

# Solid-state Structures of *cis*- and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines [1,2]

John Philip Tarburton, Cynthia S. Day, Victor W. Day,\*

Iraj Tavaniepour and Norman H. Cromwell\*

Department of Chemistry, University of Nebraska,

Lincoln, Nebraska 68588

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Solid-state structures have been determined for *cis*- and *trans*-1-cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines using single-crystal X-ray diffraction techniques. The *cis* isomer crystallizes in the centrosymmetric monoclinic space group  $P2_1/c$  (No. 14), with  $a = 18.669(3)\text{\AA}$ ,  $b = 5.709(1)\text{\AA}$ ,  $c = 17.412(2)\text{\AA}$ ,  $\beta = 96.29(1)^\circ$  and  $Z = 4$ ; the *trans* isomer crystallizes in the noncentrosymmetric orthorhombic space group  $Pna2_1$  (No. 33), with  $a = 17.089(2)\text{\AA}$ ,  $b = 18.729(3)\text{\AA}$ ,  $c = 5.749(1)\text{\AA}$  and  $Z = 4$ . Full-matrix least-squares refinement of the structural parameters led to the following final agreement factors:  $R_1$  (unweighted, based on  $F$ ) = 0.040 and  $R_2$  (weighted, based on  $F$ ) = 0.054 for the 2592 independent reflections of the *cis* isomer having  $2\theta_{\text{MoK}\alpha} < 55^\circ$  and  $I > 3\sigma$ , and  $R_1 = 0.033$  and  $R_2 = 0.031$  for the 1504 independent reflections of the *trans* isomer having  $2\theta_{\text{MoK}\alpha} < 55^\circ$  and  $I > 3\sigma$ . The statistically significant differences that exist between the two isomers for two bond lengths and ten bond angles ( $p < 0.05$ ) appear to be the direct result of the *p*-toluyl group orientation with respect to the cyclohexyl and phenyl substituents. In the *cis* isomer it is *anti* with respect to the *N*-cyclohexyl group and *cis* with respect to the phenyl group, whereas in the *trans* isomer it is *syn* with respect to the *N*-cyclohexyl and *trans* with respect to the phenyl group. Three-ring to carbonyl hyperconjugation is correlated with stereoelectronic interactions in the *trans* isomer. Bonding, determined by X-ray and nmr studies, is discussed for the three-membered aziridine ring proper; while bonding, determined by X-ray studies, is discussed for substituents of the aziridine ring. These aziridinyl ketone compounds are of importance as potential mammalian DNA alkylating anti-tumor agents in solid-state solid-state systems. To date only a *trans* isomer has demonstrated this biological activity in tumor-bearing rats.

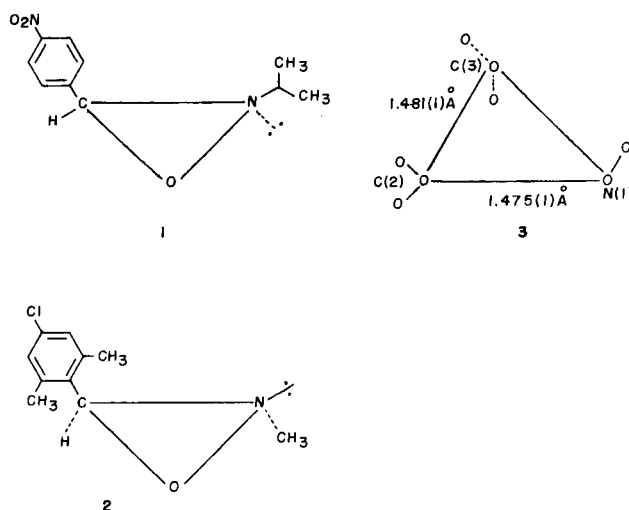
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## Introduction.

Over fourteen years have passed since the possible configurations of *cis*- and *trans*-1-alkyl-2-aryl-3-arylaziridines were tentatively assigned by pmr in our laboratories [3]. This work, wherein the 1-alkyl was assessed to be *anti* to the 2-aryl group in the *cis* isomer and *syn* to the 2-aryl group in the *trans* isomer, was later reinforced in 1978 by a  $^{13}\text{C}$  nmr study we published on these aziridines [4]. Previous ir and uv studies also supported these particular configurational assignments [5]. However, a high precision X-ray crystallographic study of these aziridines which could confirm these possible structural assignments has not appeared in the literature to date. In contradistinction, the stereochemistry of *cis*-2-isopropyl-3-(4-nitrophenyl)oxaziridine (**1**) and *trans*-2-methyl-3-(2,6-dimethyl-4-chlorophenyl)oxaziridine (**2**) has previously been rigorously established by X-ray crystallography (Scheme I) [6,7]. Unsubstituted aziridine has been well characterized by microwave techniques (**3**, Scheme I) [8].

In view of the widespread interest in *N*-membered heterocycles and compounds containing three-membered rings, it appeared that a high-precision X-ray structural study of the aforementioned aziridines would not only unambiguously establish the conformational and configurational preferences of these species but also might permit detailed assessment of more subtle structural features. Of particular interest were: (1) the spatial rela-

Scheme I



tionship of the *N*-cyclohexyl group to the carbonyl moiety which had been assigned by pmr and  $^{13}\text{C}$  nmr as '*syn*' in the *trans* isomer; (2) the structural effects, if any, of three-ring to carbonyl hyperconjugation earlier shown to be present by ir, uv and  $^{13}\text{C}$  nmr in the *trans* isomer; (3) the general nature of the bonding present in isomeric aziridines; and (4) the relationship, if any, of biological activity for this class of aziridinyl compounds to the configuration of the isomer.

Table I

Table I (continued)

Atomic Coordinates in Crystalline <i>cis</i> and <i>trans</i> -1-Cyclohexyl-2-phenyl-3-( <i>p</i> -toluyl)aziridines <b>4</b> and <b>5</b> [a,b]					Isotropic Thermal Parameters				
Atom Type [c]	Fractional Coordinates			Isotropic Thermal Parameters [d], B, Å <sup>2</sup>	Atom Type [c]	Fractional Coordinates			Isotropic Thermal Parameters [d], B, Å <sup>2</sup>
	10 <sup>3</sup> X	10 <sup>3</sup> Y	10 <sup>3</sup> Z			10 <sup>3</sup> X =	10 <sup>3</sup> Y =	10 <sup>3</sup> Z =	
O	2126(1)	5772(2)	2161(1)	4.9	H <sub>51</sub>	359(1)	91(3)	38(1)	1(1)
	3225(1)	-186(1)	0(-)[d]	4.8		52(2)	-72(2)	243(6)	3(1)
N	2810(1)	1839(2)	1509(1)	3.3	H <sub>52</sub>	384(1)	-92(3)	108(1)	2(1)
	1876(1)	-257(1)	3495(5)	4.4		70(2)	-3(2)	62(6)	3(1)
C <sub>1</sub>	1957(1)	3824(3)	2351(1)	3.6	H <sub>61</sub>	328(1)	-404(4)	33(1)	3(1)
	3320(2)	-296(1)	2081(8)	4.0		77(2)	-81(2)	-235(6)	4(1)
C <sub>2</sub>	3116(1)	1194(3)	2282(1)	3.3	H <sub>62</sub>	385(1)	-282(5)	-15(1)	5(1)
	2122(2)	471(2)	3056(8)	4.2		-7(2)	-95(2)	-122(7)	4(1)
C <sub>3</sub>	2314(1)	1674(3)	2100(1)	3.3	H <sub>71</sub>	292(1)	-64(5)	-90(1)	5(1)
	2719(2)	-72(2)	3826(6)	4.2		40(2)	-201(2)	99(8)	5(1)
C <sub>4</sub>	2737(1)	-96(3)	946(1)	3.3	H <sub>72</sub>	273(1)	-348(4)	-95(1)	4(1)
	1641(1)	-685(2)	1468(7)	4.4		48(2)	-206(2)	-202(7)	4(1)
C <sub>5</sub>	3453(1)	-557(4)	636(1)	3.9	H <sub>81</sub>	192(1)	-299(4)	-2(1)	2(1)
	771(2)	-559(2)	1021(8)	5.1		183(2)	-172(2)	-170(7)	4(1)
C <sub>6</sub>	3378(1)	-2566(5)	521(1)	5.0	H <sub>82</sub>	170(1)	-118(4)	-71(1)	4(1)
	490(2)	-1012(2)	-1015(9)	6.0		163(2)	-240(2)	19(7)	4(1)
C <sub>7</sub>	2785(1)	-2074(6)	-599(1)	5.6	H <sub>91</sub>	232(1)	191(4)	2(1)	2(1)
	658(2)	-1793(2)	-639(12)	6.8		154(2)	-159(2)	351(7)	5(1)
C <sub>8</sub>	2075(1)	-1530(5)	-286(1)	4.9	H <sub>92</sub>	171(1)	86(4)	51(1)	3(1)
	1522(2)	-1919(2)	-131(10)	6.5		235(2)	-156(1)	219(6)	4(1)
C <sub>9</sub>	2161(1)	484(4)	291(1)	4.3	H <sub>α2</sub>	380(1)	78(4)	366(1)	3(1)
	1796(2)	-1469(2)	1932(8)	5.6		212(1)	185(1)	245(5)	2(1)
C <sub>α1</sub>	3641(1)	2814(3)	2711(1)	3.3	H <sub>α3</sub>	466(1)	319(4)	436(1)	4(1)
	1828(1)	1048(1)	4622(7)	4.4		162(2)	280(2)	472(6)	4(1)
C <sub>α2</sub>	3947(1)	2218(4)	3450(1)	4.5	H <sub>α4</sub>	504(1)	675(4)	381(1)	4(1)
	1875(2)	1757(2)	3902(8)	5.4		101(2)	251(2)	836(6)	4(1)
C <sub>α3</sub>	4457(1)	3663(5)	3849(1)	5.2	H <sub>α5</sub>	455(1)	776(5)	254(1)	4(1)
	1577(2)	2296(2)	5273(9)	6.4		96(2)	130(2)	963(6)	4(1)
C <sub>α4</sub>	4670(1)	5702(4)	3514(1)	4.9	H <sub>α6</sub>	364(1)	522(4)	186(1)	2(1)
	1238(2)	2142(2)	7365(4)	6.1		145(2)	38(1)	723(6)	3(1)
C <sub>α5</sub>	4378(1)	6287(4)	2782(1)	4.6	H <sub>β2</sub>	170(1)	25(3)	333(1)	2(1)
	1193(2)	1443(2)	8114(8)	6.2		467(1)	-41(1)	0(5)	1(1)
C <sub>α6</sub>	3863(1)	4859(3)	2383(1)	4.0	H <sub>β3</sub>	74(1)	-14(4)	406(1)	3(1)
	1484(2)	897(2)	6730(7)	5.4		585(2)	-92(1)	113(6)	3(1)
C <sub>β1</sub>	1365(1)	3473(3)	2848(1)	3.2	H <sub>β5</sub>	-9(1)	609(4)	330(1)	3(1)
	4052(1)	-644(1)	2924(6)	3.7		483(2)	-153(1)	726(6)	3(1)
C <sub>β2</sub>	1318(1)	1495(3)	3302(1)	3.9	H <sub>β6</sub>	87(1)	659(4)	255(1)	2(1)
	4117(2)	-979(1)	5066(6)	4.4		369(1)	-98(1)	607(5)	2(1)
C <sub>β3</sub>	756(1)	1247(4)	3756(1)	4.6	H <sub>β71</sub>	-27(2)	255(7)	473(2)	9(1)
	4812(2)	-1310(2)	5698(7)	4.8		630(3)	-157(3)	662(1)	10(1)
C <sub>β4</sub>	224(1)	2922(4)	3753(1)	4.4	H <sub>β72</sub>	-83(2)	235(8)	394(2)	11(1)
	5457(2)	-1295(1)	4280(7)	4.5		622(2)	-212(2)	486(10)	9(1)
C <sub>β5</sub>	271(1)	4886(4)	3297(1)	4.3	H <sub>β73</sub>	-57(2)	422(8)	434(2)	11(1)
	5395(2)	-955(2)	2141(7)	4.7		663(2)	-143(2)	437(8)	7(1)
C <sub>β6</sub>	836(1)	5183(3)	2856(1)	3.9					
	4699(2)	-639(2)	1464(6)	4.3					
C <sub>β7</sub>	-408(1)	2532(7)	4221(2)	6.6					
	6228(2)	-1625(2)	4994(11)	6.4					
	10 <sup>3</sup> X =	10 <sup>3</sup> Y =	10 <sup>3</sup> Z =						
H <sub>2</sub>	320(1)	42(3)	239(1)	1(1)					
	217(1)	63(1)	142(6)	2(1)					
H <sub>3</sub>	203(1)	25(3)	209(1)	1(1)					
	287(1)	-10(1)	547(5)	1(1)					
H <sub>4</sub>	260(1)	-156(3)	120(1)	1(1)					
	193(1)	-54(1)	8(5)	1(1)					

[a] The first entry for each atom is for the *cis* isomer **4** and the second entry is for the *trans* isomer **5**. [b] Figures in parentheses are the estimated standard deviations in the last significant digit. [c] Atoms labelled in agreement with Figure 1. [d] For nonhydrogen atoms, this is the equivalent isotropic thermal parameter calculated from  $B = 4[V^2 \text{det}[\text{Bi}_i]]^{1/3}$ ; for hydrogen atoms, it is the isotropic thermal parameter actually refined.

## Results and Discussion.

The aziridines of the present study are *cis*-1-cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridine (**4**) and *trans*-1-cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridine (**5**) (see Scheme (II)). The atom labelling schemes used throughout this discussion are shown for the *cis* (**4**) and *trans* (**5**) isomers in Figure 1.

Scheme 11

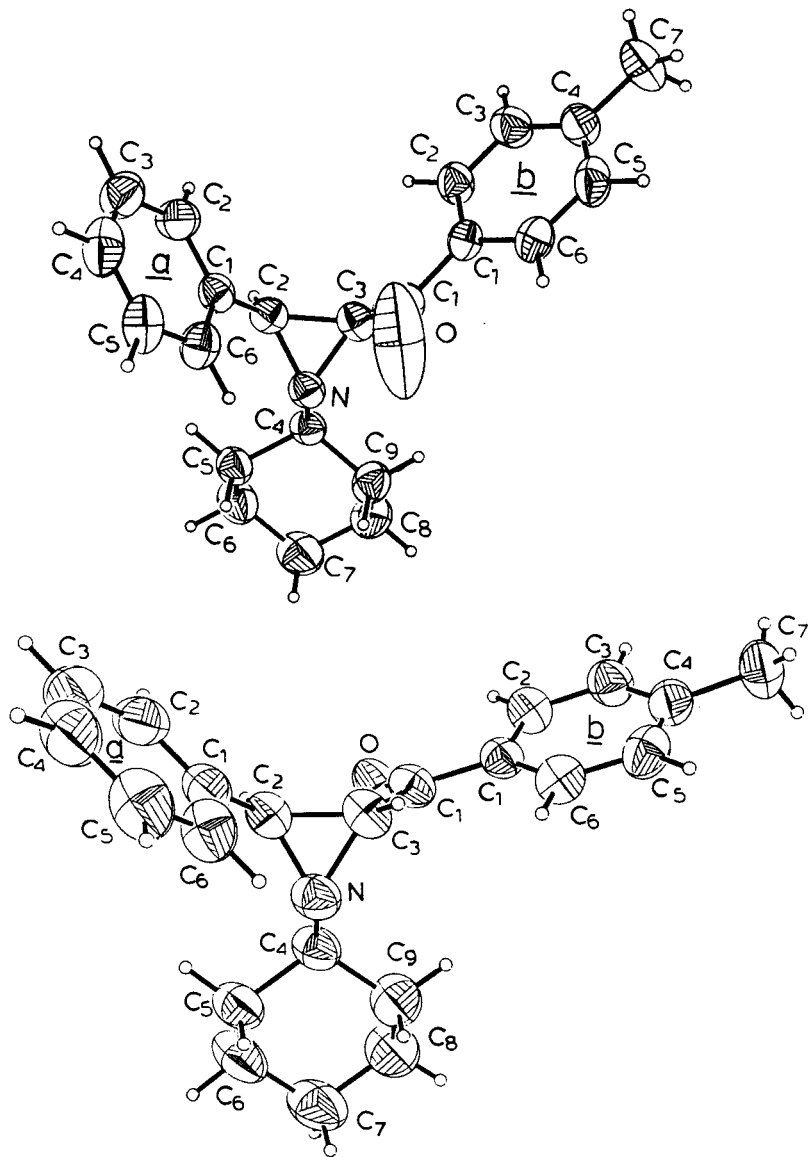
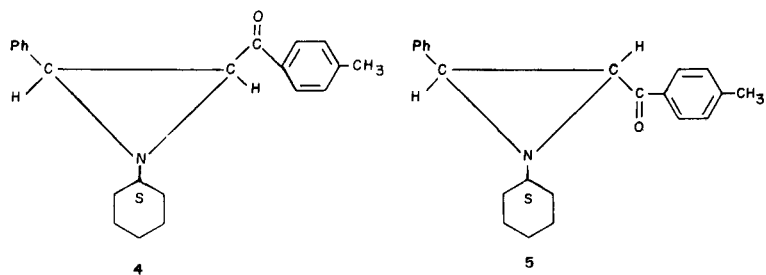


Figure 1. Perspective ORTEP drawings of the solid-state structures for the: (a) *cis*-4 and (b) *trans*-5 1-Cyclohexyl-2-phenyl-3-(*p*-toluy)aziridines. All nonhydrogen atoms are represented by thermal ellipsoids drawn to encompass 50% of the electron density; hydrogen atoms are represented by arbitrarily-sized spheres for purposes of clarity.

Table II

Anisotropic Thermal Parameters for Nonhydrogen Atoms in Crystalline *cis* and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)azridines, **4** and **5** [a,b]

Atom Type [c]	B <sub>11</sub>	B <sub>22</sub>	B <sub>33</sub>	B <sub>12</sub>	B <sub>13</sub>	Equivalent	
						B <sub>23</sub> Isotropic [d], B, Å <sup>2</sup>	B, Å <sup>2</sup>
O	6.0(1)	2.8(1)	8.7(1)	-0.1(1)	2.9(1)	1.1(1)	4.9
	4.0(1)	7.6(1)	3.7(1)	0.7(1)	-0.1(1)	-0.1(1)	4.8
N	3.3(1)	3.2(1)	3.6(1)	-0.4(1)	0.6(1)	0.2(1)	3.3
	3.9(1)	4.6(1)	5.0(1)	-0.2(1)	0.5(1)	-0.8(1)	4.4
C <sub>1</sub>	3.5(1)	3.0(1)	4.6(1)	-0.1(1)	0.4(1)	0.4(1)	3.6
	3.7(1)	4.7(1)	3.8(4)	-0.2(1)	0.0(1)	-0.6(1)	4.0
C <sub>2</sub>	3.8(1)	2.7(1)	3.6(1)	0.2(1)	0.7(1)	0.4(1)	3.3
	3.5(1)	4.9(1)	4.4(1)	0.1(1)	0.0(1)	-0.7(1)	4.2
C <sub>3</sub>	3.6(1)	2.7(1)	4.2(1)	-0.4(1)	0.9(1)	0.3(1)	3.3
	3.8(1)	5.3(1)	3.8(1)	0.2(1)	0.0(1)	-1.0(1)	4.2
C <sub>4</sub>	3.4(1)	3.3(1)	3.5(1)	-0.7(1)	0.5(1)	0.1(1)	3.3
	3.7(1)	4.8(1)	5.1(2)	-0.2(1)	0.4(1)	-1.3(1)	4.4
C <sub>5</sub>	3.4(1)	4.7(1)	3.9(1)	-0.6(1)	0.6(1)	-0.4(1)	3.9
	3.7(1)	5.7(2)	6.6(2)	-0.2(1)	0.4(1)	-1.5(2)	5.1
C <sub>6</sub>	4.5(1)	6.2(1)	5.0(1)	-0.4(1)	1.0(1)	-1.7(1)	5.0
	3.8(1)	7.9(2)	8.4(2)	-0.2(1)	-0.7(2)	-2.9(2)	6.0
C <sub>7</sub>	5.9(1)	7.8(1)	4.3(1)	-1.6(1)	0.6(1)	-1.6(1)	5.6
	5.4(2)	7.0(2)	10.3(3)	-1.0(1)	-0.5(2)	-3.4(2)	6.8
C <sub>8</sub>	4.6(1)	6.1(1)	4.6(1)	-1.2(1)	-0.5(1)	-0.4(1)	4.9
	6.2(2)	5.4(2)	9.6(3)	0.2(1)	-0.5(2)	-2.8(2)	6.5
C <sub>9</sub>	3.8(1)	4.6(1)	4.7(1)	-0.6(1)	-0.2(1)	0.3(1)	4.3
	5.6(2)	5.2(2)	6.5(2)	0.4(1)	-0.3(2)	-1.5(2)	5.6
C <sub>a1</sub>	3.2(1)	3.3(1)	3.7(1)	0.5(1)	0.7(1)	-0.2(1)	3.3
	3.4(1)	5.0(1)	5.4(1)	0.1(1)	-0.3(1)	-1.2(1)	4.4
C <sub>a2</sub>	4.8(1)	4.9(1)	3.9(1)	0.4(1)	0.6(1)	0.2(1)	4.5
	4.3(1)	5.4(1)	7.3(2)	-0.6(1)	0.1(1)	-1.3(1)	5.4
C <sub>a3</sub>	4.6(1)	7.3(1)	4.3(1)	0.8(1)	-0.3(1)	-1.0(1)	5.2
	5.4(1)	5.3(2)	9.9(3)	-0.2(1)	-0.2(2)	-2.0(2)	6.4
C <sub>a4</sub>	3.7(1)	5.6(1)	6.6(1)	0.5(1)	-0.1(1)	-2.0(1)	4.9
	5.4(2)	6.7(2)	9.0(2)	1.0(1)	-0.5(2)	-4.2(2)	6.1
C <sub>a5</sub>	3.5(1)	3.8(1)	7.1(1)	0.0(1)	0.2(1)	-0.5(1)	4.6
	6.3(2)	7.9(2)	5.8(2)	1.2(1)	-0.1(2)	-2.5(2)	6.2
C <sub>a6</sub>	3.7(1)	3.4(1)	4.9(1)	0.1(1)	0.0(1)	0.1(1)	4.0
	5.6(1)	6.1(2)	5.0(1)	0.9(1)	-0.1(1)	-1.2(1)	5.4
C <sub>b1</sub>	3.0(1)	3.0(1)	3.7(1)	0.0(1)	0.0(1)	-0.1(1)	3.2
	3.7(1)	3.6(1)	3.9(1)	-0.1(1)	-0.2(1)	-0.8(1)	3.7
C <sub>b2</sub>	3.6(1)	3.6(1)	4.6(1)	0.6(1)	0.7(1)	0.4(1)	3.9
	5.0(1)	4.5(1)	4.0(1)	0.0(1)	0.4(1)	-0.2(1)	4.4
C <sub>b3</sub>	4.7(1)	4.7(1)	4.7(1)	0.2(1)	1.2(1)	0.8(1)	4.6
	6.4(1)	4.2(1)	4.2(1)	0.4(1)	-0.5(1)	0.1(1)	4.8
C <sub>b4</sub>	3.7(1)	5.6(1)	4.4(1)	0.2(1)	0.8(1)	-0.5(1)	4.4
	5.0(1)	3.7(1)	5.5(1)	0.2(1)	-1.2(1)	-0.6(1)	4.5
C <sub>b5</sub>	3.5(1)	4.8(1)	5.5(1)	1.2(1)	0.2(1)	-0.7(1)	4.3
	3.9(1)	5.0(1)	5.3(1)	0.2(1)	0.4(1)	-0.2(1)	4.7
C <sub>b6</sub>	3.8(1)	3.5(1)	4.6(1)	0.5(1)	-0.1(1)	0.1(1)	3.9
	4.3(1)	4.9(1)	3.7(1)	0.1(1)	0.0(1)	-0.2(1)	4.3
C <sub>b7</sub>	5.0(2)	10.5(2)	7.1(2)	0.7(2)	2.8(2)	-0.3(2)	6.6
	5.8(2)	6.0(2)	8.9(3)	1.3(1)	-2.3(2)	0.2(2)	6.4

[a] The first entry for each atom is for the *cis* isomer **4** and the second entry is for the *trans* isomer **5**. [b] Numbers in parentheses are estimated standard deviations in the last significant figure. Anisotropic temperature factors are of the form  $\exp [-(\beta_{11}h^2 + \beta_{22}k^2 + \beta_{33}l^2 + 2\beta_{12}hk + 2\beta_{13}hl + 2\beta_{23}kl)]$ ; the  $\beta_{ij}$  in Å<sup>2</sup> are related to the dimensionless  $\beta_{ij}$  employed during refinement as  $\beta_{ij} = 4\beta_{ij}/a_i^*a_j^*$ . [c] Atoms are labelled in agreement with Figure 1. [d] Isotropic thermal parameter calculated from  $B = 4[V^2 \det(\beta_{ij})]^{1/3}$ .

Final atomic coordinates and thermal parameters resulting from the X-ray structural analyses of crystalline **4** and **5** are presented in Tables I and II. Detailed comparisons of covalent bond lengths and angles involving nonhydrogen atoms in **4** and **5** are presented in Tables III

and IV, respectively. Corresponding listings of covalent bond lengths and angles involving hydrogen atoms are presented in Tables VI and VII, respectively [9].

As can be seen from Figure 1, our findings unambiguously confirm for the first time the earlier configura-

Table III

Covalent Bond Lengths (Å) for Nonhydrogen Atoms in Crystalline *cis* and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines, **4** and **5** [a]

Type [b]	4	5
O-C <sub>1</sub>	1.212(2)	1.224(5)
N-C <sub>2</sub>	1.451(2)	1.450(3)
N-C <sub>3</sub>	1.462(2)	1.494(3)
N-C <sub>4</sub>	1.473(2)	1.470(4)
Average	1.462(2,11,11,3) [c]	1.471(3,15,23,3) [c]
C <sub>1</sub> -C <sub>b1</sub>	1.490(2)	1.491(4)
C <sub>a1</sub> -C <sub>a2</sub>	1.392(3)	1.393(4)
C <sub>a1</sub> -C <sub>a6</sub>	1.384(3)	1.376(5)
C <sub>a2</sub> -C <sub>a3</sub>	1.387(3)	1.378(5)
C <sub>a3</sub> -C <sub>a4</sub>	1.380(4)	1.366(6)
C <sub>a4</sub> -C <sub>a5</sub>	1.371(3)	1.380(5)
C <sub>a5</sub> -C <sub>a6</sub>	1.387(3)	1.387(5)
C <sub>b1</sub> -C <sub>b2</sub>	1.386(2)	1.386(4)
C <sub>b1</sub> -C <sub>b6</sub>	1.390(2)	1.389(4)
C <sub>b2</sub> -C <sub>b3</sub>	1.389(3)	1.388(4)
C <sub>b3</sub> -C <sub>b4</sub>	1.379(3)	1.372(4)
C <sub>b4</sub> -C <sub>b5</sub>	1.381(3)	1.389(4)
C <sub>b5</sub> -C <sub>b6</sub>	1.382(3)	1.385(4)
Average	1.384(3,5,13,12) [c]	1.382(5,7,16,12) [c]
C <sub>1</sub> -C <sub>3</sub>	1.486(2)	1.496(4)
C <sub>a1</sub> -C <sub>3</sub>	1.487(2)	1.494(4)
C <sub>b4</sub> -C <sub>b7</sub>	1.521(3)	1.512(4)
Average	1.498(2,15,23,3) [c]	1.501(4,8,11,3) [c]
C <sub>2</sub> -C <sub>3</sub>	1.521(2)	1.506(4)
C <sub>4</sub> -C <sub>5</sub>	1.519(2)	1.526(4)
C <sub>4</sub> -C <sub>9</sub>	1.517(3)	1.516(5)
C <sub>5</sub> -C <sub>6</sub>	1.529(3)	1.523(5)
C <sub>6</sub> -C <sub>7</sub>	1.521(3)	1.506(5)
C <sub>7</sub> -C <sub>8</sub>	1.520(3)	1.523(5)
C <sub>8</sub> -C <sub>9</sub>	1.523(3)	1.529(5)
Average	1.523(3,2,8,7) [c]	1.518(5,8,12,7) [c]

[a] Figures in parentheses are the estimated standard deviations in the last significant digit. [b] Atoms labelled in agreement with Figure 1. [c] The first number in parentheses following an average value is the root mean square estimated standard deviation of an individual datum. The second and third numbers are the average and maximum deviations from the average value, respectively. The fourth number is the number of individual values used to determine the average value.

tional assignments made for *cis*- and *trans*-1-alkyl-2-aryl-3-arylaziridines by pmr and <sup>13</sup>C nmr [3,4], *i.e.* the differences between *cis* (**4**) and *trans* (**5**) result from different orientations of the C<sub>3</sub>-toluyl group with respect to the cyclohexyl and phenyl substituents: in the *cis* isomer **4** it is *anti* with respect to the *N*-cyclohexyl group and *cis* with respect to the C<sub>2</sub>-phenyl group, whereas in the *trans* isomer **5** it is *syn* with respect to the *N*-cyclohexyl and *trans* with respect to the C<sub>2</sub>-phenyl group. These different relative orientations appear to produce unfavorable steric interactions in both forms which manifest themselves in a slight lengthening of certain bonds within the aziridine ring. For example, in **4** the short C<sub>1</sub>...C<sub>A1</sub> contact (3.19(3) Å *vs.* the van der Waals value of 3.40 Å [10]) results in a 0.040 Å lengthening of the C<sub>2</sub>-C<sub>3</sub> bond relative

Table IV

Bond Angles (deg) for Nonhydrogen Atoms in Crystalline *cis* and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines, **4** and **5** [a]

Type [b]	4	5
C <sub>2</sub> NC <sub>3</sub>	62.9(1)	61.5(2)
C <sub>2</sub> NC <sub>4</sub>	115.2(1)	117.0(2)
C <sub>3</sub> NC <sub>4</sub>	113.6(1)	119.4(2)
OC <sub>1</sub> C <sub>3</sub>	122.6(2)	121.2(3)
OC <sub>1</sub> C <sub>b1</sub>	120.9(2)	120.1(3)
C <sub>3</sub> C <sub>1</sub> C <sub>b1</sub>	116.4(1)	118.7(3)
C <sub>2</sub> C <sub>a1</sub> C <sub>a2</sub>	119.6(2)	119.4(3)
C <sub>2</sub> C <sub>a1</sub> C <sub>a6</sub>	121.9(2)	121.7(3)
C <sub>b7</sub> C <sub>b4</sub> C <sub>b3</sub>	119.8(2)	122.1(3)
C <sub>b7</sub> C <sub>b4</sub> C <sub>b5</sub>	121.8(2)	119.6(3)
NC <sub>2</sub> C <sub>3</sub>	58.9(1)	60.7(2)
NC <sub>3</sub> C <sub>4</sub>	58.2(1)	57.8(2)
NC <sub>4</sub> C <sub>5</sub>	110.2(1)	108.4(2)
NC <sub>4</sub> C <sub>9</sub>	110.1(2)	109.9(3)
C <sub>5</sub> C <sub>4</sub> C <sub>9</sub>	110.5(2)	110.5(3)
C <sub>4</sub> C <sub>5</sub> C <sub>6</sub>	110.2(2)	110.5(3)
C <sub>5</sub> C <sub>6</sub> C <sub>7</sub>	111.3(2)	111.7(4)
C <sub>6</sub> C <sub>7</sub> C <sub>8</sub>	111.2(2)	111.4(3)
C <sub>7</sub> C <sub>8</sub> C <sub>9</sub>	111.0(2)	111.1(3)
C <sub>8</sub> C <sub>9</sub> C <sub>4</sub>	110.2(2)	110.1(3)
NC <sub>3</sub> C <sub>1</sub>	119.6(1)	120.8(2)
NC <sub>2</sub> C <sub>a1</sub>	118.6(1)	118.5(3)
C <sub>1</sub> C <sub>3</sub> C <sub>2</sub>	123.4(2)	117.2(3)
C <sub>a1</sub> C <sub>2</sub> C <sub>3</sub>	124.9(1)	122.6(3)
C <sub>a2</sub> C <sub>a1</sub> C <sub>a6</sub>	118.4(2)	118.8(3)
C <sub>a1</sub> C <sub>a2</sub> C <sub>a3</sub>	120.5(2)	120.4(4)
C <sub>a2</sub> C <sub>a3</sub> C <sub>a4</sub>	120.2(2)	120.4(4)
C <sub>a3</sub> C <sub>a4</sub> C <sub>a5</sub>	119.7(2)	119.9(3)
C <sub>a4</sub> C <sub>a5</sub> C <sub>a6</sub>	120.4(2)	120.0(4)
C <sub>a5</sub> C <sub>a6</sub> C <sub>a1</sub>	120.8(2)	120.5(3)
C <sub>1</sub> C <sub>b1</sub> C <sub>b2</sub>	122.5(1)	123.7(3)
C <sub>1</sub> C <sub>b1</sub> C <sub>b6</sub>	119.0(2)	117.9(3)
C <sub>b2</sub> C <sub>b1</sub> C <sub>b6</sub>	118.5(2)	118.4(3)
C <sub>b1</sub> C <sub>b2</sub> C <sub>b3</sub>	120.4(2)	120.2(3)
C <sub>b2</sub> C <sub>b3</sub> C <sub>b4</sub>	121.0(2)	121.5(3)
C <sub>b3</sub> C <sub>b4</sub> C <sub>b5</sub>	118.3(2)	118.3(3)
C <sub>b3</sub> C <sub>b4</sub> C <sub>b7</sub>	119.8(2)	122.1(3)
C <sub>b5</sub> C <sub>b4</sub> C <sub>b7</sub>	121.8(3)	119.6(3)
C <sub>b4</sub> C <sub>b5</sub> C <sub>b6</sub>	121.2(2)	120.7(3)
C <sub>b5</sub> C <sub>b6</sub> C <sub>b1</sub>	120.4(2)	120.7(3)
C <sub>b4</sub> C <sub>b7</sub> H <sub>b71</sub>	111(2)	110(3)
C <sub>b4</sub> C <sub>b7</sub> H <sub>b72</sub>	114(3)	111(3)
C <sub>b4</sub> C <sub>b7</sub> H <sub>b73</sub>	104(2)	114(3)
H <sub>b71</sub> C <sub>b7</sub> H <sub>b72</sub>	134(4)	101(4)
H <sub>b71</sub> C <sub>b7</sub> H <sub>b73</sub>	82(3)	105(4)
H <sub>b72</sub> C <sub>b7</sub> H <sub>b73</sub>	87(3)	114(3)

[a] Figures in parentheses are the estimated standard deviation in the last significant digit. [b] Atoms labelled in agreement with Figure 1.

to unsubstituted aziridine (1.521(2) Å *vs.* 1.481(1) Å). Similarly, in **5** a short O...H<sub>4</sub> contact (2.31(2) Å *vs.* the van der Waals value of 2.60 Å [10]) results in a statistically significant (*p* < 0.05) 0.019 Å C<sub>3</sub>-N bond lengthening relative to unsubstituted aziridine **3** (1.494(3) Å *vs.* 1.475(1) Å). In support of the latter finding, the 8.2 Hz <sup>1</sup>J(<sup>15</sup>N, <sup>13</sup>C) coupling constant for the C<sub>3</sub>-N bond is consistently greater than the other (endocyclic) C-N couplings

Table V

Spin-spin Coupling Constants of *cis*- and *trans*-1-Cyclohexyl-2-phenyl-3-benzoylaziridines, **4**<sup>1</sup> and **5**<sup>1</sup> [a,b]

	<i>cis</i> <b>4</b> <sup>1</sup> , in Hz	<i>trans</i> <b>5</b> <sup>1</sup> , in Hz
<sup>1</sup> J(C <sub>2</sub> -C <sub>3</sub> )	14.6	18.0
<sup>1</sup> J(C <sub>2</sub> -N)	7.8	5.2
<sup>1</sup> J(C <sub>3</sub> -N)	7.3	8.2
<sup>1</sup> J(C <sub>2</sub> -H)	164	166
<sup>1</sup> J(C <sub>3</sub> -H)	162	177

[a] For the determination of these coupling constants see references [2] and [4]. [b] Here, we are talking about coupling of <sup>13</sup>C to <sup>13</sup>C, <sup>13</sup>C to <sup>15</sup>N and <sup>13</sup>C to <sup>1</sup>H.

Table VI

Covalent Bond Lengths (Å) Involving Hydrogen Atoms in Crystalline *cis* and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines, **4** and **5** [a]

Type [b]	<b>4</b>	<b>5</b>
C <sub>α2</sub> -H <sub>α2</sub>	0.95(2)	0.95(3)
C <sub>α3</sub> -H <sub>α3</sub>	0.96(2)	1.00(3)
C <sub>α4</sub> -H <sub>α4</sub>	1.01(2)	0.97(3)
C <sub>α5</sub> -H <sub>α5</sub>	1.01(3)	1.00(3)
C <sub>α6</sub> -H <sub>α6</sub>	0.97(2)	1.00(3)
C <sub>β2</sub> -H <sub>β2</sub>	1.01(2)	0.92(3)
C <sub>β3</sub> -H <sub>β3</sub>	0.96(2)	0.99(3)
C <sub>β5</sub> -H <sub>β5</sub>	0.96(2)	0.97(3)
C <sub>β6</sub> -H <sub>β6</sub>	0.97(2)	0.94(3)
C <sub>2</sub> -H <sub>2</sub>	0.95(2)	0.99(3)
C <sub>3</sub> -H <sub>3</sub>	0.97(2)	0.98(3)
C <sub>4</sub> -H <sub>4</sub>	0.99(2)	0.98(3)
C <sub>5</sub> -H <sub>51</sub>	0.99(2)	0.96(3)
C <sub>5</sub> -H <sub>52</sub>	1.02(2)	1.03(3)
C <sub>6</sub> -H <sub>61</sub>	1.00(2)	0.98(3)
C <sub>6</sub> -H <sub>62</sub>	1.00(3)	0.97(3)
C <sub>7</sub> -H <sub>71</sub>	1.01(2)	1.11(4)
C <sub>7</sub> -H <sub>72</sub>	1.02(3)	0.99(4)
C <sub>8</sub> -H <sub>81</sub>	1.01(2)	1.11(4)
C <sub>8</sub> -H <sub>82</sub>	0.98(2)	0.94(3)
C <sub>9</sub> -H <sub>91</sub>	1.01(2)	1.04(4)
C <sub>9</sub> -H <sub>92</sub>	0.98(2)	0.97(3)
C <sub>67</sub> -H <sub>671</sub>	0.90(4)	0.95(6)
C <sub>67</sub> -H <sub>672</sub>	0.89(4)	0.92(4)
C <sub>67</sub> -H <sub>673</sub>	1.04(5)	0.86(4)
Average	0.98(3,2,9,25)	0.98(3,4,13,25) [c]

[a] Figures in parentheses are the estimated standard deviations in the last significant digit. [b] Atoms labelled in agreement with Figure 1. [c] The first number in parentheses following an average value is the root mean square estimated standard deviation of an individual datum. The second and third numbers are the average and maximum deviations from the average value, respectively. The fourth number is the number of individual values used to determine the average value.

in **4**<sup>1</sup> and **5**<sup>1</sup> (see Table V) as well as the 7.6 Hz value of aziridine itself [2,12,13].

Therefore the major differences in metrical parameters between these two isomers involve the C<sub>2</sub>-C<sub>3</sub> and N-C<sub>3</sub> bonds; these can be attributed to different types of contacts between the C<sub>3</sub>-toluyl and phenyl or cyclohexyl

Table VII

Bond Angles (deg) Involving Hydrogen Atoms in Crystalline *cis* and *trans*-1-Cyclohexyl-2-phenyl-3-(*p*-toluyl)aziridines, **4** and **5** [a]

Type [b]	<b>4</b>	<b>5</b>
NC <sub>2</sub> H <sub>2</sub>	118(1)	118(2)
C <sub>3</sub> C <sub>2</sub> H <sub>2</sub>	111(1)	115(2)
C <sub>α1</sub> C <sub>2</sub> H <sub>2</sub>	114(1)	113(2)
NC <sub>3</sub> H <sub>3</sub>	115(1)	111(1)
C <sub>2</sub> C <sub>3</sub> H <sub>3</sub>	112(1)	119(1)
C <sub>1</sub> C <sub>3</sub> H <sub>3</sub>	116(1)	117(1)
NC <sub>4</sub> H <sub>4</sub>	111(1)	111(2)
C <sub>5</sub> C <sub>4</sub> H <sub>4</sub>	107(1)	108(2)
C <sub>9</sub> C <sub>4</sub> H <sub>4</sub>	108(1)	109(2)
C <sub>4</sub> C <sub>5</sub> H <sub>51</sub>	107(1)	104(2)
C <sub>4</sub> H <sub>5</sub> H <sub>52</sub>	110(1)	108(2)
C <sub>6</sub> C <sub>5</sub> H <sub>51</sub>	110(1)	109(2)
C <sub>6</sub> C <sub>5</sub> H <sub>52</sub>	111(1)	109(2)
H <sub>51</sub> C <sub>5</sub> H <sub>52</sub>	108(2)	116(3)
C <sub>6</sub> C <sub>6</sub> H <sub>61</sub>	108(1)	104(2)
C <sub>5</sub> C <sub>6</sub> H <sub>62</sub>	109(2)	110(2)
C <sub>7</sub> C <sub>6</sub> H <sub>61</sub>	112(1)	113(2)
C <sub>7</sub> C <sub>6</sub> H <sub>62</sub>	111(1)	109(2)
H <sub>61</sub> C <sub>6</sub> H <sub>62</sub>	105(2)	110(3)
C <sub>6</sub> C <sub>7</sub> H <sub>71</sub>	109(1)	113(2)
C <sub>6</sub> C <sub>7</sub> H <sub>72</sub>	110(2)	108(2)
C <sub>8</sub> C <sub>7</sub> H <sub>71</sub>	111(1)	100(2)
C <sub>8</sub> C <sub>7</sub> H <sub>72</sub>	107(2)	112(2)
H <sub>71</sub> C <sub>7</sub> H <sub>72</sub>	109(2)	112(2)
C <sub>7</sub> C <sub>8</sub> H <sub>81</sub>	107(1)	104(2)
C <sub>7</sub> C <sub>8</sub> H <sub>82</sub>	111(1)	112(2)
C <sub>9</sub> C <sub>8</sub> H <sub>81</sub>	110(1)	108(2)
C <sub>9</sub> C <sub>8</sub> H <sub>82</sub>	111(1)	109(2)
H <sub>81</sub> C <sub>8</sub> H <sub>82</sub>	107(2)	113(3)
C <sub>8</sub> C <sub>9</sub> H <sub>91</sub>	108(1)	115(2)
C <sub>8</sub> C <sub>9</sub> H <sub>92</sub>	113(1)	109(2)
C <sub>4</sub> C <sub>9</sub> H <sub>91</sub>	108(1)	107(2)
C <sub>4</sub> C <sub>9</sub> H <sub>92</sub>	109(1)	111(2)
H <sub>91</sub> C <sub>9</sub> H <sub>92</sub>	108(2)	104(3)
C <sub>α1</sub> C <sub>α2</sub> H <sub>α2</sub>	118(1)	118(2)
C <sub>α3</sub> C <sub>α2</sub> H <sub>α2</sub>	122(1)	122(2)
C <sub>α2</sub> C <sub>α3</sub> H <sub>α3</sub>	118(1)	119(2)
C <sub>α4</sub> C <sub>α3</sub> H <sub>α3</sub>	122(1)	121(2)
C <sub>α3</sub> C <sub>α4</sub> H <sub>α4</sub>	120(1)	123(2)
C <sub>α5</sub> C <sub>α4</sub> H <sub>α4</sub>	120(1)	117(2)
C <sub>α4</sub> C <sub>α5</sub> H <sub>α5</sub>	118(1)	123(2)
C <sub>α6</sub> C <sub>α5</sub> H <sub>α5</sub>	121(1)	117(2)
C <sub>α5</sub> C <sub>α6</sub> H <sub>α6</sub>	123(1)	121(2)
C <sub>α1</sub> C <sub>α6</sub> H <sub>α6</sub>	117(1)	118(2)
C <sub>β1</sub> C <sub>β2</sub> H <sub>β2</sub>	121(1)	120(2)
C <sub>β3</sub> C <sub>β2</sub> H <sub>β2</sub>	118(1)	120(2)
C <sub>β2</sub> C <sub>β3</sub> H <sub>β3</sub>	118(1)	117(2)
C <sub>β4</sub> C <sub>β3</sub> H <sub>β3</sub>	121(1)	122(3)
C <sub>β4</sub> C <sub>β5</sub> H <sub>β5</sub>	119(1)	120(2)
C <sub>β6</sub> C <sub>β5</sub> H <sub>β5</sub>	119(1)	119(2)
C <sub>β5</sub> C <sub>β6</sub> H <sub>β6</sub>	121(1)	120(1)
C <sub>β1</sub> C <sub>β6</sub> H <sub>β6</sub>	119(1)	120(1)

[a] Figures in parentheses are the estimated standard deviation in the last significant digit. [b] Atoms labelled in agreement with Figure 1.

substituents, respectively. Furthermore, as can be seen from Figure 1, the C<sub>3</sub>-toluyl substituent has dramatically different orientations with respect to these two bonds of

the aziridine ring. In the *trans* isomer **5** the plane containing the C<sub>3</sub>-toluyl substituent is more closely aligned with the C<sub>2</sub>-C<sub>3</sub> bond whereas in the *cis* isomer **4** it is more closely aligned with the N-C<sub>3</sub> bond.

The steric compression shift of -10.4 ppm observed in <sup>13</sup>C nmr for the C<sub>4</sub> carbon in the *trans* isomer **5** [4] is presumably due to the short O...H<sub>4</sub> contact caused by the desire of the O-C<sub>1</sub>-C<sub>3</sub>-C<sub>2</sub>-C<sub>1A</sub> grouping to be nearly coplanar. This coplanarity is probably the result of three-ring-to-carbonyl hyperconjugation involving the carbonyl and C<sub>2</sub>-C<sub>3</sub> bonds in **5**. This hyperconjugation serves to significantly shorten (*p* < 0.05) the C<sub>2</sub>-C<sub>3</sub> bond in **5** relative to **4** (1.506(4) Å vs. 1.521(3) Å). In agreement with these findings are the one-bond, carbon-carbon (C<sub>2</sub>-C<sub>3</sub>) coupling constants of *J* = 14.6 Hz for the *cis* **4**<sup>1</sup> and *J* = 18.0 Hz for the *trans*-**5**<sup>1</sup> aziridine ring carbons listed in Table V. Further, both **4** and **5** have longer endocyclic C-C bonds than the 1.475(1) Å value of aziridine (**3**) itself owing to 'substituent effects.' This comparison between endocyclic bonds in aziridines **4** and **5** therefore appears meaningful and is further reinforced by the significant (*p* < 0.05) differences in values for ten bond angles involving the aziridine rings and directly attached substituents (see Table IV).

To reiterate, the short intramolecular contact produced by the C<sub>3</sub>-toluyl oxygen abutting into H<sub>4</sub> is apparently responsible for an increased steric congestion in **5**, *i.e.* the sum of the bond lengths in ring **5** is 0.016 Å greater than in ring **4**, and is principally the result of C<sub>3</sub>-N bond lengthening in **5** relative to **4** since such a contact cannot exist in **4**. Hence, the *trans* **5** is most probably locked into this particular steric configuration (see Figure 1) because of electronic effects with respect to the ring. This may well explain why the *trans* isomer is less thermodynamically stable than the *cis* isomer of 1-alkyl-2-aryl-3-arylaziridines even when the 1-alkyl group is methyl [14]. Hence, if the solid state structure is indicative of solution studies wherein hyperconjugation locks the C<sub>3</sub>-toluyl group into juxtaposition with an *N*-alkyl- $\alpha$ -hydrogen the size of the alkyl group would only be a factor for tertiary *N*-alkyl groups. Interestingly, only the *cis* isomers of 1-*t*-butyl-2-aryl-3-benzoylaziridines have been successfully synthesized in our laboratories [15].

Except for the endocyclic bonds discussed above, the metrical parameters for **4** and **5** are rather unexceptional. The twelve independent sp<sup>2</sup>-sp<sup>2</sup> phenyl carbon-carbon bonds have average lengths of 1.384 (3,5,13,12) Å and 1.382 (5,7,6,12) Å in **4** and **5**, respectively [16]; these are in close agreement with the generally accepted value of 1.397 Å. The C-H bonds in **4** and **5** have average values of 0.98 (3,2,9,25) Å and 0.98 (3,4,13,5) Å, [16], respectively; these are in excellent agreement with values determined for high-precision X-ray studies of compounds containing

similar bonds [17]. The sp<sup>3</sup>-sp<sup>3</sup> carbon-carbon bond length averages of 1.521 (3,2,8,6) Å and 1.518 (5,8,12,6) Å [16] for **4** and **5**, respectively, fall within the acceptable range for this type of bond (*cf.* Tables III and VI [9]). The remainder of the endocyclic bonds in **4** and **5** have lengths which are nearly identical and essentially those which would be

predicted from tabulated values of covalent radii. For instance, the C<sub>4</sub>-N bond lengths of 1.473(2), and 1.470(4) Å in **4** and **5**, respectively, are in excellent agreement with the value of 1.47 Å predicted [17] for an sp<sup>3</sup>-N type. In the *cis* isomer distances of 1.486(2) Å and 1.487(2) Å are observed for the C<sub>3</sub>-C<sub>1</sub> and C<sub>2</sub>-C<sub>a1</sub> bond lengths. These are nearly identical to the theoretical sp<sup>2</sup>-sp<sup>2</sup> single C-C bond length of 1.486 Å [17]. These same bonds are slightly longer in **5** and this lengthening appears to be due to increased "p" character for the ring carbon atoms. The C<sub>3</sub>-C<sub>1</sub> and C<sub>2</sub>-C<sub>a1</sub> bond lengths of 1.486(2) Å and 1.487(2) Å in **5** would seem to indicate a formal sp<sup>2.5</sup> hybridization for C<sub>2</sub> and C<sub>3</sub> since the sp<sup>2</sup> and sp<sup>3</sup> hybridized covalent single bond radii for carbon are 0.743 Å and 0.772 Å, respectively. The solution nmr data are also consistent with such an interpretation.

The values obtained by X-ray diffraction for distances of the endocyclic bonds cannot be easily related to hybridization as we are dealing with internuclear and *not* interorbital distances. However, as depicted in Table V, coupling constants have been assessed by nmr studies of **4**<sup>1</sup> and **5**<sup>1</sup>. In the case of the <sup>1</sup>J(C<sub>2</sub>-C<sub>3</sub>) couplings the percentage of "s" character is directly proportional to the coupling constant as depicted in equation 1 [18]:

$${}^1J(C_2C_3) = 0.06121(\%S_{C_2}) (\%S_{C_3}) - 10.2 \text{ Hz (1)}$$

However, as carbon atoms C<sub>2</sub> and C<sub>3</sub> are *not* equivalent, a precise measurement of "s" character is not possible in this instance. On the other hand, for cyclopropane a value of 16 Hz was calculated for carbon-carbon coupling while a somewhat lower value of 10 Hz was observed for the carboxylic acid of cyclopropane [19]. Needless to say, the *cis* and *trans* aziridines both possess additional "p" character in their C<sub>2</sub>-C<sub>3</sub> bond above that expected for a normal sp<sup>3</sup> C-C bond. Further, the <sup>1</sup>J (<sup>15</sup>N, <sup>13</sup>C) values obtained are indicative of high "p" character in the endocyclic C<sub>2</sub>-N and C<sub>3</sub>-N bonds; INDO-MO calculations of Wasylishen [11] have indicated approximately 80% "p" character. To compensate for this increased "p" character, it is suspected that the external orbitals have elevated "s" character. In fact, using equation 2 one may approximate the percent "s" character in C<sub>2</sub>-H and C<sub>3</sub>-H [18]:

$${}^1J_{CH} = 5.70 (\%S) - 18.4 \text{ Hz (2)}$$

Here, for the *cis* isomer "s" character of 31.7% and 31.8% were calculated for C<sub>2</sub>-H and C<sub>3</sub>-H, respectively. In the *trans* isomer values of 34.3% and 32.4% "s"

character were obtained for the C<sub>2</sub>-H and C<sub>3</sub>-H orbitals. Further, as discussed above, the exocyclic C<sub>2</sub> and C<sub>3</sub> orbitals were approximated as sp<sup>2</sup> in the *cis* compound for the C<sub>2</sub>-Ca<sub>1</sub> and C<sub>3</sub>-C<sub>1</sub> bonds and as sp<sup>2.5</sup> in the *trans* compound for these same bonds. On the other hand, the C<sub>4</sub>-N bond was assigned as sp<sup>3</sup>-N in both isomers. It is possible, however, that the one pair at nitrogen maintains high "s" character, thus permitting greater "p" character in all bonding orbitals at nitrogen [20,21]. However, a more recent <sup>13</sup>C nmr assessment of the lone pair at nitrogen in *N*-benzoylaziridine is that it is pyramidal [22].

Since some of our aziridinyl carbonyl compounds have shown anti-tumor activity [23], there appeared to be some impetus to find a relationship, if any, between configuration and biological activity. For example, it has been shown that selected aziridine-containing antibiotics of specific configuration possess potent anti-tumor activity. Carzinophilin A, which appears to function as a bisalkylating agent towards DNA, contains aziridine rings with an *anti* configuration [24-26]. Mitomycin C which also acts as an anticancer antibiotic contains a fused aziridine ring in the *cis* configuration as does Mitomycin B [27,28]. Our aziridinyl carbonyl compounds are presently being investigated by the National Cancer Institute for biological activity. This includes mammalian alkylation studies of DNA in tumor-bearing rats. They have reported anti-tumor action for some of the *trans* isomers in solid-state solid-state systems, *i.e.* water suspensions of the drugs in contact with cancer cells [23].

## EXPERIMENTAL

### Crystallographic Analyses.

Large well-shaped yellow parallelepiped-shaped single crystals of the known compounds [29] *cis*-**4** and *trans*-1-cyclohexyl-2-phenyl-3-(*p*-toluyl)-aziridine (**5**) (both C<sub>22</sub>H<sub>25</sub>NO, molecular weight 319.45) suitable for X-ray diffraction studies, were recrystallized from benzene and absolute ethanol, respectively. Single crystals of the *cis* isomer **4** crystallize in the centrosymmetric monoclinic space group P<sub>2</sub>/c-C<sub>2</sub>h (No. 14) [30a] with *a* = 18.669 (3) Å, *b* = 5.709 (1) Å, *c* = 17.412 (2) Å, β = 96.29 (1)° and *Z* = 4 [*d*<sub>calcd</sub> = 1.150 g cm<sup>-3</sup>, *d*<sub>measd</sub> = 1.147 g cm<sup>-3</sup>, and μ<sub>a</sub> (MoKα) [31] = 0.8 mm<sup>-1</sup>]. Single crystals of the *trans* isomer **5** crystallize in the noncentrosymmetric orthorhombic space group Pna<sub>2</sub>1-C<sub>2</sub>v (No. 33) [30b] with *a* = 17.089 (2) Å, *b* = 18.729 (3) Å, *c* = 5.749 (1) Å and *Z* = 4 [*d*<sub>calcd</sub> = 1.153 g cm<sup>-3</sup>, *d*<sub>measd</sub> = 1.146 g cm<sup>-3</sup>, and μ<sub>a</sub> (MoKα) [31] = 0.8 mm<sup>-1</sup>].

Intensity measurements were made on a Nicolet PI autodiffractometer using 1.00°-wide ω scans and graphite-monochromated MoKα radiation for specimens having the shapes of rectangular parallelepipeds with dimensions of 0.69 x 0.56 x 0.31 mm for **4** and 0.69 x 0.50 x 0.30 mm for **5**. Totals of 4247 (**4**) and 2335 (**5**) independent reflections having 2θ<sub>MoKα</sub> < 55° were measured in two concentric, approximately equal volume shells, for each compound. The scan for each reflection of both compounds was between ω settings 0.50° above and below the calculated Kα doublet value (λKα = 0.71073 Å). Counts were accumulated for 19 equal time intervals during each scan and those 13 contiguous intervals which had the highest single accumulated count at their midpoint were used to calculate the net intensity from scanning. Background counts for both compounds, each lasting for one-half of the total scan time used for the net scan (13/19th of the total scan time), were measured at ω settings

1.0° above and below the calculated Kα doublet value for each reflection. Scanning rates of 3°/minute (**4**) and 2°/minute (**5**) were used for reflections having 0° < 2θ<sub>MoKα</sub> < 43°; rates of 2°/minute (**4**) and 1°/minute (**5**) were used for reflections having 43° < 2θ<sub>MoKα</sub> < 55°. The intensities for both compounds were reduced without absorption corrections to relative squared amplitudes, |F<sub>o</sub>|<sup>2</sup>, by means of standard Lorentz and polarization corrections.

The 24 nonhydrogen atoms of both compounds were located using direct methods (MULTAN) and difference Fourier techniques. All chemically anticipated hydrogen atoms for both molecules were located from difference Fourier syntheses calculated from the appropriate full-matrix least-squares refined structural model [*R*<sub>1</sub> (unweighted, based on *F*) [32] = 0.098 and 0.078 for **4** and **5**, respectively] which incorporated unit-weighting and anisotropic thermal parameters for all nonhydrogen atoms for 1720 (**4**) or 1170 (**5**) reflections having 2θ<sub>MoKα</sub> < 43° and *I* > 3σ (*I*). These and all subsequent structure factor calculations for both compounds employed the atomic form factors compiled by Cromer and Mann [33] and a least-squares refineable extinction correction of the form [34] 1/(1 + *gIc*)<sup>1/2</sup>. The final cycles of empirically-weighted [35] full-matrix least-squares refinement for both compounds which incorporated isotropic thermal parameters for all hydrogen atoms and anisotropic thermal parameters for all others converged to *R*<sub>1</sub> (unweighted, based on *F*) values of 0.040 (**4**) and 0.033 (**5**) and *R*<sub>2</sub> (weighted, based on *F*) values of 0.054 (**4**) and 0.031 (**5**) for 2592 (**4**) and 1504 (**5**) independent reflections having 2θ<sub>MoKα</sub> < 55° and *I* > 3σ(*I*) [9].

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$$\sigma = \sum_{0}^2 a_n |F_o|^n = 0.348 + (0.474 \times 10^{-2}) |F_o| + (0.510 \times 10^{-4}) |F_o|^2,$$

the  $a_n$  being coefficients derived from the least-squares fitting of the

curve  $||F_o| - |F_c|| = \sum_{0}^2 a_n |F_o|^n$ , where  $F_c$  values were calculated from the

fully refined model using unit weighting and an  $I > 3\sigma(I)$  rejection criterion. Empirical weights for the *trans* isomer **5** were then calculated as for **4** from

$$\sigma = \sum_{0}^3 a_n |F_o|^n = 0.378 - (1.13 \times 10^{-2}) |F_o| + (4.09 \times 10^{-4}) |F_o|^2 - (2.85 \times 10^{-6}) |F_o|^3.$$