Tetrahedron Vol. 41, No. 23, pp. 5719 to 5731, 1985
Printed in Great Britain

0040-4020/85 $3.00 + .00

ASYMMETRIC NITROGEN—41†

STEREOCHEMISTRY OF BICYCLIC 1,2-*CIS*-DIAZIRIDINES

G. V. SHUSTOV,* S. N. DENISENKO, I. I. CHERVIN, N. L. ASFANDIAROV and R. G. KOSTYANOVSKY
Institute of Chemical Physics, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

(*Received in USSR* 21 *September* 1984)

Abstract—The twisting of 5- and 6-membered rings in bicyclic *cis*-diaziridines—1,5-diazabicyclo[3.1.0]hexanes **12–17** and 1,6-diazabicyclo[4.1.0]heptane **18**—is a rapid process in the time scale of ^{1}H- and ^{13}C-NMR even at −80°. According to the ^{1}H- and ^{13}C-NMR spectra, 1,5-diazabicyclo[3.1.0]hexanes **12, 13, 15a, b** and **16a, b** do, exist mostly in the boat form; only the introduction of *endo* substituents into position 3 or 6 leads to the population of the chair, as is the case with **14** and **17**. 2,4-Dialkyl substituted 1,5-diaza- and 1,3,5-triazabicyclo[3.1.0]hexanes are formed via a transition cyclization state similar in its geometry to the initial chair-shaped N-chlorodi(tri)azanes.

1,2-*cis*-Diaziridines are thermodynamically less stable than *trans* isomers which is caused by the steric and four-electron destabilizing interaction of *cis*-oriented N-substituents and lone pairs.[2a–e] According to *ab initio* calculations, unsubstituted *cis*-diaziridine is destabilized by 7.1–7.8 kcal mol^{-1} as against its *trans* isomer.[2a,d] The only example of a *cis* isomer in monocyclic compounds is 1 - (N,N - dimethylcarbamoyl)-3,3-dimethyldiaziridine whose ^{1}H-NMR spectrum contains at −50°, together with signals of the *trans* isomer, those of the *cis* form stabilized by intramolecular H-bond[3a,b] (Scheme 1); it follows from the equilibrium *cis/trans* ratio 3:4 that the energy difference between the isomers, $\Delta G°$, is 0.13 kcal mol^{-1}.

The binding of N-substituents into a relatively rigid 5- or 6-membered ring enables the fixation of the unfavorable *cis* configuration so that such bicyclic compounds can be successfully synthesized.[2e,4a–d]

Our study was aimed at investigating into the chirality of bicyclic *cis*-diaziridines—1,5-diazabicyclo[3.1.0]hexanes (DABH) and 1,6-diazabicyclo[4.1.0]heptane, finding out the preferable conformation of 1,5-DABH and the orientation of substituents in these compounds, and specifying on this basis the stereochemistry of the formation of the 2,4,6-trialkyl derivatives of DABH and of 1,3,5-triazabicyclo[3.1.0]hexane (TABH).

Synthesis

cis-Diaziridines **12–18** were obtained according to Ref. 4*a* by acting with a carbonyl compound and an alkaline solution of NaOCl on diamines **1–4** (Scheme 2).

This method of the synthesis of bicyclic diaziridines is limited by the possibility of the formation of their precursors, cyclic gem-diamines. In contrast to 6- and 7-membered rings **5–11** which give rise to diaziridines **12–18** with $n = 1, 2$, the closure of the $\geqslant$8-membered ring is apparently hampered and an attempt at synthesizing diaziridines with $n = 3, 4, 5$, R = R′ = R″ = R‴ = H, under the conditions of the synthesis of **12–18**, resulted in the isolation only of polymeric products of intermolecular condensation of 1,5-, 1,6-, and 1,7-diamines with formaldehyde.

† Asymmetric nitrogen—40, see Ref. 1.

Intermediate 1,3-diazanes (hexahydropyrimidines) **8a, b, 9a, b** are observed together with diaziridines **15a, b, 16a, b** as indicated by the ^{1}H and ^{13}C spectra of the reaction mixtures (Tables 1 and 2), the relative amount of unreacted 1,3-diazane growing with the increase of the number of Me substituents. Thus, the diazane/diaziridine ratio for **8/15** is 1:9 while for **9a/16a** and **9b/16b** it equals 6:4 and 3.3:6.7.

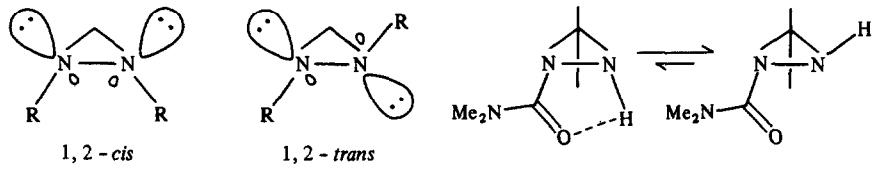
At −10°, *meso*-1,3-diazane **9a** can be crystallized out of a mixture with **15a** obtained after distillation. NH-1,3-Diazanes **8a** and **10** were obtained independently in a reaction between diamines **2a** and **3** and formaldehyde and isolated as individual compounds. NH-1,3-Diazanes known till present contain alkyl substituents at C(2).[5a–c]

The racemic and *meso* forms of diaziridine **15** obtained from an equimolar mixture of *d,l* and *meso* diamines **2a, b** were separated by column chromatography on silica. Also, isomers **15a, b** and **16a, b** were synthesized in a pure form from the *meso* and *d,l* forms of diamine **2** preliminarily separated.[6]

Chirality

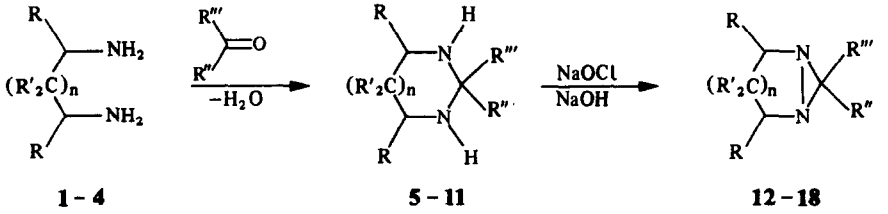
It can be assumed that unlike *trans*-diaziridines which have successfully been separated into the antipodes,[7a–e] *cis*-diaziridines are achiral since they possess a symmetry plane passing across the C atom of the ring and the middle of the N—N bond (Scheme 1). However, the nonequivalence of the Me groups of *meso* isomer **15a** manifested in its ^{1}H spectrum was reported.[8a,b] This result, together with the equivalence of the Me groups in the racemic form **15a, b**, was accounted for by the skewed form of the 5-membered ring of **8a, b**. The latter also follows from the photoelectron and Raman spectra of diaziridine **12**[8b,c] and the X-ray structure analysis of *d,l*-2,4,6-trimethyl-1,3,5-TABH.[8d]

Thus, according to Refs 8*a–d*, bicyclic *cis*-diaziridines are chiral; the mutual transformation of enantiomers (rotation around the N—N bond with eclipsing) (Scheme 3) should[8a] have a high barrier since the ^{1}H spectrum of the *meso* form **15a** is not changed by heating to 135° ($\Delta\nu_{Me}$ = 12 Hz). These data enable the evaluation of the lower boundary of the barrier, $\Delta G^{\neq}_{rot} > 22$ kcal mol^{-1}.



1, 2 - *cis* 1, 2 - *trans*

Scheme 1.



1 - 4 **5 - 11** **12 - 18**

1	R = R' = H, n = 1	**5, 12**	R = R' = R'' = R''' = H, n = 1
		6, 13	R = R' = R'' = H, R''' = Me, n = 1
		7, 14	R = R' = H, R'' = R''' = Me, n = 1
2	R = Me, R' = H, n = 1	**8a,b, 15a,b**	R = Me, R' = R'' = R''' = H, n = 1
		9a,b, 16a,b	R = R'' = Me, R' = R''' = H, n = 1
3	R = H, R' = Me, n = 1	**10, 17**	R = R'' = R''' = H, R' = Me, n = 1
4	R = R' = H, n = 2	**11, 18**	R = R' = R'' = R''' = H, n = 2

Scheme 2.

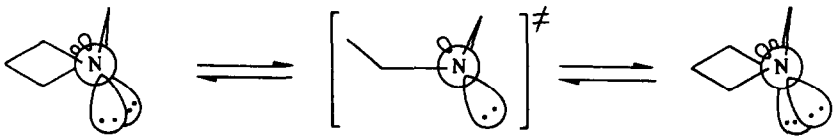
Table 1. Chemical shifts of ^1H (δ) and coupling constants (Hz) of 1,3-diazanes **8a, b, 9a, 10** in $CDCl_3$ at 400.13 MHz

	2a	2e	4a	4e	5a	5e	6	Me groups	^2J	^3J
8a	3.68	4.01	2.75	—	0.73	1.68	2.75	1.08(4,6-Me)	−12.2(2a2e) −13.1(5a5e)	11.1(5a6a) 2.8(5e6a), 6.5(6aMe)
8b	3.83		—	3.17	1.41		3.17	1.15(4,6-Me)	—	5.5(5a6a), 5.5(5e6a) 6.8(4eMe), 6.8(6aMe)
9a	3.64	—	2.75	—	0.64	1.59	2.75	1.18(2-Me) 1.05(4,6-Me)	−12.9(5a5e)	11.2(5a6a), 2.9(5e6a) 5.9(2aMe), 6.6(6aMe)
10	3.75		2.65		—	—	2.65	0.90(5,5-Me)	—	—

Broadened NH signals are observed in a 1.5–2.0 ppm range.

Table 2. Chemical shifts of ^{13}C (δ) and coupling constants $^1J_{CH}$ (Hz) of 1,3-diazanes **8a, b–10** in $CDCl_3$ at 100.62 MHz

	C(2)	C(4)	C(5)	(C6)	2-Me	4-Me	5-Me	6-Me
8a	61.61 (142.8, 145.9)	50.15 (132.5)	43.27 (125.7)	50.15 (132.5)	—	22.07 (125.1)	—	22.07 (125.1)
8b	55.22 (145.3)	44.88 (135.5)	39.87 (127.0)	44.88 (135.5)	—	19.71 (125.1)	—	19.71 (125.1)
9a	67.14 (141.6)	51.01 (134.3)	42.88 (124.5)	51.01 (134.3)	23.00 (125.7)	22.77 (125.1)	—	22.77 (125.1)
9b	60.10 (142.8)	45.53 (138.6)	39.39 (126.3)	46.97 (139.8)	23.21 (125.7)	18.60 (127.0)	—	23.11 (125.7)
10	62.11 (144.7)	57.24 (134.3)	28.97 —	57.24 (134.3)	—	—	24.53 (125.1)	—



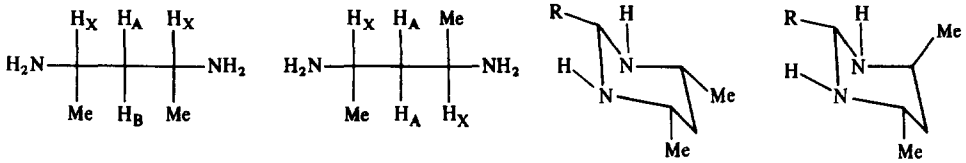
Scheme 3.

Such a high value of the barrier contradicts the existing ideas about rapid pseudorotation of saturated 5-membered rings.[9a] This casts doubt on the correctness of the assignment of the *d,l* and *meso* isomers of **15** made[8a] because under the conditions of rapid (in the NMR time scale) twisting of the 5-membered ring, the Me groups of the *meso* form **15a** should be isochronous. An analysis of molecular models of the *d,l* isomer **15b** shows that the steric equivalence of the 2,4-Me groups assumed[8a] is practically unattainable and that the anisochronism of these groups in the ^{1}H spectrum should be expected under the conditions of both rapid and hindered pseudorotation.

On the basis of these considerations, we undertook a checking of the correctness of the assignment of the configuration of isomers **15a, b**.[8a] 1,3-Diazanes **8a, b** are transformed into bicyclic diaziridines **15a, b** without the involvement of the carbon chiral centers since diastereomerically pure diamine **2** gives only one isomer **15**. Therefore, the problem of the configuration of diaziridines **15a, b** can be unequivocally solved by precisely establishing the configuration of diamines **2a, b** separated,[6] by crystallization of N,N-diacetyl derivatives.

The configurations of diamines **2a** and **2b** were assigned[6] as a result of attempted optical activation via diastereomeric adducts with 3-oxymethylene camphor. However, no reliable value of the optical rotation angle was obtained for enriched diamine **2**.

The *d,l* and *meso* forms can be unequivocally assigned on the basis of the ^{1}H spectra.[10a–d] Indeed, the CH_2 group of *d,l*-diamine **2b** having a C_2 symmetry axis gives the AA'XX' type spectrum with isochronous protons whereas in *meso* form **2a** these protons are anisochronous and the CH_2 group gives rise to the ABX_2 spectrum.



meso - **2a** d,l - **2b** meso - **8a, 9a** d,l - **8b, 9b**

The ABX_2 spectrum is also observed for the $C(5)H_2$ group of the *meso* form of 1,3-diazanes **8a**, **9a** (Table 1). Besides, **8a** has geminally anisochronous protons at C(2). The ^3J values (Table 1) point to a prevailing conformation of **8a** and **9a** with a synaxial orientation of 4- and 6-Me groups. Racemic diazane **8b** gives a simple A_2X_2 spectrum for the $C(5)H_2$ group (Table 1); the isochronism of the Me groups and protons of the ring is caused by rapid conversion of the hexahydropyrimidine ring. In 1,3-diazine **9b**, as in **8a** and **9a**, two possible chair conformations are undegenerate and among them the conformation with the equatorial 2-Me group is most populated since the axial orientation of the latter gives rise to a strong steric interaction with the axial 4-Me group.[11a] In its chemical shift in the ^{13}C spectrum, the 2-Me group of **9b** and hence is also equatorially oriented. As in Me-substituted cyclohexanes,[11a,b] the ^{13}C signals of all the equatorial Me groups of 1,3-diazanes **8a, b** and **9a, b** are observed in a weaker field as compared with the axial groups.

Thus, the assignment of the diamine **2** configuration[6] is erroneous and should be changed to opposite: α-diamine—the *d,l* form **2b** and, respectively, β-diamine—the *meso* form **2a**.

The ^{1}H and ^{13}C spectra of diaziridine **15a** obtained from *meso*-diamine **2a** reveal the isochronism of the MeCH fragments (Tables 3 and 5); these fragments are anisochronous in diaziridine **15b** obtained from racemic diamine **2b**. Hence, the assignment of isomers **15a, b** and the conclusion about the skewness of the 5-membered ring of 1,5-DABH made on the basis of ^{1}H-NMR data are also erroneous.

The isochronism of the NCH_2 and NCH(Alk) groups of the 5-membered ring is also observed in diaziridines **12–14**, **16a** and **17** (Tables 3 and 5) and in *meso* isomers of 2,4,6-trialkyl-TABH.[4b] The ^{1}H spectrum of diaziridines **12**, **15a** is not changed by cooling to −80°.† The isochronism of the C(2) and C(5) nuclei in the ^{13}C spectrum of 1,6-diazabicyclo[4.1.0]heptane **18** is retained at this temperature; according to Ref. 12, this compound should have featured an elevated barrier of rotation with eclipsing.

Thus, the twisting (pseudorotation) of 5- and 6-membered rings in bicyclic *cis*-diaziridines **12–18** is a rapid process in the ^{1}H- and ^{13}C-NMR time scale and the chirality of these compounds can only be revealed by methods possessing low characteristic time, viz. PE and IR spectroscopy and X-ray analysis.

Conformation

The boat form in which the eclipsing of the CH bonds is minimized as against the chair form is most advantageous for bicyclo[3.1.0]hexane **19** and its derivatives. According to X-ray analysis of *d,l*-2,4,6-trimethyl-TABH[8d] and 2-*p*-bromophenyl-1,3-diazabicyclo[3.1.0]hexane,[13] the introduction of one or two N atoms into the bridge head does not affect the

† The same phenomenon was also observed for the 3,3-dimethyl derivative **17** cooled to −45°.[8a]

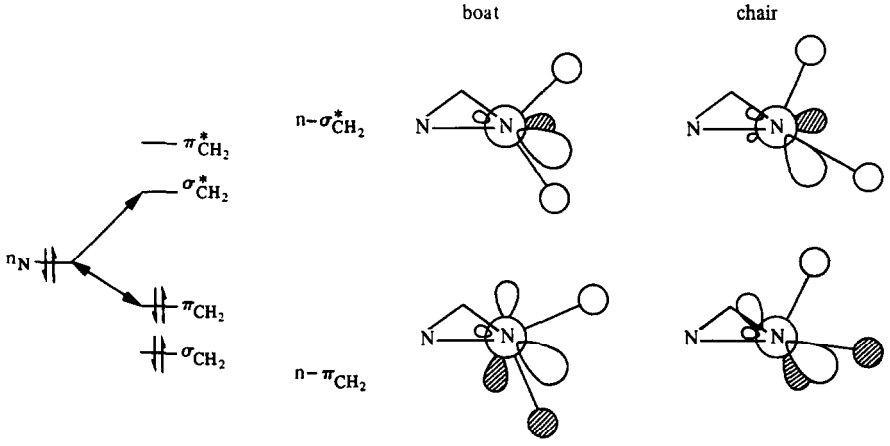
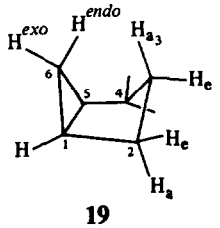


Fig. 1.

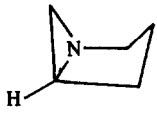
prevailing conformation of the bicyclohexane system. In this case the higher stability of the boat as compared with the chair can be explained on the basis of the PMO theory[14a,b] by the decreasing of the destabilizing four-electron $n-\pi_{CH_2}$ interaction and the increasing of the stabilizing two-electron $n-\sigma^*_{CH_2}$ interaction (Fig. 1).

Indeed, as follows from Fig. 1, the nonbonding n_N orbital in the boat is almost orthogonal to the highest occupied group orbital π_{CH_2} and overlaps to a maximum degree with the lowest unoccupied group orbital $\sigma^*_{CH_2}$ whereas in the chair the $n-\sigma^*_{CH_2}$ overlapping is clearly lower and the $n-\pi_{CH_2}$ overlapping becomes stronger. The attractive interaction of the antisymmetric combination of the σ_{CC} orbitals of C(2)—C(3) and C(3)—C(4) with the unoccupied Walsh orbital of the 3-membered ring w* (a'_2),[15a–c] stabilizing the chair seems to be compensated by the $n-\sigma^*_{CC}$ interaction in the boat (Fig. 2).

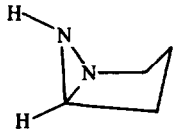
In order to verify the assumption about the prevailing population of the boat of bicyclo[3.1.0]-hexanes with bridge head nitrogen in solution, we compared the ^{1}H- and ^{13}C-NMR spectra of unsubstituted bicyclo[3.1.0]hexane **19** whose boat conformation had been established by electron diffraction and microwave techniques[16] with those of model compounds, aziridine **20**† and diaziridine **21**:



19



20



21

The assignment of the signals in the ^{1}H spectra of **19**, **20** and **21** (Table 3) was made on the basis of the known ideas of the shielding of the 6-protons of the 3-membered ring, the deshielding of the 1,5-protons,[17a] and also with the help of double resonance and the comparison of the coupling constants ^{2}J, ^{3}J and ^{4}J (Table 4) with known values for substituted bicyclo[3.1.0]hexanes.[17a,c] The coupling constants of the protons of the 3-membered ring in **19**, **20** feature the relation $^3J_{cis} > {}^3J_{trans}$[17a,b] and those of pseudoaxial and pseudoequatorial protons of the 5-membered ring of **19–21** give $^3J_{aa} > {}^3J_{ae} \gg {}^3J_{ee}$.[17a]

The assignment in the ^{13}C spectra (Table 5) was made on the basis of the coupling constants $^1J_{CH}$[15a,18a] and with the help of selective heteronuclear resonance.

The prevailing conformation of bicyclo[3.1.0]-hexanes is determined with the use of two basic criteria: the $^3J_{1,2}(^3J_{4,5})$ values from the ^{1}H spectra[17a,c] and the chemical shifts of C(3)[15a–c,18c] or C(6)[18a,b] from the ^{13}C spectra. In the first case it is quite evident that the ^{3}J values, being the functions of the dihedral angle, should be strongly dissimilar for the boat and the chair (Fig. 1). For most of the boat form derivatives of bicyclo[3.1.0]hexane, $^3J_{4e,5} = 0$ and

†Only the parameters of the ^{1}H spectrum of the 3-membered ring protons were earlier published for this compound.[17b]

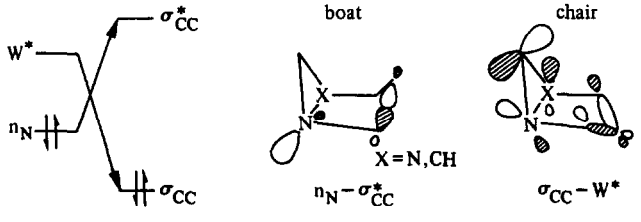


Fig. 2.

Table 3. Chemical shifts of ^1H (δ)[a] of diaziridines **12–18** and of model compounds **19–21**

	Solvent[b]	2a	2e	3a	3e	4a	4e	5	6*exo*	6*endo*	Me groups
12	A	2.65	2.84	1.01	0.91	2.65	2.84	—	2.31	1.45	—
13	A	2.65	2.87	1.03		2.65	2.87	—	—	1.68	1.12 (6*exo*)
	B	2.98	3.37	1.73	1.81	2.98	3.37	—	—	2.36	1.21 (6*exo*)
14	A	2.97	2.39	1.27	1.61	2.97	2.39	—	—	—	0.61 (6*endo*), 1.26 (6*exo*)
	B	3.23	2.85	1.95	2.26	3.23	2.85	—	—	—	1.16 (6*endo*), 1.26 (6*exo*)
15a	A	—	3.10	1.55	0.89	—	3.10	—	2.46	1.39	1.19 (2,4*ax*)
15b	A	—	3.15	0.84	0.92	3.31	—	—	2.27	1.68	1.07 (2*ax*), 0.99 (4*eq*)
16a	A	—	3.17	1.68	0.97	—	3.17	—	—	1.69	1.20 (2,4*ax*), 1.13 (6*exo*)
	B	—	3.57	2.26	1.43	—	3.57	—	—	2.31	1.33 (2,4*ax*), 1.23 (6*exo*)
16b	A	—	3.21	0.96		3.30	—	—	—	1.96	1.07 (2*ax*), 1.03 (4*eq*), 1.14 (6*exo*)
	B	—	3.58	1.48	1.54	3.55	—	—	—	2.49	1.20 (2*ax*), 1.30 (4*eq*), 1.21 (6*exo*)
17	A	2.89	2.28	—	—	2.89	2.28	—	3.00	1.91	0.65, 100 (3)
18	A	2.04	3.08	1.50	1.10	1.50	1.10	[c]	2.84	1.88	—
19	A	1.62	1.70	1.02	1.42	1.62	1.70	1.17	0.26	0.11	—
20	B	2.87	2.97	1.60	1.42	1.86	2.10	2.32	1.52	1.16	—
21	C	2.73	3.15	1.53		1.72	2.20	3.58	1.7[d]	—	—

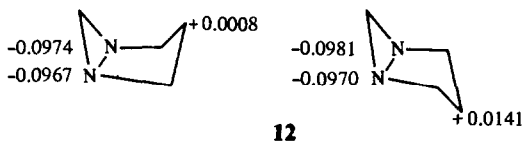
[a] The spectra of **13–16a, b, 18, 21** measured at 400.13 MHz, those of **12, 17, 19, 20** at 360 MHz.
[b] A—C_6D_6, B—$CDCl_3$, C—$CDCl_3 + C_6D_6$ (10:1 v/v).
[c] Coincide with the chemical shifts of 2a and 2e protons.
[d] The chemical shift of NH.

$^3J_{4a,5}$ = 3.3–4.6 Hz.[17a,c] The same coupling constants ^3J are observed for a proven boat **19** and model azabicycles **20, 21** (Table 4). The second criterion is based on upfield shift of C(3) and C(6) caused by steric compression in the boat (*syn*-γ-effect[15,18]) and deshielding of C(3) in the chair because of the σ_{CC}–w* interaction (*anti*-γ-effect[15]) (Fig. 2). The prevailing boat conformation of aziridine **20** and diaziridine **21** meet this criterion as well: the chemical shifts of C(3) in these compounds are close to those of **19** (Table 5) and correspond to an upfield shift as a result of the *syn*-γ-effect.

Proceeding from these data, we suggested that if in the bridge head of 1,5-DABH two N atoms are present, the boat conformation should be most populated in solution. This suggestion was supported by the ^{13}C and ^1H spectra of **12, 13, 15a, b** and **16a, b**.

The signals in both kinds of the spectra of diaziridines **12–17** (except for *exo*- and *endo*-6-H for **12, 15a, b, 17** and 2,4-H_a and 2,4-H_e for **17**) were assigned in the same manner as in the case of **19–21** (*vide supra*).

According to the CNDO/2 calculation of diaziridine **12**, the positive charge on the C(3) atom in the boat form is less than in the chair:

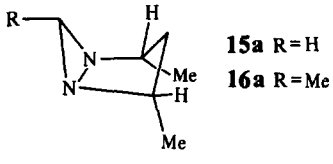


12

Therefore, an upfield shift of C(3) in the boat and downfield shift in the chair should be expected for 1,5-DABH, as in the case of its carbon analog **19**.[15]

Indeed, the chemical shift of C(3) in unsubstituted 1,5-DABH **12** is almost the same as in **19–21** (Table 5) for which the boat form has been proven (*vide supra*). A minor downfield shift of C(3) of diaziridine **13** (1.80 ppm) is due to the δ-effect of 6-Me group. In the case of diaziridines **15a, b, 16a, b**, apart from the δ-effect of the 6-Me group for **16a, b**, the deshielding β-effect of the 2,4-Me groups should be taken into account. The overall effect for *cis*-1,3-dimethylcyclopentane (a model for *meso*-**15a, 16a**) is 18.6 ppm and for the *trans* isomer (a model for *d,l*-**15b, 16b**), 16.7 ppm.[11b,19] The subtraction of these contributions gives the chemical shift of C(3): 18.5 ppm for *meso* isomers **15a, 16a** and 18.1 ppm for *d,l*-**15b, 16b** which clearly shows that the *syn*-γ-effect is manifested. The latter also follows from upfield shifts of C(3) of diaziridines **15a, b, 16a, b** as compared with the shifts of C(5) of their precursors, diazanes **8a, b, 9a, b** (Table 2). It can be assumed that besides steric compression, another cause of the shielding of C(3) in 1,5-DABH **12, 13, 15a, b, 16a, b** as well as in other bicyclo[3.1.0]hexanes **20, 21** with the N atom in the bridge head, is the shift of electron density to C(3) as a result of the n–σ^*_{CC} hyperconjugation (Fig. 2). This assumption is supported by the shift of the C(3) signal of diaziridine **13** by ~1.0 ppm downfield produced by changing the solvent from $CDCl_3$ to CD_3OD which lowers the energy of the nonbonding orbitals because of the formation of H-bonds.

The coupling constants ^3J of 2-H, 3-H and 3-H, 4-H (Table 4) indicate a dipseudoequatorial orientation of protons at C(2) and C(4) of *meso* isomers **15a, 16a** in which the 2,4-Me groups are, correspondingly, *syn*-pseudoaxial:



15a R = H
16a R = Me

In contrast to cyclohexanes[11a] and 1,3-diazanes **8a, b, 9a, b** (Table 2), this leads to a stronger deshielding β-effect of the pseudoaxial Me group (8.33 ppm) as compared with the pseudoequatorial group (6.03 ppm) in 1,5-DABH **15a, b** and **16a, b**. Also, unlike the

Table 4. ^{1}H coupling constants[a] (Hz) of diaziridines **12–18** and of model compounds **19–21**

	2a2e	3a3e	4a4e	6ex 6en	2a3a	2a3e	2e3a	2e3e	3a4e	3e4a	3e4a	3e4e	Other
12	−12.1	−13.4	−12.1	4.2	12.1	8.2	8.5	1.4	12.1	8.5	8.1	1.4	0.9 ($^4J_{2a6en}$)
13	−12.0	[b]	−12.0	—	11.7	8.3	8.1	2.0	11.7	8.1	8.3	2.0	4.9 ($^3J_{6enMe}$)
	−12.2	−13.2	−12.2	—	11.7	8.3	8.8	1.2	11.7	8.8	8.3	1.2	4.9 ($^3J_{6enMe}$)
14	−11.7	−12.9	−11.7	—	11.7	6.8	10.3	5.1	11.7	10.3	6.8	5.1	—
	−12.2	−13.1	−12.2	—	11.0	6.6	10.0	5.1	11.0	10.0	6.6	5.1	—
15a	—	−13.5	—	4.5	—	—	8.9	1.7	—	8.9	—	1.7	7.0 ($^3J_{2,4eMe}$), 0.7 ($^5J_{3a6ex}$), 0.5 ($^5J_{3e6ex}$)
15b	—	−13.2	—	4.0	—	—	7.6	0.5	10.5	—	7.5	—	7.0 ($^3J_{2eMe}$), 6.6 ($^3J_{4aMe}$), 0.9 ($^4J_{2a6en}$), 0.5 ($^5J_{3a6ex}$), 0.5 ($^5J_{3e6ex}$)
16a	—	−13.4	—	—	—	—	9.0	1.7	—	9.0	—	1.7	7.1 ($^3J_{2,4eMe}$), 4.9 ($^3J_{6enMe}$)
	—	−13.4	—	—	—	—	9.0	1.7	—	9.0	—	1.7	7.1 ($^3J_{2,4eMe}$), 4.9 ($^3J_{6enMe}$)
16b	—	−13.2	—	—	—	—	7.6	1.1	10.7	—	7.6	—	7.1 ($^3J_{2eMe}$), 6.6 ($^3J_{4aMe}$), 4.9 ($^3J_{6enMe}$)
	—	−13.2	—	—	—	—	7.6	1.1	10.7	—	7.6	—	7.1 ($^3J_{2eMe}$), 6.6 ($^3J_{4aMe}$), 4.9 ($^3J_{6enMe}$)
17	−10.7	—	−10.7	4.5	—	—	—	—	—	—	—	—	0.4 ($^4J_{2e6en}$)
18	−11.5	−13.2	−13.2	4.7	11.5	2.8	5.7	1.8	[b]	[b]	[b]	[b]	—
19	−12.3	−13.2	−12.3	−4.7	12.2	8.0	8.1	1.0	12.2	8.0	8.1	1.0	3.3 ($^3J_{4a5}$), 0.0 ($^3J_{4e5}$), 8.1 ($^3J_{6ex5}$), 4.2 ($^3J_{6en5}$), 0.9 ($^4J_{2a6ex}$)
20	−11.7	−13.2	−12.9	0.3	11.1	7.5	8.4	1.4	11.0	8.4	8.7	0.0	5.4 ($^3J_{4a5}$), 0.0 ($^3J_{4e5}$), 6.3 ($^3J_{6ex5}$), 3.3 (J_{6en5})
21	−12.6	−15.5	−13.4	—	10.3	8.1	7.7	1.5	11.7	7.6	7.9	1.0	2.9 ($^3J_{4a5}$), 0.0 ($^3J_{4e5}$)

[a] The working frequency and solvent see Table 3.
[b] Not determined.

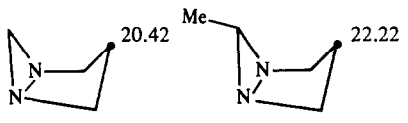
Table 5. Chemical shifts of ^{13}C (δ)[a] and coupling constants $^{1}J_{CH}$ (Hz) of diaziridines **12–18** and of model compounds **19–21** in $CDCl_3$

	C(2)	C(3)	C(4)	C(5)	C(6)	2-Me	3-Me	4-Me	6-Me
12	51.35	20.42	51.35	—	46.99[e]	—	—	—	—
	(143.7)	(133.2)	(143.7)		(165.7, 183.1)				
13	51.15	22.22	51.15	—	52.31	—	—	—	17.94
	(142.2)	(132.5)	(142.2)		(164.8)				(126.3)
14	47.88	32.87	47.88	—	60.66	—	—	—	13.15
	(137.3, 140.4)	(131.2)	(137.3, 140.4)						28.08
									(126.3)
15a	59.66	36.96	59.66	—	50.71[e]	24.24	—	24.24	—
	(139.8)	(131.8)	(139.8)		(166.0, 183.1)	(126.0)		(126.0)	
15b	60.07	34.77	56.86	—	44.43[e]	22.52	—	16.28	—
	(139.0)	(130.3)	(142.0)		(166.0, 183.1)	(126.4)		(126.0)	
16a	59.19	38.84	59.19	—	56.41	23.99	—	23.99	18.22
	(138.6)	(131.8)	(138.6)		(166.0)	(126.3)		(126.3)	(127.0)
16b	59.40	36.60	56.70	—	50.15	22.26	—	16.28	18.22
	(138.6)	(131.8)	(141.6)		(164.8)	(126.3)		(127.0)	(127.0)
17	67.54	50.39	67.54	—	64.85[e]	—	28.10	—	—
	(138.7)		(138.7)		(166.6, 180.7)		(123.9)		
							29.40		
							(126.0)		
18	47.39	17.42	17.42	47.39	59.20[b]	—	—	—	—
	(139.4)	(128.6)	(128.6)	(139.4)	(165.6, 181.6)				
19[c]	27.15	19.74	27.15	16.26[d]	5.34	—	—	—	—
	(128.1)	(128.9)	(128.1)	(165.7)	(157.4)				
20	52.53	19.35	25.72	39.25	26.38[e]	—	—	—	—
	(138.7)	(131.3)	(129.5)	(175.7)	(162.9, 171.5)				
21	53.74	19.00	26.96	58.45	—	—	—	—	—
	(136.5)	(130.0)	(127.0)	(182.0)					

[a] The spectra of **19** measured at 90.8 MHz, those of **12–17, 20** at 100.62 MHz, and of **18, 21** at 20.15 MHz.
[b] The chemical shift of C(7).
[c] Without solvent.
[d] Coincides with C(1).
[e] $^{3}J_{HC(2)N(1)C(6)}$, Hz: **12**—2.44, 8.39; **14**—4.27, 8.32; **15a**—2.44; **15b**—1.83, 6.71; **17**—6.61, 6.61.

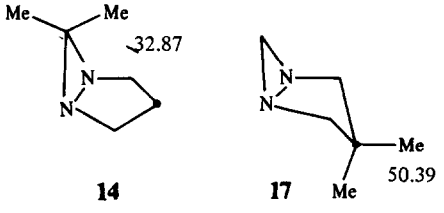
situation with monocyclohexanes (*vide supra*), the ^{13}C signals of the pseudoaxial Me groups of DABH **15a, b, 16a, b** are located further downfield than those of the pseudoequatorial ones (Table 5).

Diaziridines **14, 17** with Me substituents at C(6) and C(3) exist mostly in the chair form because the C(3) signals of these compounds are observed further downfield than the C(3) signals of boat-like diaziridines **12, 13** (Table 5):



12 **13**

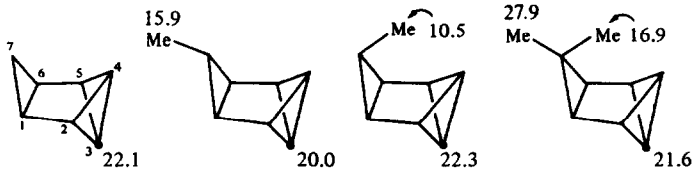
The overall effect of the Me_2C groups of cyclopentane is 8.6 ppm;[11b] for 1,3-diazane it equals 7.64 ppm.[19] Even if the highest of these contributions is taken into account, the C(3) nucleus of diaziridine **17** will be strongly deshielded as compared with C(3) in **12, 13**. It can be suggested that the deshielding *anti*-γ-effect manifesting itself in chair-form diaziridines **14, 17**, as in the cases described earlier,[15] is due to the σ_{CC}–w* interaction (Fig. 2).



14 **17**

As follows from the comparison of the ^{13}C spectra of tetracyclo[4.1.$0^{2,4}$.$0^{3,5}$]heptanes (TCH),[15c] the influence of the overall effect of the Me_2C groups of the 3-membered ring on the C(3) shift of diaziridine **14** should be minor.

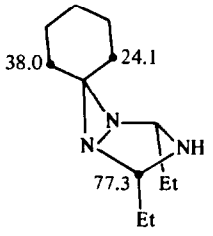
The reason of the anomalous conformation behavior of DABH **14, 17** seems to consist in the destabilization of the boat by steric repulsion of the *endo* oriented Me group and the δ-CH_2 group. This repulsion is stronger than other interactions stabilizing the boat and

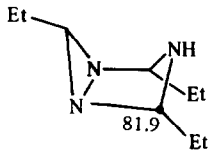


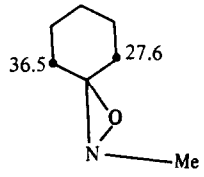
destabilizing the chair (*vide supra*). In a chair-form 6,6-dimethyl derivative **14**, the *endo*-6-Me group interacts sterically with the pseudoaxial protons at C(2) and C(4) as well which leads to the flattening of the 5-membered ring. This is most clearly evidenced by the high coupling constant $^3J_{2e,3e}$ (5.13 Hz) corresponding to a dihedral angle θ_{ee} close to 120°.[20]

The situation when the steric repulsion of the 3- and 6-*endo* substituents destabilizes the boat form of the bicyclo[3.1.0]hexane system is also encountered in the case of 3,3 - diethyl - 6,6 - diphenyl - 3 - azabicyclo[3.1.0]hexane bromide which, according to X-ray data, has the chair shape.[21]

The chair conformation could have been populated also in 6-methyl derivatives **13**, **16a**, **b** for the *endo* orientation of the 6-Me group. However, the boat conformation and the *exo* orientation of the 6-Me group are testified to not only by the C(3) shifts which conform to the shielding *syn*-γ-effect but also by the absence of this effect on C(2) and C(4) (chemical shifts of these nuclei in **13**, **16a**, **b** practically coincide with those of C(2) and C(4) in **12** and **15a**, **b** (Table 5)) which is observed in the case of 6,6-disubstituted **14** (3.47 ppm, Table 5) and 6,6-pentamethylene-2,4-diethyl-TABH (~4.5 ppm):[4b]



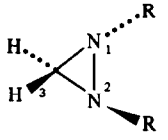




Steric compression caused by the interaction of the *endo*-6-Me group with the pseudoaxial 2,4-H in diaziridine **14** and the influence of *trans* oriented lone pair[22] result in a stronger shielding of this group in the ^{13}C spectrum as against the *exo*-6-Me shielding (Table 5); the downfield shift of the latter in diaziridine **14**, as compared with the shift of the corresponding group in **13**, **16a**, **b**, is due to the effect of the *endo*-6-Me group which, e.g. for TCH[15c] equals 12.0 ppm (*vide supra*). With these considerations taken into account, one may believe that the assignment of the ^{13}C signals of the methylene groups in 6,6-pentamethylene-TABH should be opposite to that made in Ref. 4*b*, i.e. the signals of the *endo*-CH_2 group (*trans* with respect to the lone pair) are located further upfield than those of the *exo*-CH_2 group (*cis* with respect to the lone pair), as is the case for 2-methyl-3,3-pentamethyleneoxaziridine.[22]

The ^1H spectra of 1,5-DABH **12**, **13**, **15b**, **16b** reveal a long-range coupling constant ^4J of *endo*-6-H with the pseudoaxial proton at C(2) and/or C(4) which may result from the ⌵ "dipper" location of bonds[23] only in the boat conformation. In the chair-form DABH **17**, coupling constant ^4J binds 6-H with pseudoequatorial 2,4-H whose signals, as in the case of **14**, are located further upfield than those of the pseudoaxial 2,4-H since the former actually eclipses the lone pair of the N atoms in the chair (Fig. 1).[24] The deshielding of the pseudoaxial 2,4-H of diaziridines **14**, **17** is favored by the effect of steric compression from the side of the *endo*-6-H or *endo*-6-Me group. Diaziridines **15a**, **b** also feature a long-range coupling constant ^5J of *exo*-6-H with the pseudoaxial and pseudoequatorial proton at C(3) (Table 4).

An upfield shift of C(6) (Table 5), compared with C(3) of *trans*-diaziridines[25] also speaks in favor of the prevailing population of the boat for 1,5-DABH **12**, **13**, **15a**, **b**, **16a**, **b**.



R	Me	Et	i-Pr
$\delta_{C(3)}$	58.4	56.0	54.9

The C(6) atom in the chair-form diaziridine **17** is strongly deshielded (Table 5).

The C atom of the diaziridine ring, C(6), in **12**, **15a**, **b** **17** is less affected by the substituents in the 5-membered ring and the chemical shift of this C reflects better than C(3) the degree of steric compression which monotonically decreases in the series:

15b (44.43 ppm) > **12** (46.99) > **15a** (50.71)

and drops abruptly for **17** (64.85 ppm).

The lower degree of shielding and accordingly, a lesser steric compression are also observed in the *meso* form, **16a**, as compared with the *d,l*-compound, **16b** (Table 5). This can be explained by the flattening of the 5-membered ring in the *meso* form **15a**, **16a** as a result of steric repulsion of *syn*-dipseudoaxially oriented 2- and 4-Me groups. The flattening of the 5-membered ring of *meso* compounds **15a**, **16a** in comparison with the *d,l*-**15b**, **16b**, also follows from the magnitudes of coupling constants $^3J_{2e3a}$ and $^3J_{2e3e}$ (Table 4). It was shown[17a] that for the bend angle (α) of the 5-membered ring decreasing from 25° to 5°,† the dihedral angle θ_{2e3a} changes from 24.0° to 2.5° and θ_{2e3e} grows from 99.9° to 117.8°. It follows from the ^3J–$\cos^2\theta$ dependence[20] that such a change of θ should lead to the growth of $^3J_{2e3a}$ and $^3J_{2e3e}$. Indeed, in *meso* compounds **15a**, **16a**, these coupling constants are higher than in *d,l*-**15b**, **16b** (Table 4).

Diaziridines **12**, **15a**, **b** feature a linear dependence of the chemical shift of C(6) on the geminal constant $^2J_{6exo-6endo}$ (Fig. 3). If it is assumed that the geminal coupling constant is a function of the H—C—H valence angle,[20] then this dependence will mean that the weakening of the steric compression increases the H—C(6)—H valence angle. The ^2J–$\delta_{C(6)}$ dependence in the series of the indicated DABH varies monotonically and has a sharp bend for **17** (Fig. 3) which also

† A reasonable α range for the boat conformation has been chosen. The optimization of the geometry of **12** in the boat form by the CNDO/2 procedure gives α ~ 6°.

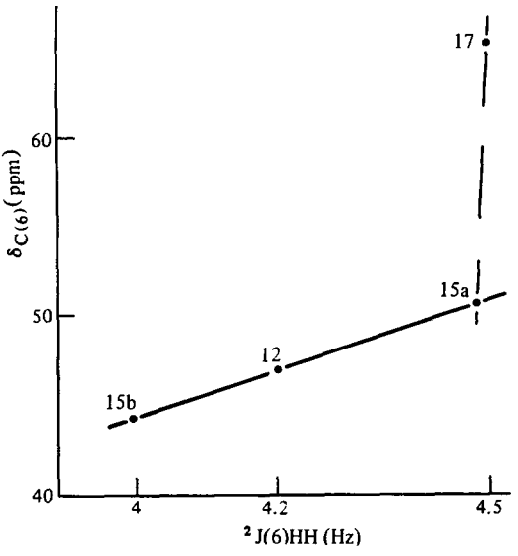


Fig. 3.

seems to be an indication of the chair conformation of this compound.

The coupling constants $^3J_{CH}$ of the C(6) atom of the diaziridine ring with the protons at C(2) and/or C(4) are distinctly observed in the ^{13}C spectra of diaziridines **12, 15a, b, 17** (Table 5). The applicability of ^3J(C, N, C, H) for conformation analysis was shown earlier on an example of nucleosides and peptides.[26] Hence, the similarity of the $^3J_{CH}$ values of C(6) with pseudoequatorial 2-H (4-H) imply the identity of the conformations of diaziridines **12, 15a, b**. For diaziridine **17**, this constant and hence its conformation, is substantially different. If we assume that the change of $^3J_{CH}$ from ~2.2 Hz in **12, 15a, b** to 6.6 Hz in **17** reflects the diminishing of the dihedral angle C(6)-N—C—H_e from ~85° (the angles were measured on molecular models) in the boat to ~30° in the chair (here H becomes pseudoaxial), then the existence of the Carplus type $^3J_{CH}$–$\phi(\theta)$ dependence can be suggested for bicyclic diaziridines.

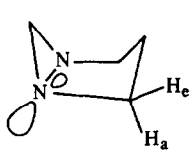
The variation of the dihedral angle lone pair-N—C—H (ξ) in going from the boat **12, 13** to a flattened chair **14** and further to the chair **17** can be followed by the change of the geminal constant $^2J_{2a2e}$ (Table 4):

According to the empirical ξ–$^2J_{HH}$ dependence for the N—CH_2 fragment, the lowest negative geminal constant should be observed for the eclipsing of the C—H bond by the lone pair and the highest constant, for the bisector orientation of the lone pair.[20] Indeed, the lone pair of the N atom, almost completely eclipsing the pseudoequatorial C—H bond in the chair **14, 17**, makes a higher positive contribution to $^2J_{2a2e}$ than the lone pair located almost bisectorily with respect to H—C(2)—H in boat **12, 13** (Fig. 1). Here diaziridine **14** with a flattened 5-membered ring, as was expected, has a more negative value of $^2J_{2a2e}$ than **17**.

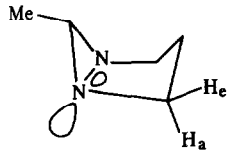
Thus, according to the above cited ^1H and ^{13}C spectral data, 1,5-DABH exists in solution mostly in the boat form; only the introduction of *endo* substituents into positon 3 and/or 6 leads to the population of the chair conformation.

The ^{13}C spectra of diaziridines **12, 15a, b, 17, 18** feature strongly differing coupling constants $^1J_{CH}$ of the 3-membered ring C with *exo* and *endo* protons (Δ^1J_{CH} = 17.4 Hz for **12, 15a**; 17.0 Hz for **15b**; 14.1 Hz for **17**, and 15.08 Hz for **18**) (Table 5). As follows from the comparison of these data with the $^1J_{CH}$ values for **13, 16a, b** having only *endo*-6-H and from the examination of the ^{13}C—H satellites in the ^1H spectrum of **15a**, the lower constant refers to *endo*-H (*trans* with respect to the lone pair), and the higher one, to *exo*-H (*cis* with respect to the lone pair), respectively. Such a relationship between the coupling constants $^1J_{CH}$ of bicyclic diaziridines **12, 15a, b, 17, 18** is opposite to that observed for bicyclic and tetracyclic cyclopropanes[15a,c] but agrees with data obtained for aziridines[27a] and oxaziridines[27b] in which the carbon of the ring has a larger $^1J_{CH}$ constant with H oriented in *cis* position to the lone pair than with *trans* H. Thus, unlike bicyclo[n.1.0]alkanes, the orientation of the lone pair of the N atoms in diazabicyclo[n.1.0]alkanes **12, 15a, b, 17, 18**, exert a decisive influence on the relationship between $^1J_{C\text{-}exoH}$ and $^1J_{C\text{-}endoH}$.

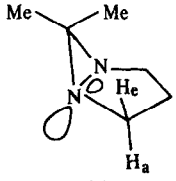
Different coupling constants $^1J_{CH}$ for C(2) with axial and equatorial H are also observed in the ^{13}C spectrum of 1,3-diazane **8a** (Table 2). In accordance with the rule of a negative contribution of the lone pair to $^1J_{C\text{-}transH}$,[26a–c] it can be supposed that the lower $^1J_{CH}$ constant (142.8 Hz) binds C(2) with axial 2-H on condition of the axial orientation of the lone pair of one of the N atoms:[19]



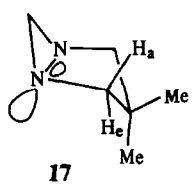
12
$^2J_{HH}$ = -12.10 Hz



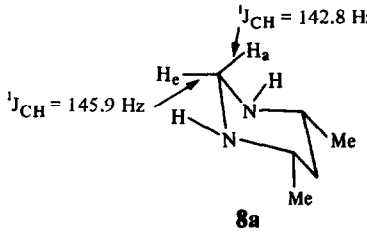
13
-11.96 Hz



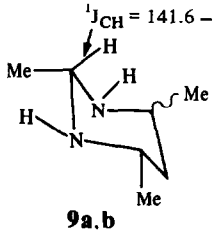
14
-11.72 Hz



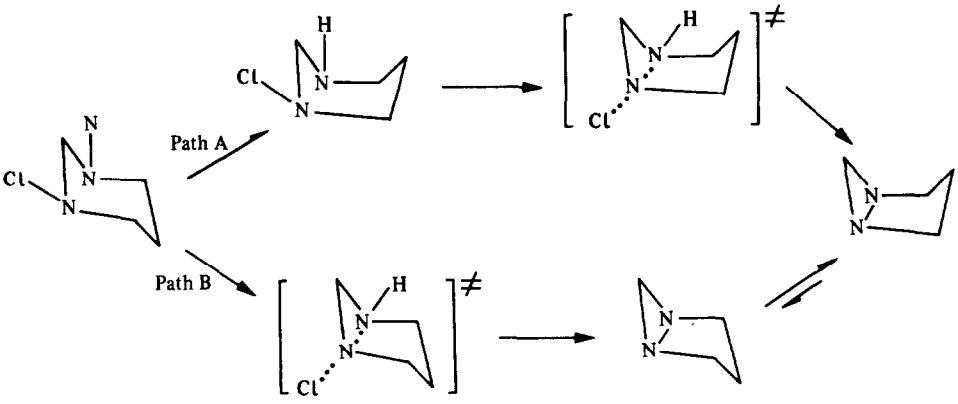
17
-10.67 Hz



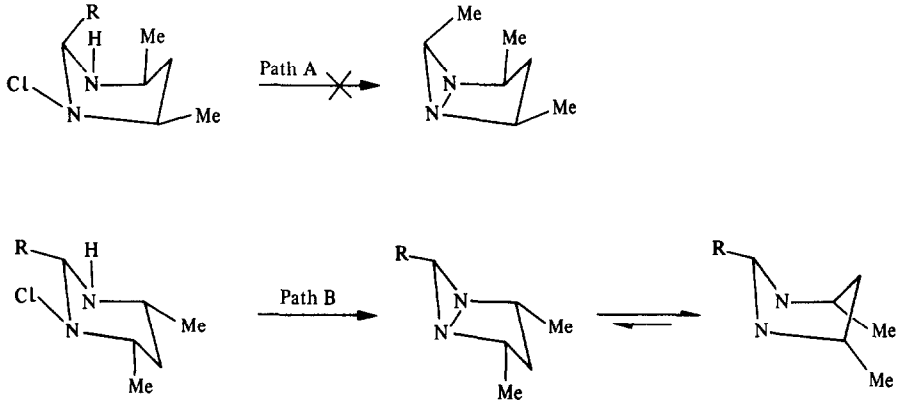
8a



9a,b



Scheme 4.



Scheme 5.

The $^1J_{C(2)H}$ values of 2-methyl substituted diazanes **9a, b** are close to the $^1J_{C(2)H_a}$ value for **8a** (Table 2) which confirms the axial orientation of 2-H and, accordingly, the equatorial orientation of the 2-Me group in these compounds.

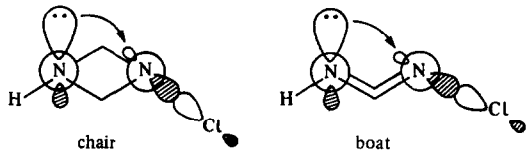
Stereochemistry of the formation of 1,5-*diazabicyclo*[3.1.0]*hexanes*

It was shown earlier that 1,3-diazanes exist mostly in the chair form and their cyclization products (1,5-DABH), in the boat form. This suggests the following mechanisms of the formation of DABH.

(a) The transition state of the cyclization of N-chlorodiazane is similar in the reaction coordinate to the reaction product (Path A). Then the factors which stabilize the boat conformation of 1,5-DABH should lower the energy of the transition state.

(b) The geometry of the transition state is close to that of the initial N-chlorodiazane (Path B) and DABH formed completely in the chair form undergoes further isomerization into the boat.

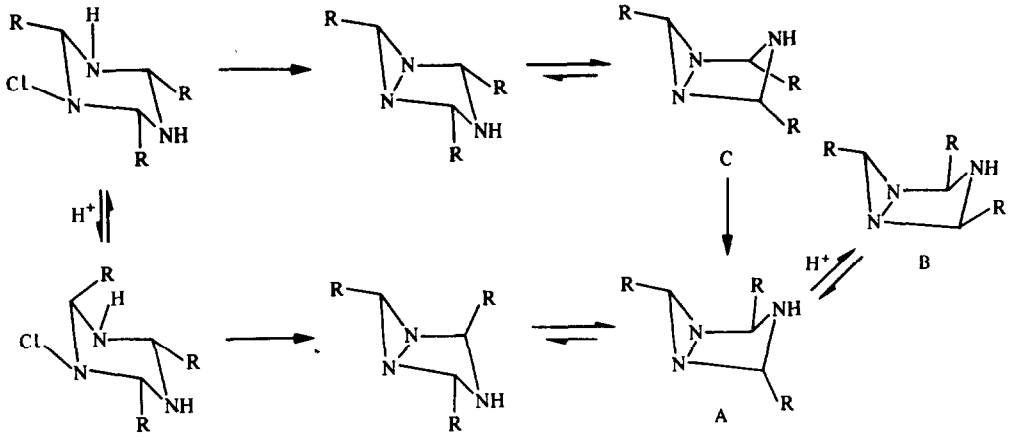
In both cases cyclization is considered as S_Ni substitution[28] during the attack of the axial lone pair of the equatorial N—Cl bond from the rear:



The formation of *meso* diaziridines **15a, 16a** only as isomers with *syn*-dipseudoaxial 2,4-Me groups in favor of path B for 2,4-dimethyl substituted DABH with a transition state similar to that of the initial N-chlorodiazane since according to path A, *meso*-**15a, 16a** should be obtained with *syn*-pseudoequatorial 2,4-Me groups (Scheme 5).

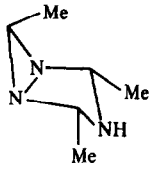
If path B is supposed to be correct also in the case of the cyclization of 2,4,6-trialkyl-1,3,5-triazanes,[4b] then the following scheme of the formation of 2,4,6-trialkyl-TABH can be accepted.

However, in this case the conformation of the *meso* isomer **C** and the orientation of the substituents R



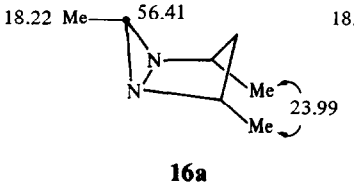
Scheme 6.

disagrees with that accepted in Ref. 4*b*:

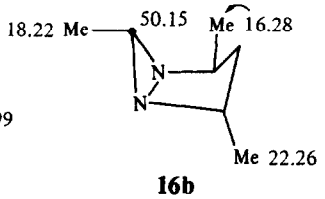


Moreover, the prevailing chair conformation was arbitrarily assumed in Ref. 4*b* also for isomers **A**, **B** which is refuted by X-ray analysis of *d,l*-2,4,6-trimethyl-TABH (**A**).[8d] It should be noted that the stabilization of the boat form of TABH by the n_N–σ^*_{CN} interaction is apparently more efficient than by the n_N–σ^*_{CC} interaction in the case of DABH (Fig. 2) since the level of the antibonding σ^*_{CN} orbital is located lower in energy than that of the σ^*_{CC} orbital.[14]

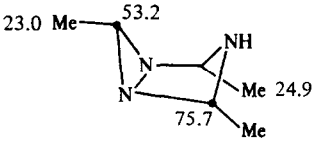
The *exo* orientation of the 6 substituent and the pseudoaxial orientation of the 2,4-substituents of the *meso* isomer **C** follows from a comparative analysis of the ^{13}C-NMR data for *meso* and *d,l*-DABH **15a**, **b**, **16a**, **b** (Table 5) and 2,4,6-trimethyl-TABH **A** and **C**:[4b]



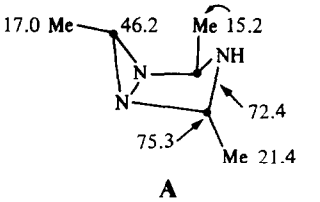
16a



16b



C



A

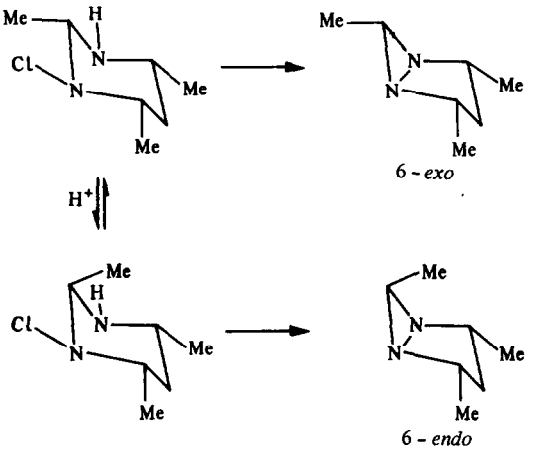
The ^{13}C signals of the 6-Me groups of *meso* and *d,l*-TABH **C** and **A** are close in their shift to those of the *exo*-6-Me groups of **16a**, **b**, the 6-Me group of the *meso* isomer **C** being even slightly deshielded in comparison with the corresponding group of the *d,l* isomer **A**; on the other hand, a considerable upfield shift should be expected for the *endo* oriented 6-Me group (*vide supra*). C(2) and C(4) are also screened in *meso* TABH **C** because of steric compression observed for the *endo* orientation of the 6 substituent (see the comparison of 6,6-pentamethylene- and 6-ethyl-TABH). As in the case of DABH **15a**, **b**, **16a**, **b** (Table 5), the ^{13}C signals of the pseudoaxial Me groups of TABH **A**, **C** are located further downfield than those of the pseudoequatorial groups.

TABH also retains the tendency to the deshielding of C(6) in *meso* isomers **C** as compared with *d,l* isomers **A**; this tendency reflects the weakening of steric compression as a result of the flattening of the 5-membered ring of the *meso* form caused by the steric interaction of *syn*-pseudoaxial 2,4-substituents. As was expected, the difference $\Delta\delta_{C(6)} = \delta^{meso}_{C(6)} - \delta^{d,l}_{C(6)}$ becomes larger with the increase of the volume of these substituents:[4b]

	Me	Et	n-Pr	i-Pr
$\Delta\delta_{C(6)}$	7.0	7.1	7.3	8.2

Besides, 6-*endo* isomer of DABH was not found in the products of the reaction of *meso* diamine **2a** with MeCHO and NaOCl; this isomer should have been produced together with 6-*exo* **16a** according to the scheme proposed in Ref. 4*b* for TABH (Scheme 7).

Thus, 1,5-DABH, as well as 2,4,6-trialkyl-1,3,5-TABH populating mostly the boat, are formed via the transition cyclization state close in its geometry to the initial N-chlorodi(tri)azane.



Scheme 7.

EXPERIMENTAL

The NMR spectra were obtained on WP-80-CY (^{13}C, 20.15 MHz), WM-400 (^1H, 400.13 MHz; ^{13}C, 100.62 MHz), and NT-360-WB (^1H, 360 MHz; ^{13}C, 90.8 MHz) spectrometers with TMS as internal standard.

The separation of the d,l *and* meso *forms of* 2,4-*diaminopentane* **2** *via* N,N-*diacetyl derivatives*

Ac_2O (129 g, 1.1 mol) was added dropwise to a stirred soln of an equimolar mixture of the *d,l* and *meso* form of **2** (28.3 g, 0.27 mol) in benzene (50 ml). After stirring for 2 hr at 60° the solvent was removed in vacuum and the residue dissolved in EtOH (55 ml) and diluted by Et_2O (700 ml). The crystals precipitated at −10° were separated and washed with Et_2O. *d,l*-N,N-Diacetyl-2,4-diaminopentane (20.5 g), m.p. 166–170° (lit.[6] m.p. 168°, α form) was obtained. The oily *meso*-N,N-diacetyl-2,4-diaminopentane (β form[6]) (31 g) was obtained from mother liquor.

The *d,l*-diacetyl derivative (20.5 g, 0.11 mol) in conc HCl (100 ml) was kept for 30 hr at 90°. After removal of HCl excess the residue was treated with sat KOH aq (25 ml) and product (b.p. 110–170°) was distilled. *d,l*-2,4-Diaminopentane **2b** (8.1 g, 72%), b.p. 60–65°/22 mm Hg (lit.[6] b.p. 60–61°/22 mm Hg, α form) was obtained after repeated distillation over solid KOH. ^1H-NMR (400.13 MHz, C_6D_6): δ, 0.90 (d, Me_2, ^3J = 6.4 Hz), 1.07 (dd, CH_2, $^3J^{cis}$ = 6.1, $^3J^{trans}$ = 6.8 Hz), 2.85 (m, 2CH).

Similarly, *meso*-2,4-diaminopentane **2a** (β form) (14.9 g, 90%) containing 14% of the *d,l* isomer was obtained from oily *meso* diacetate (31.0 g, 0.167 mol). ^1H-NMR (400.13 MHz, C_6D_6): δ, 0.86 (d, Me_2, ^3J = 6.4 Hz), 1.10 and 1.05 (m, CH_AH_B, $^2J_{AB}$ = −13.4, $^3J^{cis}$ = 5.1, $^3J^{trans}$ = 8.1 Hz), 2.73 (m, 2CH).

1,3-*Diazanes* **8a, 10**. A soln of CH_2O (0.15 g, 5 mmol) in H_2O (4 ml) was added to a stirred soln of diamine **2a** or **3** (5 mmol) in H_2O (2 ml). After 24 hr at 20° the mixture was saturated with KOH and extracted with CH_2Cl_2. After drying ($MgSO_4$) the solvent was evaporated at 16 mm Hg and the residue distilled or sublimed.

meso-4,6-*Dimethylhexahydropyrimidine* **8a**, 61% yield, b.p. 55°/15 mm Hg. (Found: C, 63.1; H, 12.4; N, 24.5. $C_6H_{14}N_2$ requires: C, 63.1; H, 12.4; N, 24.5%.)

5,5,-*Dimethylhexahydropyrimidine* **10**, 88% yield, m.p. 68–70°. (Found: C, 62.9; H, 12.7; N, 24.7. $C_6H_{14}N_2$ requires: C, 63.1; H, 12.4; N, 24.5%.)

meso-2,4,6-*Trimethylhexahydropyrimidine* **9a** was isolated from a mixture with *meso*-**16a**, m.p. 51–52°. (Found: C, 65.7; H, 12.65; N, 21.7. $C_7H_{16}N_2$ requires: C, 65.6; H, 12.6; N, 21.85%.)

Bicyclic cis-*diaziridines* **12–18** (general procedure[4a]). An aqueous soln of NaOCl (0.027 mol) was added dropwise to a cooled (15°) stirred soln of diamine (0.026 mol), NaOH (1.04 g, 0.026 mol) and carbonyl compound (0.026 mol) in H_2O (15 ml). After 6 hr at 20° the mixture was saturated with KOH and extracted with CH_2Cl_2. After drying ($MgSO_4$) the solvent was evaporated at 760 mm Hg with Vigreux column and the residue distilled. Diaziridines **16a, b** were purified by column chromatography on silica (eluent–EtOH).

1,5-*Diazabicyclo*[3.1.0]*hexane* **12**, 20% yield, b.p. 58–59°/21 mm Hg. (Found: N, 33.3. $C_4H_8N_2$ requires: N, 33.3%.)

6-*Methyl*-1,5-*diazabicyclo*[3.1.0]*hexane* **13**, 37% yield, b.p. 49–52°/13 mm Hg. (Found: C, 61.4; H, 10.2; N, 28.65. $C_5H_{10}N_2$ requires: C, 61.2; H, 10.3; N, 28.5%.)

6,6-*Dimethyl*-1,5-*diazabicyclo*[3.1.0]*hexane* **14**, 80% yield, b.p. 54°/7 mm Hg. (Found: C, 64.1; H, 10.7; N, 25.0. $C_6H_{12}N_2$ requires: C, 64.3; H, 10.7; N, 25.0%.)

meso - 2,4 - *Dimethyl* - 1,5 - *diazabicyclo*[3.1.0]*hexane* **15a**, 43% yield (from pure *meso*-**2a**), b.p. 73°/20 mm Hg.

d,l - 2,4 - *Dimethyl* - 1,5 - *diazabicyclo*[3.1.0]*hexane* **15b**, 46% yield (from pure *d,l*-**2b**), b.p. 73°/20 mm Hg. (Found (for mixture of **15a, b**): C, 64.3; H, 10.7; N, 24.9. $C_6H_{12}N_2$ requires: C, 64.3; H, 10.7; N, 25.0%.)

meso - 2,4,6 - *Trimethyl* - 1,5 - *diazabicyclo*[3.1.0]*hexane* **16a**, 12% yield (from *meso*-**2a**), b.p. 58°/15 mm Hg. (Found: C, 66.8; H, 11.0; N, 22.3. $C_7H_{14}N_2$ requires: C, 66.6; H, 11.2; N, 22.2%.)

d,l - 2,4,6 - *Trimethyl* - 1,5 - *diazabicyclo*[3.1.0]*hexane* **16b**, 20% yield (from pure *d,l*-**2b**), b.p. 55–58°/15 mm Hg. (Found: C, 66.7; H, 11.3; N, 22.1. $C_7H_{14}N_2$ requires: C, 66.6; H, 11.2; N, 22.2%.)

3,3 - *Dimethyl* - 1,5 - *diazabicyclo*[3.1.0]*hexane* **17**, 68% yield, b.p. 60–61°/11 mm Hg. (Found: C, 64.5; H, 10.8; N, 24.75. $C_6H_{12}N_2$ requires: C, 64.3; H, 10.7; N, 25.0%.)

1,6-*Diazabicyclo*[4.1.0]*heptane* **18**, 48% yield, b.p. 73–75°/18 mm Hg. (Found: C, 61.45; H, 10.3; N, 28.6. $C_5H_{10}N_2$ requires: C, 61.2; H, 10.3; N, 28.5%.)

1-*Azabicyclo*[3.1.0]*hexane* **20** was obtained according to Ref. 29, 77% yield, b.p. 107–108° (lit.[29] b.p. 107–110°).

1,6-*Diazabicyclo*[3.1.0]*hexane* **21** was obtained according to Ref. 30, detailed procedure will be published.

Acknowledgement—The authors wish to express gratitude to Dr E. M. Milvitskaya (Moscow State University) for synthesis of bicyclo[3.1.0]hexane.

REFERENCES

[1] G. V. Shustov, N. B. Tavakalyan and R. G. Kostyanovsky, *Tetrahedron* **41**, 575 (1985).

[2a] R. Bonaccorsi, E. Scrocco and J. Tomasi, *Theoret. Chim. Acta* **21**, 17 (1971); [b] J. P. Snyder, *Tetrahedron Lett.* 2451 (1972); [c] E. Haselbach, A. Mannschreck and W. Seits, *Helv. Chim. Acta* **56**, 1614 (1973); [d] W. A. Lathan, L. Radom, P. C. Hariharan and W. J. Pople, *Top. Curr. Chem.* **40**, 1 (1973); [e] C. A. Renner and F. D. Greene, *J. Org. Chem.* **41**, 2813 (1976).

[3a] R. G. Kostyanovsky, K. S. Zakharov, M. Zaripova and V. F. Rudchenko, *Tetrahedron Lett.* 4207 (1974); [b] R. G. Kostyanovsky, K. S. Zakharov, M. Zaripova and V. F. Rudchenko, *Izv. Akad. Nauk SSSR, Ser. Khim.* 875 (1975).

[4a] R. Ohme, E. Schmitz and P. Dolge, *Chem. Ber.* **99**, 2104 (1966); [b] A. T. Nielsen, D. W. Moore, R. L. Atkins, D. Mallori, J. DiPol and J. M. LaBerg, *J. Org. Chem.* **41**, 3221 (1976); [c] M. Schultz and G. West, *J. Prakt. Chem.* **312**, 161 (1970); [d] G. Geissler, I. Menz, H. Köppel, M. Kretschmer and S. Kulpe, *Ibid.* **325**, 995 (1983).

[5a] E. Bergmann, D. Herman and E. Zimkin, *J. Org. Chem.* **13**, 353 (1948); [b] R. O. Hutchins, L. D. Kopp and E. L. Eliel, *J. Am. Chem. Soc.* **90**, 7174 (1968); [c] S. F. Nelsen and P. J. Hintz, *Ibid.* **94**, 7108 (1972).

[6] C. J. Dippel, *Rec. Trav. Chim.* **50**, 525 (1931).

[7a] R. G. Kostyanovsky, A. E. Polyakov, G. V. Shustov, K. S. Zakharov and V. I. Markov, *Dokl. Akad. Nauk SSSR* **219**, 873 (1974); [b] R. G. Kostyanovsky and G. V. Shustov, *Ibid.* **232**, 1081 (1977); [c] H. Hakli, M. Mintas and A.

Mannschreck, *Chem. Ber.* **112**, 2028 (1979); [d]M. Mintas, A. Mannschreck and L. Klasinc, *Tetrahedron* **37**, 867 (1981); [e]R. G. Kostyanovsky, G. V. Shustov and N. L. Zaichenko, *Ibid.* **38**, 949 (1982).

[8a]H. P. Malone, Dissertation (1971); *Chem. Abstr.* **76**, 71880s (1972); [b]P. Rademacher and H. Koopmann, *Chem. Ber.* **108**, 1557 (1975); [c]H. P. Koopman and P. Rademacher, *Spectrochim. Acta* **32A**, 157 (1976); [d]G. B. Ansell, A. T. Nielsen, D. W. Moore, R. T. Atkins and Ch. D. Stanifer, *Acta Cryst.* **35B**, 1505 (1979).

[9a]V. G. Dashevsky, *Conformations of Organic Molecules*, p. 163. Khimiya (1974); [b]V. J. Baker, A. R. Katritzky and J. P. Majoral, *J. Chem. Soc. Perkin Trans. II* 1191 (1975).

[10a]D. Doskocilova and B. Schneider, *Coll. Czech. Chem. Commun.* **29**, 2290 (1964); [b]Y. Fujiwara and S. Fujiwara, *Bull. Chem. Soc. Japan* **37**, 1005 (1964); [c]W. B. Jennings, *Chem. Rev.* **75**, 307 (1975); [d]A. Gaudemer *Determination of Configurations by Spectrometric Methods* (Edited by H. B. Kagan), Vol. 1, p. 44. Georg Thieme, Stuttgart (1977).

[11a]D. K. Dalling and D. M. Grant, *J. Am. Chem. Soc.* **89**, 6612 (1967); [b]M. Christl, H. J. Reich and J. D. Roberts, *Ibid.* **93**, 3463 (1971).

[12]R. A. Y. Jones, A. R. Katritzky, K. A. F. Record and R. Scattergood, *J. Chem. Soc. Perkin Trans. II* 406 (1974).

[13]S. A. Hiller, Ya. Ya. Bleidelis, A. A. Kemme and A. V. Eremeyev, *J. Chem. Soc. Chem. Commun.* 130 (1975).

[14a]W. L. Jorgensen and L. Salem, *The Organic Chemist's Book of Orbitals*. Academic Press, New York (1973); [b]N. D. Epiotis, W. R. Cherry, S. Shaik, R. L. Yates and R. E. Bernardi, *Top. Curr. Chem.* **70**, 1 (1977).

[15a]M. Christl, *Chem. Ber.* **108**, 2781 (1975); [b]M. Christl, H. Leininger and E. Brunn, *J. Org. Chem.* **47**, 661 (1982).

[16]V. S. Mastryukov, E. L. Osina, L. V. Vilkov and R. L. Hilderbrandt, *J. Am. Chem. Soc.* **99**, 6855 (1977).

[17a]J. C. Rees and D. Whittaker, *Org. Magn. Reson.* **15**, 363 (1981); [b]A. A. Fomichev and R. G. Kostyanovsky, *Dokl. Akad. Nauk SSSR* **199**, 1110 (1971); [c]R. J. Abraham and G. Gatti, *Org. Magn. Reson.* **2**, 173 (1970).

[18a]R. J. Abraham, C. M. Holden, Ph. Loftus and D. Whittaker, *J. Chem. Soc. Perkin Trans. II* 1349 (1976); [b]H. Günter, W. Herrig, H. Seel, S. Tobias, A. de Meijere and B. Schrader, *J. Org. Chem.* **45**, 4329 (1980).

[19]E. L. Eliel, K. M. Petrusiewicz, *Topics in Carbon-13 NMR Spectroscopy* (Edited by G. C. Levy), Vol. 3, p. 171. Wiley, New York (1979).

[20]V. F. Bystrov, *Usp. Khim.* **41**, 512 (1972).

[21]F. R. Ahmed and E. J. Gabe, *Acta Cryst.* **17**, 603 (1964).

[22]G. J. Jordan and De L. R. Crist, *Org. Magn. Reson.* **9**, 322 (1977).

[23]M. Barfield and B. Chakrabarti, *Chem. Rev.* **69**, 757 (1969).

[24]S. F. Nelsen, P. J. Hintz and R. T. Landis, *J. Am. Chem. Soc.* **94**, 7105 (1972).

[25]R. Radeglia, *J. Prakt. Chem.* **318**, 871 (1976).

[26]P. E. Hansen, *Progress in NMR Spectroscopy*, Vol. 14, p. 175. Pergamon Press, Oxford (1981).

[27a]T. Yonezawa and I. Morishima, *J. Mol. Spectr.* **27**, 210 (1968); [b]W. B. Jennings, D. R. Boyd, Ch. G. Watson, E. D. Becker, R. B. Bradley and D. M. Jerina, *J. Am. Chem. Soc.* **94**, 8501 (1976); [c]V. M. S. Gil and J. J. C. Teixeira-Dias, *Molec. Phys.* **15**, 47 (1968).

[28]R. G. Kostyanovsky, G. V. Shustov, A. I. Mishenko and V. I. Markov, *Izv. Akad. Nauk SSSR, Ser. Khim.* 2026 (1976).

[29]P. G. Gassman and A. Fentiman, *J. Org. Chem.* **32**, 2388 (1967).

[30a]G. V. Shustov, S. N. Denisenko and R. G. Kostyanovsky, *Izv. Akad. Nauk SSSR, Ser. Khim.* 1930 (1983); [b]S. N. Denisenko, G. V. Shustov and R. G. Kostyanovsky, *J. Chem. Soc. Chem. Commun.* 1275 (1983).