The Crystal and Molecular Structure of Lappaconine Hydrobromide*

BY GEORGE I. BIRNBAUM

Biochemistry Laboratory, National Research Council of Canada, Ottawa, Canada

(Received 28 April 1969)

Crystals of lappaconine hydrobromide, $C_{23}H_{37}O_6N$. HBr, are orthorhombic, space group $P2_12_12_1$, with $a = 26 \cdot 194$, $b = 10 \cdot 160$, $c = 8 \cdot 809$ Å. Data were collected with an automatic Picker diffractometer. The structure was solved by the heavy-atom method and the refinement was carried out by the leastsquares procedure. All hydrogen atoms except one were located in a difference Fourier synthesis. The final *R* value is 0.050. The ring system of lappaconine is identical with that of lycoctonine. Two of the six-membered rings are in chair form, the other two are boat-shaped. One of the latter is stabilized by an intramolecular hydrogen bond which is part of a heterologous bifurcated hydrogen bond system.

Introduction

Lappaconine is a diterpenoid alkaloid of the aconite family which is obtained from the alkaline hydrolysis of lappaconitine. The latter was originally isolated from Aconitum septentrionale Koelle (Schulze, 1922). Khaimova, Mollov, Cerneva, Antonova & Ivanova (1964) established that the six oxygen atoms in lappaconine $(C_{23}H_{37}O_6N)$ appeared in three hydroxyl and three methoxyl groups and that an N-ethyl group was present in the molecule. The structure has been investigated by Marion and his colleagues since 1963, but certain reactions remained uninterpretable, thus precluding a conclusive elucidation of the skeleton and of the positions of the oxygenated substituents. The difficulties were partly due to the presence in lappaconine, hitherto unknown in this class of alkaloids, of oxygen functions attached to C(4) and C(9). The complete structure (I) was first reported in a preliminary communication (Birnbaum, 1969).



Experimental

Crystal data

Lappaconine hydrobromide, $C_{23}H_{37}O_6N.HBr$; F.W. 504.5. Orthorhombic:

$$a = 26 \cdot 194 \pm 0.003 \text{ Å}$$

$$b = 10 \cdot 160 \pm 0.003 \text{ Å}$$

$$c = 8 \cdot 809 \pm 0.003 \text{ Å}$$

$$V = 2344 \cdot 3 \text{ Å}^{3}$$

$$D_{x} = 1 \cdot 429 \text{ g.cm}^{-3}$$

$$D_{m} = 1 \cdot 43 \text{ g.cm}^{-3}$$

$$Z = 4$$

$$\mu = 36 \cdot 8 \text{ cm}^{-1} (\text{Cu } K\alpha), F(000) = 1064$$

Absent reflexions: h00 when h is odd, 0k0 when k is odd, 00l when l is odd. Space group: $P2_12_12_1$.

The crystals were obtained from a mixture of ethanol and petroleum spirit. They were colourless prisms elongated in the direction of the *b* axis, with a diamondshaped cross-section. At first, the data were recorded with an equi-inclination Weissenberg camera, using the multiple-film technique and nickel-filtered Cu $K\alpha$ radiation ($\lambda = 1.5418$ Å). The crystals were deteriorating as a result of X-ray exposure and thus it was necessary to use two of them in order to collect the zones hol to h8l and another one to collect hk0 to hk5.

Subsequently a Picker automatic diffractometer became available, and the data were remeasured with this instrument. The cell dimensions were determined at 1° take-off angle with a 0.02° slit, assuming $\lambda = 1.54051$ Å for Cu $K\alpha_1$ and $\lambda = 1.54433$ Å for Cu $K\alpha_2$. All results reported here are based on diffractometer data. Two crystals were used, each having been cut to a size of $0.09 \times 0.09 \times 0.28$ mm. Monochromatization was achieved by a nickel filter and a pulse-height analyzer. The moving-crystal, moving-counter method $(\theta/2\theta \text{ scan})$ was used. Of the 2291 reflexions accessible to the diffractometer $(2\theta \le 130^\circ)$ 1854 (81%) were observed. They were indexed with respect to a righthanded set of axes. In view of the crystal size a correction for absorption was considered unnecessary.

Structure determination

The structure was solved with the photographic data by the use of the heavy-atom method. After applying Lorentz and polarization corrections all the values of F^2 were correlated by the method of Hamilton, Rollett & Sparks (1965), using a program obtained from Dr Sparks. The atomic scattering factors for Br- were those given by Cromer (1965) and Cromer & Waber (1965), the values of Hanson, Herman, Lea & Skillman (1964) were used for C, N, and O, and those of Stewart, Davidson & Simpson (1965) for bonded H. The bromide ion was found at (0.187, 0.095, 0.061) in a threedimensional Patterson map. The whole structure was revealed after several rounds of structure factor calculations and Fourier syntheses. After three cycles of isotropic refinement by least-squares calculated with the block-diagonal approximation the value of R dropped to 23%. At this point the data were abandoned and refinement was continued with the diffractometer data.

The function minimized was $\sum w(F_o - F_c)^2$. A partial shift factor of 0.8 was applied in each cycle. A correc-

tion for both the real and the imaginary parts of the anomalous scattering of the bromide ion was applied during the refinement. After four cycles of isotropic refinement R was reduced to 18.4%. At this stage anisotropic thermal parameters were assigned to all 31 atoms and a further four cycles of least-squares refinement lowered R to 7.9%. A difference Fourier synthesis (Fig. 1) calculated at this point revealed the positions of all hydrogen atoms except the one attached to O(3). The map also showed two peaks close to the bromide position which, along with two negative regions, formed a cross pattern indicative of incomplete refinement of anisotropic temperature parameters of that ion. The only other peak higher than $0.25 \text{ e. } \text{Å}^{-3}$ was near the position of O(6) and was attributable to a free pair of electrons. The contributions of the 37 hydrogen atoms were included in the next three cycles of refinement, but their parameters were not refined. Af-



Fig. 1. Difference Fourier synthesis showing hydrogen atom positions. Contours begin at 0.25 e.Å⁻³ and are drawn at intervals of 0.10 e.Å⁻³

ter that another three cycles of least-squares were calculated during which only the hydrogen atom parameters were being refined. All the shifts decreased to less than 0.65σ , the average being 0.18σ . Until this stage unobserved reflexions were excluded from the refinement. In subsequent cycles those for which $F_o(=F_{th}) < F_c$ were included. The threshold values were obtained by assigning net intensity counts of 40 or 10% of the background, whichever was higher, to those reflexions whose intensities were below these thresholds. The following weighting scheme was introduced and kept until the end of the refinement:

where

or

$$\sqrt{w} = \sqrt{w' [1/(2 - 0.85 \sin^2\theta)]^{1/2}}$$

$$\sqrt{w'} = (|F_o|/25)^{1/6}$$
 when $|F_o| \le 25$

$$=(25/|F_o|)^{1/2}$$
 when $|F_o| > 25$

Five more cycles in which the parameters of the nonhydrogen atoms were refined led to convergence. A total of 19 cycles of least-squares had been calculated with the diffractometer data.

At the end of the last cycle the average coordinate shift was 0.1σ and the maximum shift equalled 0.37σ . The final agreement index calculated for 1926 reflexions (1854 observed and 72 unobserved with $F_o < F_c$) was 5.0%. The final coordinates of non-hydrogen atoms

and their temperature parameters are listed in Table 1. The coordinates of the hydrogen atoms are given in Table 2. The estimated standard deviations were derived from the inverse of the least-squares matrix. Observed and calculated structure factors are shown in Table 3. A summary of the agreement between these values can be found in Table 4. Bond lengths and angles are listed in Tables 5 and 6 respectively.

Table 2.	The final	parameters	(and their	<i>e.s.d.</i> ' <i>s</i>)	of	the
	-	hydrogen a	atoms		-	

	$10^{3}x/a$	$10^{3}y/b$	$10^{3}z/c$	В
H(11)	316 (2)	583 (7)	724 (8)	3.5 Å2
H(21)	243 (4)	697 (10)	714 (12)	6.8
H(22)	238 (4)	566 (10)	583 (13)	8.9
H(31)	251 (4)	836 (11)	518 (13)	10.3
H(32)	210 (3)	729 (8)	444 (10)	4.9
H(51)	283 (2)	492 (6)	388 (7)	1.9
H(61)	327 (2)	592 (8)	127 (8)	3.5
H(62)	351 (3)	451 (7)	198 (8)	3.7
H(71)	407 (2)	652 (5)	203 (6)	0.2
H(101)	345 (2)	405 (7)	596 (8)	3.4
H(121)	407 (2)	581 (7)	726 (8)	3.6
H(122)	397 (3)	432 (7)	789 (9)	3.9
H(131)	474 (2)	426 (7)	735 (8)	3.0
H(141)	428 (2)	267 (6)	620 (7)	1.5
H(151)	503 (3)	498 <u>(</u> 7)	325 (8)	3.0
H(152)	479 (3)	631 (7)	345 (8)	3.4
H(161)	480 (3)	656 (7)	588 (9)	3.8
H(171)	403 (2)	699 (6)	499 (7)	2.2
H(181)	297 (3)	890 (8)	318 (8)	3.7

Table 1. The final parameters (and their e.s.d.'s) of the non-hydrogen atoms

1

1

The anisotropic temperature parameters are defined by

 $\exp\left[-2\pi^{2}(U_{11}h^{2}a^{*2}+U_{22}k^{2}b^{*2}+U_{33}l^{2}c^{*2}+2U_{23}klb^{*}c^{*}+2U_{31}lhc^{*}a^{*}+2U_{12}hka^{*}b^{*})\right].$

		• ••							
	$10^4 x/a$	10 ⁴ y/b	$10^{4} z/c$	10 ³ U ₁₁	$10^3 U_{22}$	10 ³ U ₃₃	$10^3 2U_{23}$	$10^3 2U_{13}$	$10^3 \ 2U_{12}$
C (1)	3127 (3)	6509 (6)	6459 (8)	39 (3)	38 (3)	56 (4)	24 (6)	33 (7)	- 14 (6)
$\tilde{C}(2)$	2576 (3)	6694 (12)	6187 (13)	52 (5)	118 (8)	86 (7)	-14 (13)	21 (10)	35 (10)
$\tilde{C}(3)$	2430(3)	7319 (10)	4744 (13)	48 (5)	88 (6)	112 (8)	57 (13)	39 (10)	60 (9)
C(4)	2747 (3)	6936 (7)	3359 (10)	40 (4)	40 (4)	71 (5)	17 (8)	- 34 (7)	7 (6)
$\tilde{C}(5)$	3063 (2)	5680 (6)	3670 (9)	38 (3)	32 (3)	64 (4)	20 (6)	- 16 (6)	-3 (5)
C(6)	3431 (3)	5463 (7)	2340 (9)	60 (4)	35 (3)	51 (4)	2 (7)	- 34 (7)	22 (6)
$\tilde{C}(7)$	3942 (2)	6038 (6)	2879 (7)	45 (3)	37 (3)	28 (3)	18 (6)	6 (5)	2 (6)
$\tilde{\mathbf{C}(8)}$	4322 (2)	4913 (6)	3267 (7)	39 (3)	36 (3)	33 (3)	9 (6)	0 (6)	2 (5)
$\tilde{C}(9)$	4061 (2)	3939 (6)	4422 (8)	40 (3)	29 (3)	40 (3)	-6(6)	-5 (6)	-4 (5)
$\tilde{\mathbf{C}}(10)$	3709 (2)	4668 (5)	5595 (8)	39 (3)	27 (3)	37 (3)	10 (6)	18 (6)	-11 (5)
$\tilde{\mathbf{C}}(11)$	3414(2)	5910 (6)	5053 (7)	28 (2)	28 (3)	42 (3)	16 (6)	-2 (5)	-2 (5)
$\tilde{C}(12)$	4066 (2)	4944 (7)	6955 (8)	40 (3)	44 (4)	39 (4)	8 (6)	13 (6)	7 (6)
$\tilde{C}(13)$	4603 (2)	4484 (6)	6484 (7)	45 (4)	34 (3)	30 (3)	8 (5)	- 19 (6)	9 (5)
$\tilde{C}(14)$	4459 (2)	3315 (6)	5488 (7)	43 (3)	33 (3)	30 (3)	10 (6)	3 (6)	-13 (5)
C(15)	4840 (2)	5453 (6)	3914 (8)	42 (3)	33 (3)	50 (4)	2 (6)	5 (6)	2 (5)
C(16)	4904 (2)	5539 (6)	5623 (8)	33 (3)	45 (4)	45 (4)	-1(7)	7 (6)	-2 (5)
$\tilde{C}(17)$	3804 (2)	6822 (6)	4281 (7)	38 (3)	31 (3)	31 (3)	1 (6)	7 (5)	1 (5)
Č(18)	3109 (3)	8046 (7)	2907 (8)	56 (4)	34 (3)	50 (4)	-1 (6)	-22(7)	20 (7)
C(19)	3945 (3)	9151 (7)	3329 (8)	68 (4)	34 (3)	47 (4)	8 (7)	41 (7)	- 19 (7)
C(20)	4346 (3)	9473 (7)	4451 (11)	53 (4)	44 (4)	91 (6)	- 26 (9)	63 (9)	- 37 (7)
$\tilde{C}(21)$	3272 (5)	8096 (11)	8380 (12)	129 (9)	78 (7)	78 (7)	- 66 (12)	80 (14)	- 36 (13)
$\tilde{C}(22)$	5196 (3)	2019 (7)	5606 (10)	52 (4)	47 (4)	63 (5)	-1(8)	19 (8)	35 (7)
$\tilde{C}(23)$	5756 (3)	6367 (9)	5497 (12)	46 (4)	69 (5)	90 (7)	-1(11)	-17 (9)	-33 (7)
N(1)	3568 (2)	8148 (5)	3930 (6)	47 (3)	25 (2)	41 (3)	-5 (5)	15 (5)	-3 (4)
0(1)	3401(2)	7642 (5)	6929 (6)	69 (3)	56 (3)	52 (3)	- 16 (5)	46 (5)	-25 (5)
$\tilde{O}(2)$	2439 (2)	6631 (5)	2097 (8)	65 (4)	47 (3)	115 (5)	17 (7)	- 82 (7)	11 (5)
$O(\overline{3})$	4429 (2)	4239 (5)	1907 (5)	59 (3)	47 (3)	34 (2)	- 16 (4)	15 (4)	12 (5)
O(4)	3807 (2)	2963 (4)	3567 (6)	54 (2)	33 (2)	46 (3)	0 (4)	-5(4)	- 19 (4)
$\tilde{O}(\tilde{s})$	4856 (2)	2706 (4)	4652 (5)	48 (2)	40 (2)	49 (3)	10 (5)	13 (4)	32 (4)
ŌĠ	5433 (2)	5342 (5)	6012 (7)	40 (2)	52 (3)	81 (4)	12 (6)	- 26 (5)	-11 (4)
Br ⁻	1874.3 (4)	9060 à (8)	614.2 (14)	83.7 (7)	36.8 (3)	114·0 (8)	25.6 (11) -100.1 (1	2) 1.3 (8)

	Table 2 (con	nt.)	
$10^{3}x/a$	10 ³ y/b	$10^{3}z/c$	В
H(182) 326 (2)	782 (5)	195 (6)	0·7 Ų
H(191) 407 (2)	877 (6)	244 (7)	1.6
H(192) 369 (2)	1002 (6)	297 (7)	2.3
H(201) 423 (2)	949 (7)	557 (9)	3.5
H(202) = 464(3)	873 (8)	454 (10)	4.7
H(203) 451 (3)	1013 (8)	421 (10)	5.4
H(211) 300 (4)	862 (10)	849 (12)	9.7
H(212) 349 (3)	875 (7)	871 (9)	4.0
H(213) 324 (4)	733 (11)	923 (12)	8.5
H(221) 541 (3)	260 (8)	605 (9)	4.0
H(222) 498 (2)	157 (7)	658 (8)	2.8
H(223) 542 (3)	144 (7)	507 (9)	4.5
H(231) 605 (4)	628 (11)	619 (13)	9.1
H(232) 580 (3)	631 (9)	426 (11)	6.1
H(233) 560 (4)	726 (10)	571 (12)	8.5
H(N1) 342 (3)	842 (8)	465 (9)	5.2
H(O2) 235 (3)	736 (8)	171 (10)	5.3
H(O4) 360 (2)	254 (6)	429 (7)	2.2

The mean e.s.d. of B is 1.9 Å^2 .

Discussion of the structure

The ring system of lappaconine (I) is very similar to that of heteratisine (Przybylska, 1965) and it is identical with that of lycoctonine (Przybylska, 1961*a*), demethanolaconinone (Przybylska, 1961*b*) and delcosine (Marion, 1963). A perspective view of the molecule can be seen in Fig.2. Six rings can be easily discerned and are designated A to F. They are fused to one another as follows: A/C, cis; B/D, cis; D/E, cis; D/F, cis. The six-membered rings A and F are in boat conformations, the other two six-membered rings (B and D) are in chair forms. One five-membered ring (C) is a half-chair while the other (E) is envelope-shaped.

The azabicyclo[3,3,1]nonane system of rings A and B is similar to other systems which have recently been described (Tamura & Sim, 1968). It has been found

(Webb & Becker, 1967) that the simple saturated bicyclo[3,3,1]nonane compounds adopt a twin-chair conformation, with both chairs flattened. Such a conformation was found in lycoctonine hydriodide, but in the present structure, as well as in delcosine hydrobromide and heteratisine hydrobromide, ring A is a strained and flattened boat. There are two reasons for this: the formation of an intramolecular hydrogen bond between N(1) and O(1) and the avoidance of the very close contact between O(1) and C(12) which would be present if ring A was a chair. In lycoctonine, in which the methoxy group is epimeric at C(1), these reasons do not apply. The ring is considerably flattened at C(2) and C(3), as shown by greatly increased bond



Fig. 2. A perspective view of lappaconine.

0

С

N



 $C(7)-C(17)-C(11)-C(5) = -51^{\circ}$ $C(17)-C(11)-C(5)-C(6) = +43^{\circ}$



Table 3. Observed and calculated structure factors ($\times 10$)

An asterisk following $10F_o$ indicates an unobserved reflexion to which the estimated threshold value was assigned.

· FU FC ALPHA	K [FC] [FC] ALPHA	* [FO] +C = &LPHA	R FO - FC 41 PHA	* F0 FC ALPHA	K FO FC &LPHA	FO FC ALPHA	* FO FC ALPHA
H4 C, L4 C 2 314 311 3.98 4 371 305 145.83 6 652 641 143.74 8 418 432 170.96 10 339 366 4.25 H4 1.14 C	3 175 156 P4.4C 4 020 592 272.46 5 487 453 271.61 6 177 163 54.27 1 122 123 87.10 8 177 183 92.12 6 57 55 55 10 193 181 92.28 11 152 197 61.69	* 81 89 278.68 2 * 1* * 3 277.60 7 10* * 3 277.60 7 2 * 18 5 273.87 * 7 2 * 1 * 0 0 287 287 182.91 ' 1 68* 54 0.60 2 68* 25 162.58	3 528 514 107.10 6 005 515 237.40 5 204 201 327.47 0 407 451 271.40 7 310 311 42.32 P 67. 77 150.65 9 181 176 106.73 10 123 116 161.13 11 116 117 211.65	C 58* 17 278.49 1 123 14C 211.96 2 36# 37C 352.88 2 264 201 352.88 2 264 40 314.75 3 265 365 177.74 4 460 40 314.75 3 265 365 177.74 4 60 105 188.75 7 118 105 238.75 8 00 104 140.15	9 467 411 61.38 10 102 100 6.45 11 178 192 94.68 44 1.12 2 0 118 97 199.68 1 979 962 64.15 2 677 671 225.57 3 646 616 0.10	1 167 148 270,04 5 16 514 227.45 3 751 360 373,80 5 404 411 200,67 6 114 117 185.04 7 241 236 167.01 6 174 181 131.13 5 207 221 138.27 10 73 54 75.87	0 126 134 164.02 1 90 Ac 109455 2 167 1c9 128.07 3 113 133 170.00 4 674 92 11.69 5 137 144 251.42 6 61 54 326.60 7 61 48 291.59 Hz 24.14 2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	He 7, 14 1 0 344 7 310,05 1 543 50 205,01 2 800 852 05,01 3 405 597 15,07 4 645 597 15,07 4 645 471 40,77 6 454 471 40,77 6 454 441 273,37 7 366 302 5,11 8 409 406 178,71 9 118 131 264,64	4 102 173 322.17 H= 10, 102 173 322.17 C 445 444 92.11 1 41 147 144.35 2 107 144 1149.25 3 259 343 170.90 4 220 215 109.79 € 102 116 79.89 C 70 72 291.44 € 238 65 303.94	3 647 648 6.56 4 67 478 235.69 5 468 522 261.69 3 76 68 532 261.69 7 76 68 534.67 8 237 239 141.29 9 244 257 165.45 10 66* 68 76.65 11 110 14* 116.25 14* 2, 14* 2 9 423 411 350.23	10 19 24 124 14 124 12 2 1 411 461 27.63 2 513 526 98.62 3 739 737 30.56 4 162 206 121.61 5 137 274 223.72 7 7351 374 186.42 7 351 374 186.43	c 0 195,23 1 177 207 283,14 2 0.7* 56 61,69 3 121 134 250,47 4 05 73 068,30 5 124 116 137,67 6 96 913,167 7 0.62 54 14* 255,14* 2 0.125 2.0
r- 2, L* C C 244 267 188.44 1 420 437 177.53 2 1962 1062 350.17 3 779 757 2.45 4 846 R17 1.42 4 202 162 1.05 6 245 2.16 7.11 7 3'7 3'7 181.49 6 212 216 7.11 7 3'9 3'7 181.49	10 52 0 190.00 H 13, L 0 1 187 165 255.67 2 503 444 03.82 3 56 86.61 4 105 780 44.61 5 201 145 272.65 6 201 212 272.65 7 80 772.97	6 57+ 16 84.68 H+ 26.14 0 0 125 127 3.74 1 00 37 155.63 1 00 37 155.63 3 175 117 185.85 4 112 97 157.85 4 112 97 117 185.75 5 48 61 185.72	10 199 100 144.18 11 57* 50 83.02 H* 8.1* 1 0 60 50 83.02 1 578 517 125.07 2 616 607 196.76 3 773 776 119.42 4 333 340 187.80 5 103 83 274.98 • 171 10 327.35	9 123 126,238.86 ++ 19, 1+ 1 C 283 284 271.97 1 256 266 216.67 2 185 165 761.59 3 76 73 341.21 4 250 235 88.51 5 215 226 337.57 6 118 136 73.96 7 169 164 338.67	1 1056 1042 321.76 2 946 948 140.40 3 648 627 314.76 4 368 353 344.51 5 497 487 485 345.45 7 433 450 135.69 8 343 364 268.47 9 68* 22 205.86 10 246 258 227.24 11 120 120 315.14	10 274 176.24 10 83 78 705.72 H= 13.4 2 2 1 23 14.4 2 2 1 242 234 146.47 2 3 3.4 4.4 170.49 4.71.07 4 10 147 146.17 146.17 146.17	82 F0 [7:220 1 235 245 332.50 2 F1 114 226.60 3 65* 70 [47,499 4 83 77 [36,72 8 84 92 1194.31 6 98 80 101.62 H+ 260.L+ 2 0 604 25 18.54 1 654 51 155.27
C 68* 3P 210,42 IC 256 265 183.61 I1 129 12* 1.61 P* 3. L* C 1 839 76# 271.29 2 544 655 93.03 3 309 297 269.21 4 114 117 91.71	H 251 26 273.44 9 66 26 100.20 10 53 3 32 281.22 H* 14, 1* 0 0 793 777 161.91 1 521 489 181.66 2 522 15 320.55 3 511 544 182.47	HE 27. LE 0 L 65* 55.266.82 2 201 209 772.10 3 76 67 89.44 4 59* 51 276.64 5 55 53 273.37 HE 28. LE 9	7 340 335 276,50 8 07- 31 25.02 0 316 324 233,77 10 84 110 7#0,30 11 0 45 10.03 ++ 9, L+ 1 0 612 012 270.93	e 102 124 7.68 4 110 115 168.67 H= 20. L4 1 C 120 124 281.26 1 129 142 154.54 2 98 94 256.77 3 89 95 37.46	με 3, L* 2 0 1065 1077 0.63 1 417 419 165.50 2 580 592 103.72 3 842 659 142.71 4 307 319 204.63 5 161 192 131.52 6 231 240 273.54 9 165 163 277	7 213 326 46.13 F 1F4 712 222.63 9 111 121 344.06 10 60 88 200.00 H= 14. (+ 2 0 105 111 353.18 1 106 114 254.02 2 77 4H 228.55	2 195 105 312-21 3 11P 120 225.40 4 147 103 220.78 5 03 70 8.03 +* 27, L* 2 C 71* 27 0.60 1 104 75 145.38 2 02 71 244.51
5 273 224 43.84 6 27 604 271.50 7 240 231 62.05 8 522 522 233.70 9 242 522 523 273.50 10 212 216 772.59 11 164 177 272.74 14 6, L4 0	4 004 401 2.34 5 360 324 160.68 6 370 300 3.56 7 54 2010 3.56 7 54 20130 3.56 8 68* 15 0.15 9 155 156 4.34 10 125 146 18*67 H= 15, L* 0	0 155 140 174.45 1 62+ 20 145.67 2 61+ 17 0.32 3 55 44 9.47 4 55+ 33 180.60 He 25. 137 91.05	1 491 406 704,99 2 833 776 147,14 3 103 91 13,14 4 264 257 160,77 5 141 139 266,93 7 419 405 53,41 8 303 309 4,91 9 186 187 113,26 19 186 187 113,26 1 12,178	+ 21, L+ 1 C 233 227 91.42	4 4.21 1.21 2.5 6.5 6 2.22 304 5.22 10 100 150 331.65 11 56 100 2.7.17 H= 4. L= 2 0 558 568 0.23 1 6.32 6.33 180.40	3 +23 +27 159.60 4 124 145 52.70 5 286 306 76.16 7 147 14.74 7 121 272 89.30 8 10 16 127.73 6 157 159 377.59 10 67 86 164.20 11 17	3 00* 43 51.10 4 5* 34 271.54 5 73 59 290.01 H= 28.1* 2 0 120 116 1P1.31 1 99 71 331.67 2 5P* 41 115.00 3 08 87 59.42
C 12P 134 140.00 1 Gel G45 358.12 2 387 361 180.00 3 713 732 144.05 4 241 232 0.0 5 448 14 324.59 6 7 67 0.08 7 653 653 2.92 8 66* 57 179.88 9 30(9 30(5.502)	1 505 475 273.13 2 115 113 273.83 3 401 580 260.15 4 1C8 98 274.65 5 372 349 94.20 6 235 213 91.10 7 243 277 93.74 9 232 224 272.54 10 55* 51 92.41	2 130 156 52.20 3 48 17 88.33 4 83 100 92.55 H+ ⁹ C, LF 0 C 133 110 182.32 1 54 48 35.44 2 101 10C 358.97 H= C 1 1	11 50 39 254-14 He 10, L# 1 0 41 95 290-44 1 730 641 305-86 2 488 472 305-81 3 319 330 303-15 4 399 397 117.07 5 359 340 214.00 6 357 357 93.21	1 152 152 334.43 2 125 12C 80.00 3 117 131 177.17 4 226 205 9.61 5 156 154 223.14 6 88 9 68.45 7 104 132 175.97 6 1C5 86 20.21 H= 22. L= 1	2 1127 1128 266.63 3 565 561 150.87 4 528 511 320.64 5 428 440 168.49 6 285 289 168.49 7 99 128 11.68.78 8 138 146 65.56 9 224 224 5.51 10 108 129 96.66 11 56* 50 187.27	He 1: L* C 0 487 496 2,67 1 252 159 298.22 2 160 142 266.03 84 95 33.61 4 72 381 203.66 5 553 77.61 6 172 186 137.11 7 177 160 92.64 8 137 142 68.67	4 74 of 12,94 H= 29, 14 2 0 -56* 19 194,06 1 56* 39 161,21 2 61 -51 05,82 3 57 64 237,23 H= 30, 14 2
10 245 27 190.00 11 057 74 183.03 14 55 6 7 183.03 14 55 6 7 183.03 14 50 51 192 271.44 5 1511 192 271.45 5 205 192 71.48 5 205 192 71.58 5 205 71.58 5	He lb, L+ 0 0 790 765 2.36 1 55+ 16 180.0C 2 50+ 37 18.23 3 190 183 180.07 4 335 310 183.76 5 148 143 180.17 6 87 74 187.80 8 170 184 197.63 9 15 2.6 10 18 197.63 9 15 2.6 10 78 197.65 10 78 197.55 10 78 197.55 10 78 197.55 10 78 197.55	1 69 86 289.72 2 63 530 2.65 1 40 150 289.84 4 175 178 4.58 4 77 178 4.58 14 95 183.60 5 52 69.16 14 95 183.60 5 52 69.16 6 78 183.60 11 176 182 271.84	7 600 340 102.42 B 123 125 734.56 9 121 215 734.56 10 181 215 86.71 10 181 149 21.64 11 106 117 794.64 H 111.L* 1 0 277 202 01.10 1 476 467 19.77 2 '370 349 1.55 3 324 244 334.11	0 364 377 91.01 1 130 121 254.65 2 163 156 28.94 4 153 156 28.94 4 153 167 286.94 5 167 167 286.94 7 151 157 255.42 7 151 132 65.42 9 37 255.42 7 151 136 65.24 9 38 25 212.62 He 23.14 1 0 186 167 90.13 0 186 167 90.13	He S. L. Z 0 154 170 5.4 C 1 651 600 61.50 2 631 655 456 4 605 542 255 5 127 135 53.21 6 3.46 3.47 161.48 7 207 193 170.47 8 2.67 297 194.79 10 92.8 86.45 4.46	G 170 141 265-47 10 75 53 30-01 HF 16. L= 7 C 426 423 2.63 1 234 746 70.10 2 175 144 7.50 3 130 149 A4.53 4 6.4 75 273.45 5 155 143 275.455 6 170 163 778.26 8 #C 105 788.26	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
10 141 154 05.43 11 142 154 272.73 14 142 154 272.73 15 0.14 C 0 063 083 -3.19 1 574 533 2.25 2 354 41100.11 3 914 874 2.22 4 49 22 552.96 5 200 188 1.80 0 711 076 157.30	H+ 17. L+ 0 1 192 104 66.55 2 59 59 20201 3 122 138 272.00 4 63* 61 276.01 5 523 468 272.54 c 103 184 91.01 7 102 178 275.52 8 65* 38 101.07 9 152 156 93.65	++ 1. L = 1 (: :50 *15 268.44 1 :40 :40.13 2 :50 :13 36.05 3 :17 :705 :44.10 4 :40 :44 :41 5 :47 :174.72 :321 7 :41 :155 :150.62 6 :10 :171.73 :171.73 6 :22 :227.25 :227.25	5 355 346 142,47 6 126 128 277,13 7 206 207 224,45 8 113 110 337,43 9 75 79 328,00 10 121 167 128,45 11 184 183 6,39 H= 122, L= 1 C 896 685 92,42 1 186 144 61,73 2 334 95,61	1 140 147 147,78	11 37* 00 47.27 H* 0, L* 2 0 003 002 2.09 1 745 725 90.11 2 391 377 346.46 3 120 112 149.41 4 328 120 149.23 5 439 423 246.52 6 450 461 240.549 7 258 253 241.63 8 95 111 256.11	H 17. L 2 107 91 65.41 H 17. L 2 100 165.70 1 164 168 74.20 2 115 170 218.24 4 294 246 377.06 5 366 375.25 6 84 96 127.26 7 134 124 129.75	q 156 147 97.54 10 64 26 198.57 11 55* 18 26*.89 #* 1.1 18 26*.89 #* 1.1 40 11 55* 18 7.67 12 74.0 *1.07 13 640 474 14 47 *7.07 2 660 474 3 640 *24 3 640 724 3 640 310 3 540 310
7 410 306 143.4 8 192 176 176.47 9 221 226 164.9 10 114 9 10.60 11 78 64 176.87 H= 7, L= C 1 891 877 92.59 2 98 117 98.71 3 725 717 270.71	H+ 18, L= C 0 237 239 184-50 1 293 296 2.11 3 70 -0 28.C 4 184, 178 3.87 5 678 30 6.15 6 68 54 14.42 7 340 352 141.42	11 111 145 8.84 He 2, 14 1 C 2503 20C0 60,00 1 768 761 716.32 2 372 349 71.12 3 1306 1459 80.10 4 398 399 254.27 5 207 311 42.53	3 248 242 21.68 4 16 444 293.77 5 217 274 24.44 6 609 592 259.10 7 82 82 358.67 8 97 74 102.99 9 60* 48 113.92 10 150 14C 108.96 H= 13. L= 1	3 F9 BE 40.02 4 Co+ 2E B0.15 5 71 7E 20.54 6 60* 27 136.30 7 181 17C 285.39 H* 25, L* 1 0 56 112 87.83 1 162 177 211.02 2 169 176 185.64	 \$ 190 210 170.15 \$ 2*6 236 6.60 \$ 11 69 70 55.84 \$ 7, L* 2 \$ 0*6 676 1#2.67 \$ 492 113.74 \$ 235 239 95.57 \$ 372 361 100.45 \$ 462 412.44 	P 64* 38 175.47 G 57* 102 123.49 H* 16, 1* 7 Q 233 331 187.791 1 87 109 304.11 2 764 226 104.60 3 194 164 209.70 4 197 166 64.51 5 207 306 51.61	7 215 225 200,26 # 246 243,190,56 9 9 241 237 266,21 10 64* 37 76,13 11 39 12 232,08 Hx 2+ 1* 3 0 310 315 247.95 1 364 357 184.95
4 443 444 267.47 5 51 42 341.64 6 PC 91 273.83 7 179 165 270.51 8 236 226 273.15 9 352 92.48 17 66* 41 85.11 11 324 312 53.69 H* A.L* C	8 85 11 163.23 6 110 90 185.76 1 208 278 272.08 2 368 365 93.20 3 102 91.63 4 105 94 68.76 5 190 165 267.37 6 180 171 272.28	7 347 353 528.00 8 146 164 300.45 9 177 164 232.17 10 297 297 89.02 11 60 52 149.01 H= 2, L= 1 C 4C 61 61.14 1 67.6 891 197.15	0 53 73 279-18 1 350 365 141.69 2 503 574-366.00 3 450 448 75.30 4 204 210 6.42 5 503 593 0.21 6 91 81 347.65 7 105 100 324.94 8 113 110 6.09 9 202 255 194.98	3 88 1C1 300.16 4 04 47 160.97 5 01* 51 316.86 6 50* 51 354.84 H* 20, 1* 1 C 67* 18 293.10 1 115 11C 49.00 2 60* 35 267.71 3 72 67 255.69	5 666 674 246.59 6 523 540 354.26 7 251 256 326.72 8 96 95 312.63 9 118 136 29.43 10 233 271 169.29 11 87 99 53.53 H= 8, L= 2 0 219 241 187.68	C 251 222 11.40 7 17C 107 135.6P 9 54* 31 107 233.5P 9 54* 31 107.90 9 101 103 C-36 1 219 216 247.97 2 247 242 113.53 3 146 146 172.30	210 211 24.4 24.7 24.3 27.4 4 224 43.7 24.3 27.4 27.4 27.4 5 37.7 356.35% 27.4
() 776 757 183.79 1 455 466 179.99 2 1124 10°C 18°.95 3 217 2°C4 0.05 4 755 771 2.49 5 64 74 C.10 6 627 617 3.33 7 63* 52 0.0 8 89 74 180.21 5 6* 14 180.89 17 222 200 186.42 11 46* 47 18'5.21	7 156 156 41.43 8 210 13 274.30 9 72 64 272.78 H+ 20, L+ 0 0 204 202 359.94 1 157 140 163.91 2 162 147 359.94 3 552 546 182.15 4 126 127 180.00 5 269 275 180.74	2 173 19 36 100.15 3 218 364 104.55 4 240 257 164.75 5 460 475 3.71 6 714 355 118.69 7 278 242 17.22 8 242 25 248.44 9 106 200 139.45 10 c 7* 30 221.16 11 140 125 162.67 He 4, L= 1	H* 14. L* 1 C 310 327 274.33 1 326 327 51.46 2 60 57 187.27 3 418 426 86.61 4 289 281 190.27 5 112 99 181.60 6 64* 18 37.69 7 140 133 261.29	4 e ⁻⁰ 66 153.78 5 82 74 234.89 6 58* 27 115.82 H* 27, L= 1 C 64* 26 256.82 2 116 114 347.82 2 155 144 31.13 3 555 16 66.39 101 116 319.24 4 97 162.08	1 289 260 275.57 3 329 318 125.18 3 062 050 277.77 4 761 752 338.60 5 572 565 77.60 6 263 260 330.50 7 172 179 75.25 8 96 90 215.51 9 222 229 330.31 10 184 171 200.70 11 181 182 257.41	4 107 66 310.37 5 167 175 176,67 6 187 175 176,67 6 187 175 376.11 7 92 92 62.76 8 +00 54 244.96 6 35 11 3.6 ⁴ H* 2C.1 - 7 C 65* 35 177.19 1 746 267 741.23 2 2 244.26.71	He 3. [1 * 3 C 466 439 274.95 1 127 156 110.79 2 551 535 745.67 3 455 467 344.72 4 411 127.61 5 182 173 320.24 6 547 554 65.08 7 4.7 556 67.20 P 151 130 311.93 9 159 173 126.21
HT 0, L4 C 1 1054 1043 272.01 2 400 16 161.03 3 600 15 00.77 4 387 376 61.79 5 372 362 66.78 6 773 262 67.76 6 773 262 271.41 7 451 475 92.07 # 220 211 273.12 5 600 52 283.20	6 127 121 170,40 7 122 134 5,66 8 600 7 176,66 9 48 62 9,70 1 317 312 271,20 2 110 105 270,20 3 75 66 91,19 4 281 280,72,36 5 100,8 117 9,18	1135 1144 272.54 1324 725 370.08 2355 327 212.19 324 325 327 4 825 727 73.63 5 721 72.74 85 7 725 756 45.95 7 72.75 566 45.95 7 72.75 76.74 75.75 7 72.75 756 45.95 7 72.75 76.74 75.75 10 73 25.77 71.74 11 79 71.57 71.47	c 170 177 41.22 9 203 171 284.78 10 94 114 280.54 W- 15. L+ 1 0 345 382 260.84 1 273 267 331.62 2 466 417 187.13 3 176 165 264.67 1 5 280 273 201.55 6 219 210 306.44	M* 28. L* 1 C 123 134 63.39 1 61 65.137.84 2 85 74.300.64 3 52* 51.284.53 4 54* 51.284.53 4 54* 11.0 ** 29. L* 1 C 58* 37.86.90	H+ 9, L= 2 0 400 415 3,59 1 724 720 752,35 2 264 377 172,34 3 734 236 211,55 4 149 147 124-50 5 346 337 100-28 6 162 173 217-20 7 174 205 53,13 6 285 270 264,33,33 6 285 270 264,33,33	3 224 352 101.P2 4 83 62 113.P5 5 104 105 247.P0 0 124 145 100.77 7 100 103 44.F8 0 17 114 67.30 H= 21.L 2 0 116 127 106 174 14.5 20.11 114 27.11 116 127 4.20 116 128.20 12.11 128.20 12.11 128.20 <t< td=""><td>10 143 142 275.07 11 91 8 239.50 H* 4. L* 3 0 39* 55 288.42 1 572 591 341.56 2 513 494 271.39 3 260 266 141.59 4 277 216 110.49 5 502 501 181.19 6 1307 114.616</td></t<>	10 143 142 275.07 11 91 8 239.50 H* 4. L* 3 0 39* 55 288.42 1 572 591 341.56 2 513 494 271.39 3 260 266 141.59 4 277 216 110.49 5 502 501 181.19 6 1307 114.616
IC 116 11* 60,20 11 03 07 202.34 ₩* 10, L* C 0 162 152 12.24 1 05 77 103.60 2 224 312 2.18 3 742 710 102.40	6 67* 24 103.68 7 77 92 62.01 8 57* 87 97.82 H* 22. L* 0 0 67* 52 14.+0 1 67* 37 10.88 2 145* 191 1.55	11 #9 40 17.48 	C 217 217 30044 7 174 174 177 177 08 8 312 308 10.36 9 109 84 57.20 10 54* 27 8.19 H* 16, 1* 1 C 227 213 90.30 1 201 214 200.33	1 76 42 64.62 2 76* 46 280.81 3 53* 57 137-11 += 3C, t + 1 0 163 162 271.68 1 59 57 56.35 2 68 57 206-17	10 167 103 25.68 11 79 175 264.67 H= 10, L= 2 0 347 350 3.99 1 942 948 118.10 2 536 534 280.50 3 281 291 227.29	3 11e 123 5e.13 4 187 200 203.03 5 6.8* 36 336.01 6 153 144 175.09 7 94 161.57 2 54 35 74.69 H# 72. L= 2	7 377 366 195.19 8 209 217 370.09 9 144 143 55.45 10 179 196 272.71 11 230 242 347.47 He 5.1* 3 0 921 918 92.29
4 577 5€2 182.18 4 261 387 158.04 e 481 554 182.51 7 288 281 3.03 P 56 132 0.20 C 272 207 2.01 16 363 327 2.03 11 444 44 181.25 F+ 11. L+ C 1 66 82 004.31	3 63 84 174.05 4 143 163.27 5 6 6 7	2 33 51 194.26 4 331 326 167.61 7 186 147 186.27 6 165 99 356.21 1 6 165 99 356.21 1 7 151 199 72.33 1 1 105 199 356.67 1 1051 199 72.33 1 1 05 399 356.67 1 61 4 352 65.66 1 618 689 240.04 2 485 447 41.18	2 361 300 2000 2 361 300 2000 3 3 3 300 2000 5 40 200 00 5 40 200 00 7 213 221 120.10 8 606 100 181.57 9 183 175 72.10 10 78 66 267.00 He 17, (+ 1)	H= C, L = 2 C 007 814 2-62 1 374 328 264.72 2 42 66 169.13 3 129 124 272.56 4 415 414 163.42 5 344 344 274.87 6 478 446 183.01 7 420 412 272.21 8 66 43 3.05	4 405 420 251.e7 5 250 272 574.70 6 315 375 183.42 7 234 234 280.00 8 68* 31 134.04 9 142 130 721.33 10 c1* 57 53.55 11 7 0 77 111.79 H* 11. L* 2 0 627 604 359.47	C 60* 35 0.72 1 16 167 56.0C 2 136 167 56.0C 5 7 62 79.55 6 0* 05 146.05 5 74 26 273.55 6 23* 51 166.4C 7 134 145 703.35 8 51* 31 338.70 H= 27, L* 2	1 290 540 374.50 2 449 429 170.42 3 260 239 107.42 4 336 335 744.27 5 460 453 180.37 7 253 238 265.97 7 195 177 113.60 8 254 257 174.60 10 224 273 182.24 11 97 75 342.84
1 56 63 99.43 2 1116 1052 271.98	2 113 130 <2.43 3 68+ 52 273.10 4 107 110 91.53	0 744 352 55.66 1 618 869 240.04 2 485 487 63.18	HE 17. LA 1	7 420 413 272.21	0 627 604 359.47	H= 27. L+ 2	11 97 75 348.84

STRUCTURE OF LAPPACONINE HYDROBROMIDE

Table 3 (cont.)

* FO FC 4L >++4	K FC FC ALPHA	# FG FC ALPHA	* FO FC 44.PHA	K FO FC ALPHA	K FO FC ALPHA	К (FC) (FC) АЦРНА	K FO FC ALPHA
H* 0,1* 3 C 242 255 43.10	1 83 95 142.77 2 114 130 69.68 3 447 450 112.49	5 67 62 153.17 10 266 268 179.12 11 61 56 301.99	H= 13, L= 4	C 56* 27 186.97	7 147 145 101.21 8 65 110 187.99 5 91 70 317.74	2 112 104 210.08 3 81 79 265.05	5 58+ 52 72.30
1 680 685 219.58 2 317 312 358.6C 3 461 413 117.87	4 120 127 23C.74 5 148 146 34.15 6 199 182 231.64	H= 2. L= 4	1 309 327 211.29 2 217 229 185.85 3 224 244 185.67	2 54* 3C 255.44 7 90 106 320.85	H= 11. L= 5	H# 25, L# 5 .	C 650 39 344.21
4 215 228 322.75 5 314 325 348.23 6 287 298 280.26	7 169 159 285.65 9 119 97 158.05 9 66 98 303.26	0 80 85 191.6c 1 529 533 270.84 2 470 446 137.13	4 294 295 338.65 5 164 154 48.54 6 251 257 354.16	H= 26, L= 4	0 60* 67 106.46	0 58* 25 272.68	2 308 311 147.54
7 139 144 6.72 8 265 275 175.81 9 175 176 238.18	H= 18, L= 3	3 167 177 129.56 4 505 502 104.78 5 330 350 176.59	7 212 202 47.33 8 141 155 322.00 9 183 184 329.84	1 68 56 236.37	3 156 169 172.84 4 171 180 249.87	3 142 141 250.48	5 113 116 224.59 6 94 73 8.20
10 162 168 120.72 11 53 67 200.64	C 78 95 269.87 1 157 155 161.50 2 230 238 175 40	6 235 238 280.16 7 R2 66 285.90	H+ 14. L+ 4	1 175 172 91.62	o 315 309 258.C5 7 130 134 299.86	C 54+ 58 97.13	8 117 117 251.5*
H+ 7,L+ 2	3 299 296 36.65	9 67 29 0.37 10 61 41 319.49	0 213 207 2.08	2 371 378 3,65 3 109 164 93,35 4 374 377 2,44	\$ 63* 27 289.59 9 119 125 245.05	1 55 63 7.42 2 69 64 20.54	H= 12, L= 6
1 669 675 139.73 2 541 536 94.15	6 147 139 316.10 7 138 139 342.85	H= 3, L= 4	2 135 153 347.87 3 295 307 154.47 4 361 373 265.78	5 187 183 91.47 6 99 10E 184.98 7 378 398 270.57	H= 12. L= 5 0 62+ 10 39.53	H= C, L= 6	1 105 108 248.20 2 298 323 111.03 3 233 254 201.14
4 268 371 17.19 5 115 112 115.55	9 88 76 256.31	C 587 571 1.37 1 606 612 208.53 2 296 301 56.51	5 83 74 74.02 6 190 198 130.17 7 146 145 17.87	8 343 345 182.88 9 208 208 271.92 10 55* 18 348.21	1 384 403 168.85 2 167 178 320.40 3 138 139 38.92	1 59* 37 250.52 2 149 167 122.09 3 212 222 271.07	4 132 142 26.62 5 113 105 125.22
6 175 175 168.12 7 337 322 287.62 5 118 137 178.98	0 102 191 276.16	3 471 482 175.14 4 112 104 184.55 5 359 375 161.45	8 176 163 111.18 5 56* 50 348.0P	H= 1,L= 5	+ 160 178 174.05 5 238 247 15.51 6 68+ 81 54.63	4 134 136 3.15 5 160 188 273.67 6 68* 56 11.53	7 88 94 325,45 8 73 96 309,25
10 127 114 310.75 11 5?• 5 ^c 192.28	1 205 213 190.12 2 225 225 182.83 3 122 127 13.27	e 228 249 150.92 7 241 251 7.08 8 128 59 218.71	H= 15, L= 4 C 456 483 2.69	C 259 287 91.95 1 494 502 76.34 2 170 168 124.50	7 137 146 284.39 6 62* 4 170.73 9 101 129 211.52	7 68 53 274.38 8 51 75 1.96 5 225 222 91 93	H+ 13, L+ 6
H. 8, L. 2	4 109 114 126.93 5 136 140 301.31 6 130 174 112.72	9 115 80 354.18 10 104 105 29.57	1 136 120 345.02 2 64 67 254.21 3 310 317 33.39	3 257 251 78.96 4 103 102 280.24 5 63 64 206.75	H* 13. 1* 5	H* 1, L* 6	1 348 374 177.43 7 222 228 243.04
C 471 466 89.11 1 468 445 55.73 2 261 278 170.36	7 77 77 12.09 8 65 64 320.79	Ma 4, La 4	4 133 137 143.27 5 102 95 280.30 6 221 233 170.66	6 654 25 140.05 7 113 72 215.25 P 89 51 277.14	0 179 204 275.73 1 174 188 217.94	C 243 366 182.23 1 190 159 282.80	4 68• 75 205.78 5 117 135 104.00
3 278 282 132.87 4 572 611 176.40 5 120 124 316.37	H* 20, L= 3 0 95 93 85.14	1 262 162 196.48 2 626 635 219.27 3 187 189 246.69	7 66* 43 45.72 8 62* 61 31.51 9 54* 46 191.75	6 131 136 212.41 10 107 104 70.48	3 81 78 300.12 4 139 146 136.85	3 125 14 ⁴ 11.40 4 156 173 8 ⁴ .73	7 91 95 332.04 8 100 121 108.54
e 175 177 22.16 7 E5 102 270.47 8 149 145 5.52	1 340 366 343.92 2 68* 44 315.31 3 174 165 283.35	4 107 101 303.48 5 136 146 71.77 6 127 130 86.20	H# 15, L# 4	H= 2. L= 5	6 300 310 108.07 7 53 94 259.62	6 239 243 59.76 7 83 77 67.41	H= 14, 1= 0
9 153 137 255.48 10 80 75 99.22	4 68* 24 8.49 5 262 256 181.25 6 73 50 39.10	7 111 112 229.95 8 260 245 100.56 9 81 72 125.18	0 110 116 170.65 1 163 177 36.94	1 203 21 210.36	\$ 52+ 19 258.59	6 64 60 356.78 5 107 54 200.87	0 65* 78 9.66 1 189 195 244.61 2 118 117 332.74
H# 9+ L= 2 C 695 722 271.32	7 105 114 150.82 8 129 118 711.36	10 127 104 29.57	7 404 414 309.37 4 67* 58 323.04	4 172 195 128.14 5 480 502 334.25	0 149 143 89.07	C 59+ 26 160.40	7 76 75 316.10 4 123 114 231.50 5 197 189 52.71
1 305 312 260.8C 2 124 122 291.37 3 441 445 242.06	HH 21, L+ 3	C 621 615 1.28	6 6A 56 68.59 7 175 181 251.90	7 e3• 14 305.10 6 284 275 49.59	2 93 119 240.40 3 180 199 237.77	1 204 207 242.53 2 172 158 351.80 3 203 223 170.77	6 110 114 141.13 7 66 71 2.55 8 125 124 76.94
4 144 145 121.58 5 59 54 255.88 6 115 95 54 255.88	1 180 179 322.04	2 519 511 41.27 3 743 737 5.47	9 77 74 133, 34	10 120 116 20.05	5 160 170 215.13 6 62 65 309.43	4 207 259 100.45 5 171 179 58.31 6 128 132 227.49	H= 15, L= e
7 344 345 112,07 8 171 175 18,84 5 150 105 86 70	4 68• 41 259.38 5 199 185 201.89	5 120 119 264.69 6 320 338 143.66	0 275 279 184.03	0 254 300 274.53	7 %5 109 120.49 8 58* 51 10.12	7 175 202 358.89 8 91 90 264.06 9 46* 56 12.20	0 96 82 4.64
10 54 107 237.53	7 58 22 99.90 8 71 52 233.09	8 68 47 204.77 9 183 198 195.66	2 441 438 145.15 3 95 104 357.02	2 337 348 336.21 3 165 177 292.93	HR 15. Le 5 C 375 369 91.66	H= 2+_L= 6	3 128 134 30.02 4 131 130 209.04 5 150 164 300.95
C 291 283 270.92	H= 22, L= 3	H= 6, L= 4	5 145 132 249.54 6 183 177 359.22	4 129 140 cl.92 5 240 252 193.37 6 365 365 89.71	1 475 489 29C.92 2 289 298 54.87 3 68 71 236.50	0 60* 5 91.06 1 120 157 211.71 2 75 95 323.83	6 76 58 212.64 7 113 16C 242.12
2 329 315 19.59 3 504 496 258.79	1 132 115 254.20	0 137 144 181.69 1 423 404 39.16	8 5A+ 41 237.88	7 269 252 110.69 8 67* 53 226.76 6 10° 85 147.38	4 7a 87 201.65 5 155 106 178.22 6 110 110 236.69	3 202 229 222.01 4 198 190 179.73 5 130 122 266.38	H= 16, L# 6
5 370 381 193.84 6 256 25C 161.21	4 157 150 341.45 5 163 114 42.26	2 455 455 66.41 3 118 150 271.47 4 470 470 73.15	NN 19, L+ 4	10 139 14C 255.45	7 70 61 136.25 8 106 99 184.96	6 202 190 143.88 7 25 90 325.11 8 178 145 46 50	1 145 146 340,65 2 156 153 110,95
P 351 324 151.45 9 195 185 42.61	7 67 67 207.47	5 148 143 253.02 e 102 87 113.e1 7 175 176 216.53	1 243 26C 294.97 2 89 58 55.94 3 102 118 76.52	C 135 137 94.05 1 358 412 328.29	H= 10, L= 5 C 67+ 28 267.57	6 570 21 287.03	+ 125 109 53.50 5 91 97 297.90
H= 11, L= 3	0 684 32 80.22	8 226 224 285.30 5 117 92 125.28 10 113 100 254.74	4 213 203 L00.82 5 65 55 27.57 6 66 63 323.30	2 351 352 44.46 3 233 256 267.35 4 51* 66 41.65	1 67 102 310.61 2 75 82 329.89 3 221 210 24.33	C 60* 41 4.27	7 66 81 97.39
0 333 354 55.03 1 275 268 304.20	1 123 119 158.79 2 169 160 152.72 3 125 146 44.99	7, L. 4	7 93 95 47.15 8 153 141 244.63	5 306 274 215.51 6 329 336 5.94 7 113 127 95.05	4 296 289 352.15 5 117 102 119.22	2 263 295 261.40	0 76 58 160.40
2 254 254 320.17 3 281 290 73.73 4 409 438 288.44	4 73 101 67.97 5 77 69 18.21 6 56 95 174.3*	C 271 278 186.44 1 249 248 6.28 2 188 192 244.17	H= 19, L= 4	8 67* 25 132.57 6 63* 34 340.18	7 48 29 46.59 9 158 149 166.42	5 105 101 41.95 5 97 110 73.6C	2 260 296 140.45 3 85 81 38.35
5 170 162 181.37 6 241 223 267.31 7 127 135 39.71	7 510 43 258.54 He 24, Le 3	2 189 171 165.52 4 505 506 22.50 5 134 165 267.14	1 76 96 208.45 2 218 227 239.96 3 396 398 177.31	N 5.1. 1	H+ 17, L= 5	e 168 161 47.C8 9 138 123 158.61	5 63• 78 121.30 6 157 149 1.99
8 102 111 215.46 5 644 15 341.46 10 233 211 116.52	0 89 92 85.84	6 103 102 285.73 7 145 158 32.74 8 668 50 263.13	4 93 98 223.58 5 242 234 110.40 6 146 135 199.25	0 250 252 94.75	1 140 134 120.68 2 210 235 163.84	H# 5,1: 6	7 52* 41 26.95
H+ 12, L+ ?	2 200 192 216.78 3 131 128 132.10 4 55 96 127.24	9 57* 32 281.90 10 241 227 161.29	7 122 117 2c.08 P 64 94 134.35	3 165 16F 341.41 4 421 425 307.45	4 56 89 184.G3 5 177 169 352.40	1 101 106 279.54	0 107 122 0.60 1 131 133 275.10
C 58* 27 235.80 1 685 706 170.32 2 455 443 321.30	5 48* 50 339.01 6 55* 41 41.02	No A, La 4	P= 20, L+ 4	e 284 285 282.85 7 141 107 355.03	7 38 87 282.30 8 3° 20 26.24	4 228 223 5e.35 5 267 287 219.92	2 67• 40 203.24 3 123 123 150.6P 4 57• 5 29.44
3 362 37C 77.97 4 90 89 57.08 5 251 242 1.86	H* 25, L* 3	1 452 453 264.67 2 141 143 350.20 3 372 386 172 09	1 145 154 130.64 2 184 191 373.90	5 62 62 68.22 16 179 162 53.70	H# 19, Lx 5	7 154 136 201.41 8 93 70 308.91	6 79 67 16°.51
e 66* 15 14.60 7 314 307 358.95 8 151 154 80.71	1 73 95 299.07 2 102 97 136.22 3 122 91 262.44	4 105 107 13.55 5 533 559 106.63 6 105 131 176.79	4 +3 73 241.45 5 74 87 358.72	H* 6, L* 5	1 205 202 45.e1 2 265 280 211.49	9 40 83 150.11	0 180 168 3.32
9 90 82 222.55 16 110 95 113.35	4 132 114 122.77 5 56* 28 226.16 6 51* 25 148.17	7 274 271 84.29 9 68* 84 318.64 9 116 117 205 70	7 574 10 359.4R	1 117 132 129.c1 2 384 356 329.72	4 131 141 167.42 5 104 124 359.15	0 223 233 1P3.10 1 174 184 161.55	1 67* 5° 157.63 2 74 74 315.34 3 64* 30 110.41
H+ 13, L= ? 0 531 547 272.63	H= 26, L= 3	10 113 66 169.71	0 125 130 2.99	4 141 157 73.72 5 194 197 354.07	7 60 P6 218.61	2 344 352 130.28 3 196 191 294.54 4 159 158 101.65	4 62* 34 257.28 5 77 77 80.68 6 109 86 115.39
1 500 530 222.40 2 170 166 282.50 3 170 154 35.33	0 115 116 90.45 1 63* 65 344.57 2 82 68 66.54	0 726 742 2.25	2 119 91 124.50	7 102 82 300.90 8 205 226 190.75	0 196 203 273.52	5 131 155 23.95 c 156 166 60.51 7 67* 59 168.38	H= 20, L= 4
4 176 168 55.09 5 319 300 8.63 6 230 226 88.10	3 60* 25 313.97 4 103 102 341.88 5 114 94 171.90	2 166 149 184.54 3 166 156 133.33	5 7P 96 216.91 6 59 93 133.54	10 59 54 150.91	1 132 116 3.96 2 145 130 239.29 3 68* 37 5.54	8 146 130 255.57 5 137 10P 36.56	C 42 108 3.77 1 103 111 40.97 2 140 146 257.85
7 282 265 325.48 8 67* 50 335.56 9 76 75 230.15	H= 27, L= 3	5 95 59 160.82 6 316 301 168.21	H* 22, L= 4	0 250 296 272.25	5 64 62 188.46 6 134 121 104.59	H= 7, [+ 6 C 240 242 182.73	3 143 130 350.31 4 85 65 208.23 5 107 93 299.79
10 125 123 249.30 H+ 14. LF 3	0 136 141 93.71 1 74 73 15.72 2 141 124 45.49	8 126 126 136.51 5 63* 32 320.79	0 163 155 192.20	2 57• 82 140.10 3 419 422 62.77	H= 20, L= 5	1 405 426 233.11 2 174 161 168.35 3 113 121 206.61	H= 21, L= 6
0 244 272 273.19 1 167 16C 337.36	3 57* 20 121.31 4 122 123 314.44	H= 10, L+ 4	3 115 104 17.25 4 148 157 7-17	5 196 194 320.63 6 83 AC 103.63	0 118 101 92.54 1 238 244 347.76	4 245 258 332.50 5 317 309 110.10 6 241 239 16.75	0 63 63 187.17 1 170 146 62.88 2 62* 44 213.58
2 302 323 203.57 3 266 287 107.95 5 277 297 165.62	NR 29, L= 3	0 68 80 5.49	* 121 112 0.07	7 273 256 296.74 8 165 153 353.05 9 113 110 256.55	2 53 76 275.35 3 111 94 247.01 4 130 132 329.51	7 105 100 80.98 8 62* 35 160.07 5 54* 50 12.35	3 55 95 344.56 4 182 180 74.84 5 90 72 256.74
5 G3 88 222.76 8 195 194 23.62 7 241 213 208.70	1 147 135 142.62 2 95 94 26.74	2 161 153 293.12 4 345 356 26P.64	C 100 176 184.09	10 57 56 255,50 H+ 8,1+ 5	5 148 147 174.14 6 95 115 275.17 7 62 50 225.00	H= f.L. 6	4= 22. L= 6
8 201 178 355.47 9 6C* 44 49.15 10 51* 45 267.60	H# 29, L# 3	6 67 41 352.75 7 68 55 260.00	2 94 64 72.29 72 79 139.25	0 152 163 272.80	H# 21, L# 5	C 63* 26 149.66 1 118 118 279.57 2 64* 25 244.50	0 150 143 183.95
H* 15, L+ ?	0 53+ 42 277.60 1 52+ 30 86.65	\$ 159 160 114.03 10 114 112 19.33	5 72 65 212.87 5 53• 72 326.54	2 489 507 206.01 3 125 142 226.94 4 245 257 151.62	0 116 133 95.81 1 67* 67 295.34 2 110 91 30.14	3 139 134 264.44 4 154 130 141.95 5 128 130 86.24	3 57• 23 243.19 4 123 117 65.57
C 92 7E 94.32 1 256 262 291.15	H= 0, L= 4	H# 11, L# 4	H* 24, L* 4	5 15* 145 187.28 e 69 41 272.03 7 68* 42 271.79	3 65* 19 347.05 4 113 129 333.29 5 59 48 165.98	6 195 184 173.09 7 118 105 345.53 6 56 92 68.36	M* 23. L* 6
3 447 455 280.56 4 101 162 323.74	0 356 377 175.85 1 600 584 92.58	1 231 341 78.66	1 146 140 267.42 2 64 61 50.90	8 250 240 14.15 5 172 154 72.86	6 191 176 225.77 H= 22, L= 5	9 70 66 270.17	1 91 92 231.04 2 109 102 168.37 3 123 130 156.69
6 68* 58 189.06 7 149 153 117.51 8 141 135 10.00	3 373 353 271.10 4 154 138 181.14	4 176 177 10.66 5 117 115 344.45	3 67* 59 174.42 4 50* 26 134.78 5 98 119 64.44	H= 9, L= * C 132 107 86.73 1	0 co* 20 99,19 1 80 78 171,31	0 64* 15 57.43 1 200 189 80.12	H4 24, L¥ 6
< 192 158 61.26	6 186 195 179.76 7 315 320 272.61	0 270 292 12.06 7 262 265 215.04 8 88 71 338.96	H= 25, 1= 4	1 273 246 240.96 2 60+ 40 28.47 2 222 224 266.33	2 97 108 344.22 3 109 99 77.84 4 55 71 338.78	2 121 125 313.55 3. 128 130 145.87 4 143 155 251.02	0 55* 37 10.08 1 94 70 226.45 2 53* 46 232.21
6 221 20¢ 02.55	9 138 155 44.40 10 68* 42 2.78	10 5P 57 275,92	0 197 200 2.95 1 77 66 271.54 2 115 106 299.29	4 160 198 76.23 5 115 118 266.43 6 23 62 1.11	5 80 84 344.48 0 51* 10 21.43	5 68* 28 247.67 6 225 210 195.64 7 65* 13 249.20	N# 25, L# 6
2 143 197 343.55 3 342 372 267.75	H+ 1.L= 4	0 225 224 357.19	7 103 91 157.27 4 135 124 245.65 5 52* 38 303.92	7 146 154 109.23 8 166 170 249.50 9 33 74 146.01	H= 23. L= 5 0 136 144 272.06	8 60* 57 15.26 9 51* 27 731.46	0 51+ 15 147.47
5 126 105 357.96 6 237 244 234.24 7 47 45 105 105 105 105 105 105 105 105 105 10	0 259 313 186.22 1 101 101 337.32	2 247 248 105.03 3 192 194 343.04	H+ 26, L+ 4	H+ 10+LE 5	1 50 59 223.57 2 63* 50 222.57 3 125 122 74.33	HP 10, LP 6	1 66* 10 132.97
e 161 15C 175.43 5 56* 6t 116.42	3 246 233 207.60 4 358 413 11.77	5 184 190 30.58 6 247 253 285.94	C 60* 22 165,90 1 50* 37 24.29 2 88 85 298,04	C 59* 56 102.87 1 151 212 1.50 2 225 34* 16.75	4 160 150 157.62 5 65 55 308.08	1 242 331 34.40 2 143 127 235.67 3 167 166 249.43	3 207 223 93.03 6 270 355 0.51 5 66 46 766 00
HI 17, LA 3	6 304 313 9.62 7 110 121 21.07	6 73 6 19.65	3 56* 25 337.91 4 93 #7 212.25	2 140 142 178.54 4 272 257 313.41 7 160 201 232.72	H# 24. LE 5 0 137 123 273.76	4 76 90 47.50 5 276 287 270.77 6 158 151 7.64	e 57* 03 183.469 7 110 113 273.65 6 145 142 181.52
				c 716 21F 272.04	1 61 • 71 227.09 1	7 100 45 198.63	

Table 3 (cont.)

×	10	FC SLPHA	×	FO	FC SLPHA	×	FC	*C &L PHA	l x	FO	FC ALPHA		FO	FC ALPHA	×	FD	۴C	ALPHA	× 1	s c'	FC ALP	••	ĸ	FG	FC ALPH	4
	1. 1.	` ,	1	104	142 241.05	7	50	60 186.58	i			1	118	107 197.60	4	59+	60 Z	05.55	ç		37 93.	9	4	51•	71 794.2	n
			2	83	58 112.18		14. 14	,	1	13*	NC 274.75	2	144	147 346.25	5	48	41 1	e0.70	2	178	170 31.	10 H.	17		9	
ì	65	51 170.44		239	256 161.71				1 2	98	72 177 75	4	20*	55 125.44	н	14+ L#	6		2	62	57 69.	2		\$7.	45 277.0	14
- ?	60	6 246.69	5	155	154 268.06	1	127	45 95.57		2. 1.			*** 77	36 319.64	0	630	37	9.78	3	165	158 170.		ĭ	57.	37 176.4	4
1	108	112 203.30	ĩ	74	74 240.47	2	67.	36 340.11				1	78	7: 333.07	1	113	120	74.25		4. 1.4	9		2	51.	23 127.7	£
1	68	57 262.01	8	544	73 286.15	1 2	159	155 313.50	1	300	1 97.72		7. 1.	e e	1 5	67.	61 3	57.09			•		·			
i	lof	157 340.01	н.	8. L.	7	5	170	114 185.24	2	65.	09 182.87				1 :	113	97 1	92.92	ŝ	***	77 200.	12 He	1). L.	9	
,	147	137 336.47		89	70 48.04	e e	\$7.	41 9.56	- 1	67.	23 15.02	Ĩ	233	211 244.05	1 '	/8	•, ,		; ;	د ٤٠	54 178.	99	0	62	5# 270.0	20
	2. L.	,	i	179	198 320.13	H.	15, 14	7	5	174	169 89.74	2	e 8 •	65 84.42	41	15. L.	۴		1		40 300.		2	53+	35 41.1	19
	179	175 273.13		152	131 282.67	l (156	92 \$5.59	1 7		4 247.12		86	72 263.13	0	76	75 3	18.40	5	54.	24 142.	03	3	70	90 289.4	•0
i	121	137 276.72	1	68.	71 208.63	1	126	142 200.70	:			: :	53	57 98.35		61*	50 1	43.76		5. 1.*	ç		1.		9	
- ;	316	32 299.25	è		51 345.01	{	15+	10 14.23	1			1 1	46.	15 169.50	3	104	89 3	91.56	i .						178 92.1	
:	50	75 144.67	1	103	86 90.34	1 :	187	189 102.73	1 1	123	24 358.54		8. 14		1 *	· · ·	13	3.1.	1 1	120	103 172.	36	1	55	48 21P.3	, į
ě	100	115 14.21	°	24-	31 340.10	6	77	64 268.65	1 2		41 207.03				н.	16. L.			1	• • •	74 8.	44	2	50	42 77.4	••
~	e 3• 70	11 138.68	H.	۰. ۱۰	7		14. 1.	,	1	145	144 300.35	ÎÎ	176	28 242.74	0	198	186 1	82.51	1	67	82 1+2	во н	- 11	5. L.	9	
v			0	00*	24 262.07	1.			1 :	129	137 51.00	2	67.	102 272.13	1	59.	36 1	42.28	÷	54.	13 16.	°5	•	67	74 92.0	51
**	3. 1.	,	;	336	201 80.05	1 5	110	23 59.15	9	103	36 200.42		41	92 233.44	1 5	50.	13 3	26.5P		e. 1.	9		·			
5	2.82	271 270.94	3	68.	79 109.55	Ż	6.7	76 321.29	1			1 1	69	PC 70.36	•	58	75	42.39	6	64	70 273.	55 "). l•	19	
;	242	54 151.87	5	124	194 194.08	1 2	115	109 292.07	1		•		• •		He	17	8		1	¢5	104 40.		?	22.	71 101.5	27
2	80	107 149.92	ę,		61 224.77	1	52.	46 28.29	· ·	97	109 176.43	н.	۰. ۱.	f		58+	6 2	01.94	5	60.	44 1.	\$0	ż	53.	10 155.4	٥ <u>،</u>
:	40	122 215.78	8	\$i.+	53 188.93				2	6.9	80 127.94	0	68+	10 13.75	1	114	83 2	25.83	1 :	57.	58 141.	20	3	51+	58 90.0	30
5	115	8e 135.49		10. 1.	,	н.	17. 1.	7	1	294	255 171.56		110	154 144.54	1 5	88	83 1	41.63	ií	,,,-		~ н		1. L.	10	
	63*	50 302.89				c	149	140 272.13	5	65.	47 153.91	1	114	\$8 301.79					H-	7	9		0	55.	10 11.0	07
	4. 1.	,	î	123	127 94.77		÷C	10' 269.07	9	61	60 47.52	3	67	35 214.60	1	101 11			1 0	114	119 270.	P4	1	55*	39 107.	79
			2	221	214 351.52	3	82	102 76.54				0	56	91 113.06	1 ?	55+	34 1	171.21		127	100 167	ce i	5		42 288.	38
ŝ	175	170 78.11	3	09.	34 184.73		83	72 349.75	1	J. (•		HT	10. L-	E	2	53+	36 3	34.02	3	6.7.4	43 11	13			10	
2	07+	26 340.73	5	91	78 103.00			,		221	7 163.34	1 .	1.18	134 182.00	н.	19. 14			5	40*	27 104	41			10	
4	·	4 247.08	1	52	64 292.75	1			1 2	50.	45 303.62	1	120	121 356.87									5	55+	39 177.1	12
1	1 16	131 284.91	н.			1 :	123	146 271.67	1 4	680	39 00.35	3	140	151 352.35	1	109	131	23.41	1				ż	51.	58 3.0	69
,	e1+	21 113.87				2	144	160 241.16		8*	A3 176.84	1	63	65 18.04		0. 1.			c 1	620	39 01.	45 I 17 H		3. 1.	10	
۴	55.	40 255.70	1	68.	59 118.75		57.	45 87.63	;	54+	45 19.79		60	6" 31.77	1				2	110	109 346	11				•••
••		,	1 2	167	194 148.46	5	•</td <td>72 217.22</td> <td></td> <td>4. 1.</td> <td></td> <td></td> <td>11</td> <td></td> <td></td> <td>160</td> <td>150</td> <td>91.10</td> <td>1 2</td> <td>55.</td> <td>36 254</td> <td>6</td> <td>i -</td> <td>5</td> <td>5 61.</td> <td>45</td>	72 217.22		4. 1.			11			160	150	91.10	1 2	55.	36 254	6	i -	5	5 61.	45
¢	140	154 47.54	1 4	67.	11 217-13	HE	1<, L•	,				1				99	85	93.29	5	50+	27 117.	70	2	53*	38 204.4	42
ļ	144	146 154.57	1	65 ·	49 57.32	1 6	50.	37 271.00	1		73 0.12	l î	156	135 102.29		50+	23	\$1.23		د, ر.	ç	<u>і</u> н	•	4. 1.	10	
;	1 36	135 317.42	,	92	65 270.75	1 1	105	148 124.81	2	90	79 9.54	1	118	125 145.65	1				1 .	A1 *	26 261	0.5	e	61	47 180.	A 6
5	163	162 321.51		12. 1.	, ,	1 5	163	97 224.55	1 2	64.	67 73.95	1 4	157	127 73.16					i	ē.•	25 156	6.9	1	54*	11 83.	65
÷.	172	136 243.47				1 4	54.0	70 40.37	5	85	AA 307.31	1 1	82	77 158.22		05* 65	21	360.90	: ;		25 30	6	ć.			
	5	37 195.05	1 i	123	139 61.77		20. 1.	,	7	54	5e 217.53	1					39	113.62	1 *	***	53 2¢e	P6 H	•	5. L.	19	
		,	2	149	142 ZC3.2P 95 50.53	1 .	78	63 90.05		s. L.	9		12. 1.			134	130	210.69		10. 1.	ç		<u>c</u>	54+	30 1 53.	34
			-	120	119 101.54	1	5 Q 0	48 23.12				1 5	60.	14 181.40		149	135	30.45			5 1 29	43	2	91	100 86.	49
ĥ	120	\$7 157.00	1	153	146 67.42	3	67	68 198.10	1	160	138 82.29	2	121	112 90.24	н	2. 1.	• •		1	e0+	41 100	en (10	
	69	70 55.54	1	54.0	38 249.00	•	117	111 347.24	1	178	123 144.17	1 2	63.	67 1c0.7c		1 1 7 4	120	271.70	2	-94 -	00 14	S "	•	0, L•	10	
- 4	68+	51 110.05	H#	13. 1.			21. 4.	,	1 2	178	174 101.49	1 1	105	6C 115.09		05*	50	10.70	4	52.	35 744	22	;	57.	2 207.	36
5	144	122 22.63			31 284 43		*0	88 94.31	5	84	75 242.73		11. 1.			78	65	734.98	н.	11. 1.	<u>،</u>	1	ż	50.	44 193.	71
5	27	AC 284.25	ĭ	145	142 315.03	1 i	50.0	33 181.30	1 7	59	4P 758.67	1			1	60*	41 .	205.54	! .	112	112 271			7. 1.	10	
F	· · ·	32 30.96	1 2	06 #7*	49 209.01	1 ?	54+	55 26.77	н.	5. 14			64+	130 2.31 5C 288.12	1	, 10		141125	1 1	127	127 272	c7				
••	7	,	1 5	174	156 148.51	11			Γ.			2	105	76 247.04	1 **	3. L	• •		1 1	72	67 263	83	î	51.	44 117.	5
c	125	175 86.54		63• 59•	24 50.00	1 **	<i>a</i> . •	,	1 ^		-3 355.43	1 '	~2	** 1.0.42					i í							

Table 4. Agreement summary

1854 observed reflexions $(3 \cdot 3 \le |F_o| \le 250 \cdot 2)$



Note. $|F_{th}| =$ threshold amplitude = 1.7 to 6.8.

angles and by the fact that C(2) is at a distance of only 0.48 Å from the mean plane through C(1), C(3), C(4) and C(11), while C(5) is displaced by 0.66 Å from that plane. This distortion is also manifested by the torsional angles (Fig. 3) adjacent to C(2) and C(3) which greatly deviate from the calculated values of \pm 52 and 0° respectively (Hendrickson, 1967). The presence of a bond between C(6) and C(7) causes an appreciable closing of the valence angle C(5)–C(11)–C(17) (97.9°) and a concomitant increase in the adjacent angle C(1)–C(11)–C(5) (113.3°) in ring A.

The five-membered ring C can best be described as a distorted half-chair. The atoms C(11) and C(17) are displaced by 0.49 and 0.34 Å respectively to the opposite sides of the plane defined by C(5)-C(6)-C(7).

In an ideal half-chair these distances would amount to +0.39 Å (Brutcher & Bauer, 1962).

Ring D is badly distorted from an ideal chair conformation. Being in the centre of the structure this ring is strained by all other ring systems and this is made evident by abnormal bond angles and torsional angles. There is a significant flattening of the ring at C(9) and C(10), and the opposite effect at C(11) and C(17).

Ring E is fairly close to an envelope. C(14) is at a normal distance of 0.76 Å from the mean plane through the other four atoms. However, these four atoms do not lie in a plane ($\chi^2 = 54.7$) and the torsional angle for the bond C(10)-C(12) equals $+4^{\circ}$ instead of 0°. The distortion can be ascribed to the strain transmitted from rings D and F.

STRUCTURE OF LAPPACONINE HYDROBROMIDE

Table 5. Intramolecular bond lengths

C(1) - C(2)	1·477 (11) Å	C(2) - H(21)	0.07 (10) Å
C(1) - C(11)	1.571 (9)	C(2) - H(22)	1.22(10) A
C(2) - C(3)	1.472 (16)	C(3) - H(31)	122(11) 1.15(11)
$C(3) \rightarrow C(4)$	1.526 (13)	C(3) - H(32)	0.00(8)
C(4) - C(5)	1.546(9)	C(5) - H(51)	1.00 (6)
C(4) - C(18)	1.527 (10)	C(6) - H(61)	1.13(0)
C(5) - C(6)	1.533 (10)	C(6) - H(62)	1.01(7)
C(5) - C(11)	1.544 (9)	C(7) - H(71)	1.0+(7)
C(6) - C(7)	1.535 (10)	C(10) - H(101)	0.92(3)
C(7) - C(8)	1.553 (9)	C(12) - H(121)	0.92(7)
C(7) - C(17)	1.514 (9)	C(12) - H(122)	1.07(8)
C(8) - C(9)	1.575 (9)	C(13) - H(131)	0.87(7)
C(8) - C(15)	1.572 (9)	C(14) - H(141)	1.02(6)
C(9) - C(10)	1.570 (9)	C(15) - H(151)	0.91(7)
C(9) - C(14)	1.538 (9)	C(15) - H(152)	0.97(7)
C(10)-C(11)	1.555 (8)	C(16) - H(161)	1.09(7)
C(10)-C(12)	1.546 (9)	C(17) - H(171)	0.96 (6)
C(11) - C(17)	1.537 (8)	C(18) - H(181)	0.97(8)
C(12) - C(13)	1.550 (9)	C(18)-H(182)	0.96(5)
C(13) - C(14)	1.528 (9)	C(19)–H(191)	0.94(6)
C(13) - C(16)	1.525 (9)	C(19)-H(192)	1.15 (6)
C(15)-C(16)	1.518 (10)	C(20) - H(201)	1.03 (8)
C(19) - C(20)	1.480 (11)	C(20) - H(202)	1.08(7)
C(17) - N(1)	1.514 (7)	C(20)-H(203)	0.82(8)
C(18) - N(1)	1.505 (9)	C(21)-H(211)	0.89 (10)
C(19) - N(1)	1.515 (9)	C(21) - H(212)	0.93 (8)
C(1) = O(1)	1.418 (9)	C(21) - H(213)	1.08 (11)
C(4) - O(2)	1.409 (10)	C(22) - H(221)	0.91(8)
C(8) - O(3)	1.408 (8)	C(22) - H(222)	1.12(7)
C(9)O(4)	1.412 (8)	C(22)-H(223)	0.96 (7)
C(14) - O(5)	1.416 (8)	C(23)-H(231)	1.00 (11)
C(16)-O(6)	1.440 (7)	C(23)-H(232)	1.09 (10)
C(21) - O(1)	1.400 (12)	C(23)-H(233)	1.01 (10)
C(22) - O(5)	1.409 (9)	N(1) - H(N1)	0.79 (8)
C(23)-O(6)	1.417 (10)	O(2)H(O2)	0.85 (9)
C(1) - H(11)	0.98 (7)	O(4)H(O4)	0.94 (6)

Table 6. Bond angles

$\begin{array}{cccc} C(2)C(1)-O(1) & 116 \cdot 0 \ (7) & C(9)C(10) \\ C(11)-C(1)-O(1) & 107 \cdot 6 \ (5) & C(11)-C(10) \\ C(1)-C(2)-C(3) & 116 \cdot 7 \ (9) & C(1)-C(11) \\ C(2)C(3)-C(4) & 116 \cdot 0 \ (8) & C(1)C(11) \\ C(3)C(4)-C(5) & 111 \cdot 2 \ (6) & C(1)C(11) \\ \end{array}$	$\begin{array}{cccc} -C(12) & 103\\ -C(12) & 113\\ -C(5) & 113\\ -C(5) & 108\\ -C(10) & 108\\ -C(17) & 115\\ -C(10) & 114\\ \end{array}$	-9 (5) -0 (5) -3 (5) -1 (5) -7 (5)
$\begin{array}{cccc} C(11)-C(1)-O(1) & 107\cdot 6 \ (5) & C(11)-C(10)\\ C(1)-C(2)-C(3) & 116\cdot 7 \ (9) & C(1)-C(11)\\ C(2)-C(3)-C(4) & 116\cdot 0 \ (8) & C(1)-C(11)\\ C(3)-C(4)-C(5) & 111\cdot 2 \ (6) & C(1)-C(11)\\ \end{array}$)-C(12) 113)-C(5) 113)-C(10) 108)-C(10) 108)-C(17) 115)-C(10) 114	·0 (5) ·3 (5) ·1 (5) ·7 (5)
$\begin{array}{cccc} C(1)-C(2)-C(3) & 116\cdot7 & (9) & C(1)-C(11)\\ C(2)-C(3)-C(4) & 116\cdot0 & (8) & C(1)-C(11)\\ C(3)-C(4)-C(5) & 111\cdot2 & (6) & C(1)-C(11)\\ \end{array}$)-C(5) 113)-C(10) 108)-C(17) 115)-C(10) 114	·3 (5) ·1 (5) ·7 (5)
$\begin{array}{cccc} C(2)-C(3)-C(4) & 116 \cdot 0 & (8) & C(1)-C(11) \\ C(3)-C(4)-C(5) & 111 \cdot 2 & (6) & C(1)-C(11) \\ C(3)-C(4)-C(5) & 111 \cdot 2 & (6) & C(1)-C(11) \\ \end{array}$	$\begin{array}{c} -C(10) & 108 \\ -C(17) & 115 \\ -C(17) & 115 \\ -C(10) & 114 \\ \end{array}$	·1 (5) ·7 (5)
C(3)-C(4)-C(5) 111·2 (6) $C(1)-C(11)$	-C(17) 115 -C(10) 114	$\cdot 7(5)$
	-C(10) 114	1 (3)
C(3) - C(4) - C(18) 111.0 (7) $C(5) - C(11)$.5 (5)
C(3)-C(4)-O(2) 112.0 (7) $C(5)-C(11)$)-(((17) 97	(3)
C(5) - C(4) - C(18) 108.9 (6) $C(10) - C(11)$	-C(17) = 107	(3)
C(5)-C(4)-O(2) 105.4 (6) $C(10)-C(12)$	-C(13) 107	-9(5)
C(18)-C(4)-O(2) 108.2 (6) $C(12)-C(13)$	-C(14) 98	(3)
C(4) - C(5) - C(6) 108.7 (6) $C(12) - C(13)$	-C(16) = 112	(3)
C(4) - C(5) - C(11) 109.5 (5) $C(14) - C(13)$	-C(16) 113	(0, (5))
C(6) - C(5) - C(11) 104.5 (5) $C(9) - C(14)$	-C(13) 101	$\cdot 7(5)$
C(5) - C(6) - C(7) 104.9 (6) $C(9) - C(14)$	-O(5) 111	(1)
C(6) - C(7) - C(8) 110.3 (5) $C(13) - C(14)$	-O(5) 116	(3)
C(6) - C(7) - C(17) 104.1 (5) $C(8) - C(15)$	-C(16) 118	(3)
C(8) - C(7) - C(17) 111.2 (5) $C(13) - C(16)$	-C(15) 113	$\cdot 4(5)$
C(7) - C(8) - C(9) 109.1 (5) $C(13) - C(16)$)-O(6) 105	(5)
C(7) - C(8) - C(15) 112.1 (5) $C(15) - C(16)$)–O(6) 109	.5 (5)
C(7) - C(8) - O(3) 107.4 (5) $C(7) - C(17)$	-C(11) 101	$\cdot 7(5)$
C(9) - C(8) - C(15) 111.1 (5) $C(7) - C(17)$	N(1) 113	·5 (5)
C(9) - C(8) - O(3) 109.3 (5) $C(11) - C(17)$	-C(1) 110	$\cdot 8'(5)$
C(15)-C(8)-O(3) 107.8 (5) $C(4)-C(18)$	-N(1) 113	(0)
C(8) - C(9) - C(10) 112.6 (5) $C(20) - C(19)$	-N(1) 112	$\cdot 2(6)$
C(8) - C(9) - C(14) 111.1 (5) $C(17) - N(1)$	-C(18) 112	$\cdot \hat{8}(\hat{5})$
C(8) - C(9) - O(4) 107.5 (5) $C(17) - N(1)$	-C(19) 113	·8 (5)
C(10)-C(9)-C(14) 101.0 (5) $C(18)-N(1)$	C(19) 110	·9 (5)
C(10)-C(9)-O(4) 114.0 (5) $C(1)-O(1)-O(1)-O(1)-O(1)-O(1)-O(1)-O(1)-O$	-C(22) 114	·3 (7)
C(14)-C(9)-C(4) 110.8 (5) $C(14)-O(5)-C(1$	-C(22) 111	·8 (5)
C(16)-C(6)-	C(23) 113	•4 (6)

Ring F is forced into the boat form in order to make the substituents at C(8) and C(16) equatorial and thus reduce 1,3-interactions. Since C(14) is at the flap of the envelope of ring E it cannot assume its normal position in ring F. It is being forced further away from the mean plane of ring F [defined by C(8), C(9), C(13), and C(16)] and its distance from that plane is 0.85 Å instead of the normal distance of 0.73 Å. Consequently, the axial methoxy group attached to C(14) pushes away the C(15) methylene group, causing a considerable flattening. This is shown by the large angle C(8)–C(15)–C(16) (118.3°) and the short distance (0.36 Å) of C(15) from the mean plane of the ring. The torsional angles are correspondingly abnormal.

All bond lengths in this structure appear to be normal. It should be noted that the standard deviations obtained from the least-squares refinement are underestimated owing to the block-diagonal approximation and the lack of an absorption correction. An increase of the calculated values by 50% appears justified. There are three $C(sp^3)-C(sp^3)$ single bonds [C(1)-C(2),C(2)-C(3), C(19)-C(20)] which are significantly shorter than normal, ranging from 1.472 to 1.480 Å. They all involve carbon atoms with large thermal motion, and this must be the cause of the apparent shortening of these bonds. An attempt to correct bond lengths by assuming rigid-body vibration of the molecule failed since the assumption was not justified.

All bonds involving hydrogen atoms are of reasonable length, being within 2σ of values normally found in X-ray analyses. The angles, which are not listed, range from 92 to 127° . Their mean e.s.d. being $4\cdot 3^{\circ}$ (for angles involving one hydrogen atom) and $6\cdot 8^{\circ}$ (for angles involving two hydrogen atoms), they are all either normal within experimental error, or their deviations can be explained by the distortions discussed above.

The hydrogen bond system is illustrated in Fig.4. The bromide ion accepts two hydrogen atoms from hydroxyl groups in two symmetry-related molecules. It also appears probable that there is a bifurcated hydrogen bond present in which the proton attached to the quaternized nitrogen atom is donated to O(1) in the same molecule as well as to Br-. Bifurcated hydrogen bonds have been reported in the past, but they are rare. In a recent review (Donohue, 1968) only five acceptable cases were listed. In all reported cases both acceptors were the same type of atom. This appears to be the first case of what may be called heterologous bifurcated hydrogen bonds, in which two very different atoms act as acceptors. It is remarkable that one of them is an ether oxygen atom, a type of atom rarely found to play the rôle of an acceptor. Although the presence of a heavy atom resulted in rather high e.s.d.'s in hydrogen positions the following arguments can be put forward in favour of such a hydrogen bond occurring in this structure. (a) The position of H(NI) was clearly indicated in the difference Fourier synthesis and it was refined by least-squares to give reasonable values for the covalent bond length and bond angles.



Fig. 4. Hydrogen bond system; O(2') is in the molecule at $\frac{1}{2} - x, \overline{y}, \frac{1}{2} + z$, O(4") is in the molecule at x, 1 + y, z.

(b) The H(Nl)...O(l) distance of 2.16 Å is significantly shorter (by 0.4 Å) than the sum of the van der Waals radii. The H...O distance in 'linear' N-H...O hydrogen bonds has been found to lie in the range of 1.83-2.17 Å. Hamilton & Ibers (1968) list 2.0 Å as the 'observed value'. An increase of this distance by 0.1-0.2Å has generally been observed in cases of symmetrical bifurcation. (c) Hamilton & Ibers (1968) give 2.4 Å as the observed H...Cl- distance in 'linear' N-H...Clhydrogen bonds. In a bifurcated hydrogen bond in glycine hemihydrochloride (Hahn & Buerger, 1957) in which a hydrogen atom is being donated to two chloride ions the two H...Cl- distances were found to be 2.52 and 2.62 Å. Since the ionic radius of Br^- is 0.15 Å longer than that of Cl⁻ (Pauling, 1960) the H...Br⁻ distance in a bifurcated N-H...Br- hydrogen bond could be as long as $2 \cdot 7 - 2 \cdot 8$ Å. (d) The N-H bond bisects exactly the angle $Br^- \dots N(1) \dots O(1)$. The angles Br⁻...N-H (37°) and O(1)...N-H (38°) are too large for 'linear' hydrogen bonds, but are quite normal for bifurcated hydrogen bonds (Donohue, 1968). (e) H(NI) lies in the same plane as Br^- , H(O2') and H(O4''). The equation for this plane is 0.6772X + 0.0024Y +0.7358Z = 9.1812 and $\chi^2 = 4.6$.

Considering all these points, the inference of a heterologous bifurcated hydrogen bond appears reasonable although not much can be said about its strength. It should be noted that a similar bifurcated hydrogen bond system was postulated in the closely related structure of heteratisine hydrobromide (Przybylska, 1965) although the hydrogen atom was not located. This postulate is now indirectly confirmed since the $N^+...O$ and the $N^+...Br^-$ distances are practically identical in both structures. A heterologous bifurcated hydrogen bond system was recently claimed to have been found in the alkaloid haloxine (Nilsson, 1968). In view of the H...O and N...O distances (2.52,3.12 Å) the presence of such a system in that structure appears very unlikely. Considering the very short distance between O(3) and O(4) (2.545 Å) there exists the possibility of another intramolecular hydrogen bond with O(3) donating a proton to O(4). Although the appropriate region of the difference Fourier synthesis was carefully searched no peak ascribable to the missing hydrogen atom could be found. One can therefore assume that the hydrogen atom is disordered and that there is no hydrogen bond between these two hydroxyl groups.

The absolute configuration of several closely related alkaloids has been established in the past (e.g. lycoctonine, Przybylska & Marion, 1959). The assignment was confirmed in lappaconine by refining both enantiomers. The respective weighted R factors, $R' = (\sum w\Delta^2/\sum wF_0^2)^{1/2}$, were 0.065 and 0.058 and the ratio 1.1 is highly significant (Hamilton, 1965). All diagrams are drawn with a right-handed set of axes and show the correct enantiomer.

Apart from the hydrogen bonds there are no intermolecular distances which are significantly shorter than the sum of van der Waals radii. The crystal structure can be described as consisting of pleated sheets formed by anti-parallel chains of lappaconine cations,



Fig. 5. Projection of the structure along the *b* axis. The hydrogen bonds $O(4)-H\cdots Br^-$ involve molecules related to those shown by a translation along the *b* axis (*cf.* Fig. 4).

arranged head-to-tail and connected to each other *via* $N-H--Br^---H-O(4)$ hydrogen bonds. The chains are parallel to the *y* axis and within each sheet they are cross-linked by $N-H---Br^---O(2)$ hydrogen bonds. A view of the structure is shown in Fig. 5.

The author wishes to thank Dr L. Marion and Dr N. Mollov for supplying him with crystals of lappaconine hydrobromide, and is grateful to Dr M. Przybylska for her continued encouragement and interest in this work. The programs of Ahmed, Hall, Pippy & Huber (1966) were used for all computations.

References

- AHMED, F. R., HALL, S. R., PIPPY, M. E. & HUBER, C. P. (1966). NRC Crystallographic Programs for the IBM/360 System. IUCr World List of Crystallographic Computer Programs. 2nd ed., Appendix, p. 52.
- BIRNBAUM, G. I. (1969). Tetrahedron Letters, 2193.
- BRUTCHER, F. V. & BAUER, W. (1962). J. Amer. Chem. Soc. 84, 2233.
- CROMER, D. T. (1965). Acta Cryst. 18, 17.
- CROMER, D. T. & WABER, J. T. (1965). Acta Cryst. 18, 104.
- DONOHUE, J. (1968). In Structural Chemistry and Molecular Biology. Ed. A. RICH & N. DAVIDSON. San Francisco: Freeman.

- HAHN, T. & BUERGER, M. J. (1957). Z. Kristallogr. 108, 419.
- HAMILTON, W. C. (1965). Acta Cryst. 18, 502.
- HAMILTON, W. C. & IBERS, J. A. (1968). Hydrogen Bonding in Solids, p. 16. New York: Benjamin.
- HAMILTON, W. C., ROLLETT, J. S. & SPARKS, R. A. (1965). Acta Cryst. 18, 129.
- HANSON, H. P., HERMAN, F., LEA, J. D. & SKILLMAN, S. (1964). Acta Cryst. 17, 1040.
- HENDRICKSON, J. B. (1967). J. Amer. Chem. Soc. 89, 7036.
- KHAIMOVA, M., MOLLOV, N., CERNEVA, P., ANTONOVA, A. & IVANOVA, V. (1964). Tetrahedron Letters, 2711.
- KLYNE, W. & PRELOG, V. (1960). Experientia, 16, 521.
- MARION, L. (1963). Pure Appl. Chem. 6, 621.
- NILSSON, B. (1968). Acta Cryst. B24, 252.
- PAULING, L. (1960). The Nature of the Chemical Bond, p. 518. Ithaca: Cornell Univ. Press.
- PRZYBYLSKA, M. (1961a). Acta Cryst. 14, 424.
- PRZYBYLSKA, M. (1961b). Acta Cryst. 14, 429.
- PRZYBYLSKA, M. (1965). Acta Cryst. 18, 536.
- PRZYBYLSKA, M. & MARION, L. (1959). Canad. J. Chem. 37, 1843.
- SCHULZE, H. (1922). Arch. Pharm. 260, 230.
- STEWART, R. F., DAVIDSON, E. R. & SIMPSON, W. T. (1965). J. Chem. Phys. 42, 3175.
- TAMURA, C. & SIM, G. A. (1968). J. Chem. Soc. (B), p. 1241.
- WEBB, N. C. & BECKER, M. R. (1967). J. Chem. Soc. (B), p. 131.

Acta Cryst. (1970). B26, 765

The Structure of a New Natural Amino Acid, 2,3-cis-3,4-trans-3,4-Dihydroxy-L-proline

BY ISABELLA L. KARLE

Laboratory for the Structure of Matter, U.S. Naval Research Laboratory, Washington, D.C. 20390, U.S.A.

(Received 28 April 1969)

The formula of a new amino acid isolated from the cell walls of the diatom *Navicula pelliculosa* was confirmed by X-ray analysis to be 2,3-*cis*-3,4-*trans*-3,4-dihydroxyproline. The material crystallizes in space group $P2_12_12_1$ with cell dimensions $a=8\cdot38\pm0\cdot01$, $b=8\cdot43\pm0\cdot01$ and $c=8\cdot56\pm0\cdot01$ Å, Z=4 and a calculated density of 1.613 g.cm⁻³. Atoms C(4), C(5), N and C(2) of the five-membered ring lie in a plane to within $\pm 0\cdot009$ Å while C(3) is 0.60 Å above the plane. The carboxyl group is equatorial while each of the two hydroxyl groups is axial to the ring. Four different hydrogen bonds, two NH···O bonds and two OH···O bonds, bind the molecules into a tight network. The structure was determined with the use of the symbolic addition procedure for phase determination.

Introduction

Proline, an imino acid rather than an amino acid, occurs in many proteins but is present in especially large quantities in collagen. 4-Hydroxyproline is found in scleroproteins and keratins. It was isolated from gelatin by Fischer in 1902. Recently, a dihydroxyproline was isolated from the protein material of the cell walls of the diatom *Navicula pelliculosa* (Nakajima & Volcani, 1969). The X-ray analysis was undertaken in order to confirm the structural formula of this new naturally occurring amino acid and to compare its structure with that determined for proline (Kayushina & Vainshtein, 1966) and hydroxyproline (Donohue & Trueblood, 1952). A preliminary report on the structure and mass spectrum of dihydroxyproline has been published (Karle, Daly & Witkop, 1969).

Experimental

Crystals in the form of colorless acicular prisms were provided by Dr B. E. Volcani of the Scripps Institute of Oceanography. The largest of these was selected for the X-ray analysis. Even though the cross-section of