 7.6, 7.6, *Me*CH_2–C(2)); 1.35 (*d*, *J* = 7.0, Me–C(4)); 1.47 (*s*, ^{t}Bu, 1 H of MeCH_2–C(2)); 1.65–1.76 (*m*, 1 H of MeCH_2–C(2)); 2.27 (*q*, *J* = 7.0, H–C(4)); 2.84 (*dd*, *J* = 7.6, 7.6, H–C(2)); 4.72 (*s*, H–C(5)); 5.21 (br. *s*, NH); 6.24 (br. *s*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 14.1 (*Me*CH_2–C(2)); 16.3 (Me–C(4)); 18.6 (MeCH_2–C(2)); 28.5 (Me_3C); 48.1 (C(4)); 59.8 (C(2)); 81.3 (C(5)); 95.4 (Me_3C); 109.9 (C(1)); 133.2 (C(7)); 133.6 (C(6)); 153.9 (^{t}BuO*C*O); 210.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 282 (5, $[M+1]^+$), 226 (100, $[M-C_4H_8]^+$), 182 (51, $[M-C_5H_8O_2]^+$). Anal. calc. for $C_{15}H_{23}NO_4$ (281.35): C 64.03, H 8.24, N 4.98; found: C 64.10, H 8.20, N 4.99.

tert-*Butyl* rel-*[(1*R,*2*S,*4*S,*5*S*)-4-Ethyl-2-methyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3b$_{\mathbf{IV}}$**): Colorless oil. IR (film): 3339, 2975, 1708, 1522, 1456, 1367, 1350, 1248, 1165, 1049, 1016. ^{1}H-NMR ($CDCl_3$): 0.99 (*dd*, *J* = 7.6, 7.6, *Me*CH_2–C(4)); 1.07 (*d*, *J* = 6.8, Me–C(2)); 1.46 (*s*, ^{t}Bu); 1.77–1.86 (*m*, MeCH_2–C(4)); 2.10 (*dd*, *J* = 7.6, H–C(4)); 3.0 (*q*, *J* = 7.6, H–C(2)); 4.87 (*s*, H–C(5)); 5.26 (br. *s*, NH); 6.24–6.29 (*m*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 9.8 (*Me*–C(2)); 12.1 (*Me*CH_2–C(4)); 23.9 (MeCH_2–C(4)); 28.5 (Me_3C); 53.2 (C(4)); 55.5 (C(2)); 79.1 (C(5)); 95.3 (Me_3C); 132 (C(7)); 134 (C(6)); 154.0 (^{t}BuO*C*O); 207.9 (C(3)). CI-MS (NH_3, 70 eV, 150°): 282 ($[M+1]^+$), 226 ($[M-C_4H_8]^+$), 182 ($[M-C_5H_8O_2]^+$). Anal. calc. for $C_{15}H_{23}NO_4$ (281.35): C 64.03, H 8.24, N 4.98; found: C 63.95, H 8.06, N 4.93.

tert-*Butyl* rel-*[(1*R,*2*S,*4*S,*5*S*)-2,4-Diethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3c$_{\mathbf{I}}$**): Colorless oil. IR (film): 3335, 2969, 2877, 1707, 1521, 1458, 1367, 1248, 1166, 1102. ^{1}H-NMR ($CDCl_3$): 0.98 (*dd*, *J* = 7.6, 7.6, *Me*CH_2–C(4)); 1.03 (*dd*, *J* = 7.6, 7.6, *Me*CH_2–C(2)); 1.46 (*s*, ^{t}Bu, 1 H of MeCH_2–C(2)); 1.64–1.74 (*m*, 1 H of MeCH_2–C(2)); 1.82 (*q*, *J* = 7.6, MeCH_2–C(4)); 2.06 (*dd*, *J* = 7.6, H–C(4)); 2.82 (*dd*, *J* = 7.6, 3.6, H–C(2)); 4.85 (*s*, H–C(5)); 5.25 (br. *s*, NH); 6.22 (br. *s*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 12.1 (*Me*CH_2–C(4)); 14.1 (*Me*CH_2–C(2)); 18.5 (MeCH_2–C(2)); 23.8 (MeCH_2–C(4)); 28.5 (Me_3C); 55.5 (C(4)); 60.2 (C(2)); 79.1 (C(5)); 81.0 (Me_3C); 95.5 (C(1)); 132.1 (C(7)); 134.1 (C(6)); 154.0 (^{t}BuO*C*O); 209.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 296 (4, $[M+1]^+$), 240 (100, $[M-C_4H_8]^+$), 196 (73, $[M-C_5H_8O_2]^+$), 179 (20, $[M-C_5H_9O_2N]^+$). Anal. calc. for $C_{16}H_{25}NO_4$ (295.37): C 65.06, H 8.53, N 4.74; found: C 65.15, H 8.49, N 4.68.

tert-*Butyl* rel-*[(1*R,2S,*4*R,5S*)-2,4-Diethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3c$_{II}$**): Colorless oil. IR (film): 3336, 2968, 2877, 1708, 1651, 1520, 1458, 1366, 1247, 1161, 1052. ^{1}H-NMR ($CDCl_3$): 0.97–1.05 (*m*, *Me*CH$_2$–C(2), 1 H of MeC*H*$_2$–C(4), *Me*CH$_2$–C(4)); 1.46 (*s*, ^{t}Bu, 1 H of MeC*H*$_2$–C(2)); 1.64–1.74 (*m*, 1 H of MeC*H*$_2$–C(2)); 1.79–1.87 (*m*, 1 H of MeC*H*$_2$–C(2)); 2.55–2.60 (*m*, H–C(4)); 2.82 (*dd*, *J* = 8.0, 3.2, H–C(2)); 4.99 (*dd*, *J* = 4.4, 1.6, H–C(5)); 5.26 (br. *s*, NH); 6.19–6.24 (*m*, H–C(6), H–C(7)). ^{13}C-NMR ($CDCl_3$): 12.1 (*Me*CH$_2$–C(4)); 14.0 (*Me*CH$_2$–C(2)); 18.6 (Me*C*H$_2$–C(2)); 19.1 (Me*C*H$_2$–C(4)); 28.4 (*Me*$_3$C); 55.7 (C(4)); 61.0 (C(2)); 79.3 (C(5)); 80.9 (Me$_3$*C*); 95.7 (C(1)); 132.1 (C(7)); 134.1 (C(6)); 154.0 (^{t}BuO*C*O); 207.5 (C(3)). CI-MS (NH_3, 70 eV, 150°): 296 (3, $[M+1]^+$), 240 (100, $[M-C_4H_8]^+$), 196 (62, $[M-C_5H_8O_2]^+$), 179 (22, $[M-C_5H_9O_2N]^+$). Anal. calc. for $C_{16}H_{25}NO_4$ (295.37): C 65.06, H 8.53, N 4.74; found: C 64.99, H 8.60, N 4.71.

tert-*Butyl* rel-*[(1*R,5S*)-2,2,4,4-Tetramethyl-3-oxo-8-oxabicyclo[3.2.1]oct-6-en-1-yl]carbamate* (**3d**): Colorless oil. IR (film): 3316, 2978, 2932, 1704, 1471, 1387, 1367, 1332, 1247, 1163, 1054. ^{1}H-NMR ($CDCl_3$): 0.95 (*d*, *J* = 6.8, Me–C(2)); 1.05 (*d*, *J* = 6.4, Me–C(2)); 1.46 (*s*, ^{t}Bu), 1.56–1.63 (*m*, H$_a$–C(6)); 1.67–1.75 (*m*, H$_b$–C(7)); 1.88–1.95 (*m*, H$_a$–C(7)); 1.98–2.08 (*m*, H$_b$–C(6)); 2.79–2.85 (*m*, H–C(4)); 3.68 (*d*, *J* = 5.6, H–C(2)); 4.47 (*dd*, *J* = 7.6, 4.8, H–C(5)); 5.24 (br. *s*, NH). ^{13}C-NMR ($CDCl_3$): 9.0 (*Me*–C(2)); 9.8 (*Me*–C(2)); 24.2 (C(6)); 28.1 (*Me*$_3$C); 31.6 (C(7)); 49.4 (C(4)); 52.9 (C(2)); 78.2 (C(5)); 80.1 (Me$_3$*C*); 94.2 (C(1)); 154.0 (^{t}BuO*C*O); 209.1 (C(3)). CI-MS (NH_3, 70 eV, 150°): 296 (23, $[M+1]^+$), 257 (98), 240 (86, $[M-C_4H_8]^+$), 196 (100, $[M-C_5H_8O_2]^+$). Anal. calc. for $C_{16}H_{25}NO_4$ (295.37): C 65.06, H 8.53, N 4.74; found: C 65.20, H 8.45, N 4.80.

4. *Hydrogenation of Cycloadducts* **3a$_{II}$** *and* **3a$_I$**. A soln. of **3a$_{II}$** (232 mg, 0.87 mmol) in abs. EtOH (5 ml) under N_2 was added dropwise to 10% (*w*/*w*) Pd/C catalyst (46.5 mg) under Ar. After the addition, the system was purged by at least five cycles of vacuum/H_2 (pumping out and back filling with H_2). The mixture was stirred overnight under H_2 under vigorous stirring and then filtered through *Celite*®. The mixture was concentrated: **3e$_{II}$** (218 mg, 90% yield).

In an independent experiment, but following the same procedure, **3a$_I$** was hydrogenated to afford product **3e$_I$** in 98% yield.

tert-*Butyl* rel-*[(1*R,2S,*4*R,5S*)-2,4-Dimethyl-3-oxo-8-oxabicyclo[3.2.1]oct-1-yl]carbamate* (**3e$_{II}$**): Colorless oil. IR (film): 3348*s* (N–H), 2976, 1711*s* (C=O), 1521 (N–H), 1367, 1330, 1275 (^{t}Bu), 1160*s* (C–O–C), 1028*s* (C–O–C asym.). ^{1}H-NMR ($CDCl_3$): 0.95 (*d*, *J* = 6.8, Me–C(4)); 1.05 (*d*, *J* = 6.4, Me–C(2)); 1.46 (*s*, ^{t}Bu); 1.56–1.63 (*m*, H$_a$–C(6)); 1.67–1.75 (*m*, H$_a$–C(7)); 1.88–1.95 (*m*, H$_b$–C(7)); 1.98–2.08 (*m*, H$_b$–C(6)); 2.79–2.85 (*m*, H–C(4)); 3.68 (*d*, *J* = 5.6, H–C(2)); 4.47 (*dd*, *J* = 7.6, 4.8, H–C(5)); 5.24 (br. *s*, NH). ^{13}C-NMR ($CDCl_3$): 9.0 (*Me*–C(2)); 9.8 (*Me*–C(4)); 24.2 (C(6)); 28.1 (*Me*$_3$C); 31.6 (C(7)); 49.4 (C(4)); 52.9 (C(2)); 78.2 (C(5)); 80.1 (Me$_3$*C*); 94.2 (C(1)); 154.0 (^{t}BuO*C*O); 209.1 (C(3)). CI-MS (NH_3, 70 eV, 150°): 270 (100, $[M+H]^+$), 231, 214 (60, $[M-{}^t\text{Bu}]^+$), 170 (100, $[M-\text{COO}^t\text{Bu}]^+$). Anal. calc. for $C_{14}H_{23}NO_4$ (269.34): C 62.43, H 8.61, N 5.20; found: C 62.39, H 8.66, N 5.13.

tert-*Butyl* rel-*[(1*R,2S,*4*S,5S*)-2,4-Dimethyl-3-oxo-8-oxabicyclo[3.2.1]oct-1-yl]carbamate* (**3e$_I$**): Colorless oil. IR (film): 3351*s* (N–H), 2975, 2932, 1711*s* (C=O), 1526 (N–H), 1456, 1371, 1331, 1281 (^{t}Bu), 1163*s* (C–O–C), 1057*s* (C–O–C asym.). ^{1}H-NMR ($CDCl_3$): 1.04 (*d*, *J* = 7.0, Me–C(4)); 1.32 (*d*, *J* = 7.0, Me–C(2)); 1.47 (*s*, ^{t}Bu); 1.54–1.62 (*m*, H$_a$–C(6)); 1.73–1.81 (*m*, H$_a$–C(7)); 1.91–1.98 (*m*, H$_b$–C(7)); 2.20–2.30 (*m*, H$_b$–C(6), H–C(4)); 3.73 (br. *s*, H–C(2)), 4.34 (*d*, *J* = 7.6, H–C(5)); 5.21 (br. *s*, NH). ^{13}C-NMR ($CDCl_3$): 8.7 (*Me*–C(2)); 12.9 (*Me*–C(4)); 28.5 (*Me*$_3$C); 29.1 (C(6)); 30.4 (C(7)); 50.6 (C(2)); 51.9 (C(4)); 78.4 (C(5)); 80.4 (Me$_3$*C*); 93.9 (C(1)); 154.1 (^{t}BuO*C*O); 212.3 (C(3)). CI-MS (NH_3, 70 eV, 150°): 270 (100, $[M+H]^+$), 231, 214 (40, $[M-{}^t\text{Bu}]^+$), 170 (90, $[M-\text{COO}^t\text{Bu}]^+$). Anal. calc. for $C_{14}H_{23}NO_4$ (269.34): C 62.43, H 8.61, N 5.20; found: C 62.40, H 8.59, N 5.17.

5. *Rearrangement of* **3a–c** *under Basic Conditions: General Procedure.* A soln. of **3** (0.27 mmol) in abs. EtOH (1 ml) was added to a suspension of TTBAL-H (molar ratio TTBAL-H/**3**/5 : 1) in abs. EtOH (2 ml), and the mixture was stirred under N_2 in an ultrasound reactor, at r.t. for 4 h. Then 6% NaOH soln. (4 ml) was added, and the mixture was stirred for additional 15 min at r.t. The crude was extracted with AcOEt (5 × 10 ml) by using a centrifuge, and the combined org. layer was dried (Mg_2SO_4) and concentrated. The resulting residue was submitted to CC (silica gel, hexane/AcOEt of increasing polarity): **4a–c**.

tert-*Butyl [(1*E,4Z,6Z*)-2,4-Dimethyl-3-oxocyclohepta-1,4,6-trien-1-yl]carbamate* (**4a**): Colorless oil. IR (film): 3282, 2979, 1721, 1564, 1530, 1472, 1368, 1314, 1246, 1159, 1074, 1041. ^{1}H-NMR ($CDCl_3$): 1.52

(*s*, ^{t}Bu); 2.26 (*s*, Me−C(4)); 2.28 (*s*, Me−C(2)); 6.46 (br. *s*, NH); 6.79 (*dd*, *J* = 8.4, 1.2, H−C(6)); 7.16 (*ddd*, *J* = 8.4, 1.2 , 1.2, H−C(5)); 7.51 (*d*, *J* = 1.2, H−C(7)). ^{13}C-NMR ($CDCl_3$): 16.5 (*Me*−C(4)); 23.5 (*Me*−C(2)); 28.4 (Me_3C); 81.8 (Me_3C); 129.7 (C(6)); 130.4 (C(7)); 133.0 (C(5)); 142.7 (C(2), C(4)); 149.3 (^{t}BuO*C*O); 153.0 (C(1)); 186.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 251 (16, $[M+2]^+$), 250 (100, $[M+1]^+$), 194 (7, $[M-C_4H_8]^+$), 176 ($[M-C_4H_8O]^+$). Anal. calc. for $C_{14}H_{19}NO_3$ (249.31): C 67.45, H 7.68, N 5.62; found: C 67.49, H 7.72, N 5.53.

tert-*Butyl [(1*E*,4*Z*,6*Z*)-4-Ethyl-2-methyl-3-oxocyclohepta-1,4,6-trien-1-yl]carbamate* (**4b**): From $\mathbf{3b_{III}}+\mathbf{3b_{IV}}$. Colorless oil. IR (film): 3287, 2975, 2927, 1722, 1589, 1528, 1464, 1367, 1309, 1244, 1158, 1018. ^{1}H-NMR ($CDCl_3$): 1.16 (*dd*, *J* = 7.6, 7.6, *Me*CH_2−C(4)); 1.51 (*s*, ^{t}Bu); 2.24 (*s*, Me−C(2)); 2.68 (*q*, *J* = 7.6, MeCH_2−C(4)); 6.40 (br. *s*, NH); 6.82 (*dd*, *J* = 8.4, 1.2, H−C(6)); 7.06 (*dd*, *J* = 8.4, 1.2, H−C(5)); 7.56 (*d*, *J* = 1.2, H−C(7)). ^{13}C-NMR ($CDCl_3$): 13.8 (*Me*CH_2(4)); 16.4 (*Me*−C(2)); 28.4 (Me_3C); 29.2 (Me*C*H_2−C(4)); 81.8 (Me_3C); 129.8 (C(6)); 130.3 (C(7)); 131.4 (C(5)); 135.4 (C(2)); 142.1 (C(4)); 153.0 (^{t}BuO*C*O); 154.2 (C(1)); 186.9 (C(3)). CI-MS (NH_3, 70 eV, 150°): 264 (13, $[M+1]^+$), 236 (22), 208 (100, $[M-C_4H_8]^+$), 164 ($[M-C_5H_8O_2]^+$). Anal. calc. for $C_{15}H_{21}NO_3$ (263.33): C 68.42, H 8.04, N 5.32; found: C 68.48, H 7.97, N 5.21.

tert-*Butyl [(1*E*,4*Z*,6*Z*)-2,4-Diethyl-3-oxocyclohepta-1,4,6-trien-1-yl]carbamate* (**4c**): Colorless oil. IR (film): 3278, 2972, 2932, 1719, 1587, 1528, 1460, 1368, 1324, 1242, 1157, 1050. ^{1}H-NMR ($CDCl_3$): 1.15 (*dd*, *J* = 7.6, *Me*CH_2−C(4)); 1.17 (*dd*, *J* = 7.6, *Me*CH_2−C(2)); 1.52 (*s*, ^{t}Bu); 2.67 (*q*, *J* = 7.6, MeCH_2−C(4)); 2.69 (*q*, *J* = 7.6, MeCH_2−C(2)); 6.45 (br. *s*, NH); 6.80 (*dd*, *J* = 8.8, 1.2, H−C(6)); 7.04 (*dd*, *J* = 8.8, 1.2, H−C(5)); 7.40 (*d*, *J* = 1.2, H−C(7)). ^{13}C-NMR ($CDCl_3$): 12.8 (*Me*CH_2−C(2)); 13.8 (*Me*CH_2−C(4)); 23.6 (Me*C*H_2−C(2)); 28.4 (Me_3C); 29.1 (Me*C*H_2−C(4)); 81.8 (Me_3C); 129.7 (C(6)); 130.9 (C(7)); 131.4 (C(5)); 141.1 (C(2)); 141.6 (C(4)); 153.3 (^{t}BuO*C*O); 154.6 (C(1)); 186.9 (C(3)). CI-MS (NH_3, 70 eV, 150°): 278 (16, $[M+1]^+$), 222 (100, $[M-C_4H_8]^+$), 178 ($[M-C_5H_8O_2]^+$). Anal. calc. for $C_{16}H_{23}NO_3$ (277.36): C 69.29, H 8.36, N 5.05; found: C 69.38, H 8.15, N 5.25.

tert-*Butyl* rel-*[(1*E*,5*R*,6*Z*)-5-Hydroxy-2,4-dimethyl-3-oxocyclohepta-1,6-dien-1-yl]carbamate* (**5**): Colorless oil. IR (film): 3333, 2979, 2935, 1707, 1640, 1585, 1503, 1454, 1369, 1246, 1156, 1046, 1013. ^{1}H-NMR ($CDCl_3$): 1.23 (*d*, *J* = 7.0, Me−C(4)); 1.48 (*s*, ^{t}Bu); 1.89 (*s*, Me−C(2)); 2.80 (*dq*, *J* = 11.4, 7.0, H−C(4)); 4.43 (*dd*, *J* = 11.4, 2.0, H−C(5)); 6.13 (br. *s*, NH); 6.31 (*s*, H−C(6), H−C(7)). ^{13}C-NMR ($CDCl_3$): 14.4 (*Me*−C(2)); 14.9 (*Me*−C(4)); 28.4 (Me_3C); 57.6 (C(4)); 69.5 (C(5)); 81.9 (Me_3C); 122.9 (C(2)); 123.0 (C(6)); 139.1 (C(1)); 139.7 (C(7)); 152.6 (^{t}BuO*C*O); 203.7 (C(3)). CI-MS (NH_3, 70 eV, 150°): 268 (5, $[M+1]^+$), 212 (85, $[M-C_4H_8]^+$), 168 (32, $[M-C_5H_8O_2]^+$). Anal. calc. for $C_{16}H_{23}NO_3$ (277.36): C 69.29, H 8.36, N 5.05; found: C 69.18, H 8.41, N 5.43.

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