2.16 mmol) and 4.006 g of benzophenone in 750 ml of *tert*-butyl alcohol; 1.095 mEinsteins; 9.31 mg of biphenyl; *cis*-3,3,5-trimethyl-1-phenyl-1,4-hexadiene, 312 mg, 1.56 mmol; *trans*-3,3,5-trimethyl-1-phenyl-1,4-hexadiene, 20 mg, 1.00×10^{-1} mmol, $\Phi = 0.087$.

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Conformational Studies of 1,3-Thiazolidines

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Abstract: The nmr spectra of 1,3-thiazolidine, 2-*tert*-butyl-1,3-thiazolidine, *N,S*-diacetylcysteamine, *N,N,S*-triacetylcysteamine, cysteamine hydrochloride, sodium 2-aminoethylmercaptide, and bisaminoethyl disulfide have been obtained and completely analyzed. On the basis of the coupling constants the thiazolidines are considered to exist in conformations close to envelopes with either C-4 or C-5 as the flap atom and with the 2 substituent anti to the flap (**2** or **3a**).

Conformational analysis of five-membered rings by nmr methods is often made difficult by the profusion of nearly equienergy conformers which must be considered and by the inadequacy of the Karplus equation for determination of reliable rotational angles. In spite of these difficulties, considerable progress has been made with five-membered rings having an ethylene group isolated by heteroatoms in the 1 and 3 positions. These include 1,3-dioxolanes,[2-8] 1,3-dithiolanes,[9] and 1,3-oxathiolanes.[9-11] Research in these laboratories directed toward analyzing preferred conformations of coenzyme A necessitated study of the nmr spectra of acyclic cysteamine derivatives possessing an ethylene bridge separating sulfur and nitrogen atoms. A study of 1,3-thiazolidine and its 2-*tert*-butyl derivative was also needed as a means to define model coupling constants for gauche- and trans-related vicinal protons in the SCH_2CH_2N unit. The results of these investigations of model systems permit us to discuss the preferred conformation of the thiazolidines studied and to compare the rotational angles of thiazolidines to those of previously studied heterocycles.

Results

N,S-Diacetylcysteamine (I) and *N,N,S*-triacetylcysteamine (II) together with *N*-acetylcysteamine (III) were all obtained by acetylation of cysteamine using an excess of acetic anhydride. 2-*tert*-Butyl-1,3-thiazolidine (IV) was prepared from cysteamine hydrochloride and pivaldehyde according to the method of Tondeur, Sion, and Deray.[12]

The magnetic environments of enantiotopic protons of enantiomeric gauche rotamers of cysteamine derivatives are averaged by rotation about the C–C bond. Similarly, the enantiotopic protons of enantiomeric ring conformations of thiazolidine undergo averaging by the process of rapid pseudorotation. The diastereotopic protons of enantiomeric ring conformations of 2-substituted thiazolidines, of necessity, remain diastereotopic under pseudorotation. Thus the 60-MHz spectra of thiazolidine (Figure 1), cysteamine hydrochloride (Figure 2), sodium 2-aminoethylmercaptide, bis-2-aminoethyl sulfide, *N,S*-diacetylcysteamine (Figure 3), and *N,N,S*-triacetylcysteamine (Figure 4) all consisted of 14 line symmetrical AA′BB′ patterns in which the multiplets of one-half of the spectrum were broadened by additional coupling to nitrogen. Spectral parameters (Table I) were obtained in each of these cases by computer assisted nmr analysis using LAOCN3[13] ignoring the nitrogen coupling; however, the necessity to assign weak transitions buried under large peaks made the solutions difficult for many of the spectra. Calculated spectra were plotted by a CALCOMP 27 plotter using a program (LORE) which sums Lorentzian curves substituted for each spectral line. The quality of the fit was judged in each case by comparison of line positions and intensities of plotted spectra with the experimental spectrum. The validity of the solutions for cysteamine hydrochloride and acetylcysteamines was assessed by calculation of the 220-MHz spectrum using the parameters obtained at 60 MHz and comparison of the plots with the observed spectrum. In each case except *N,N,S*-triacetylcysteamine, the 220-MHz spectrum proved to be a six line "deceptively simple" [14] pattern. The complex spectrum

(1) Taken from the Ph.D. Thesis of T. J. B. submitted in partial fulfillment of the requirements for the Ph.D. degree in chemistry of the Polytechnic Institute of Brooklyn.

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(5) F. A. L. Anet, *J. Amer. Chem. Soc.*, **84**, 747 (1962).

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(10) G. E. Wilson, Jr., M. G. Huang, and F. A. Bovey, *J. Amer. Chem. Soc.*, **92**, 5907 (1970).

(11) D. J. Pasto, F. M. Klein, and T. W. Doyle, *J. Amer. Chem. Soc.*, **89**, 4368 (1967).

(12) R. Tondeur, R. Sion, and E. Deray, *Bull. Soc. Chim. Fr.*, 2493 (1964).

(13) S. Castellano and A. A. Bothner-By, *J. Chem. Phys.*, **41**, 3853 (1964).

(14) R. J. Abraham and H. J. Bernstein, *Can. J. Chem.*, **39**, 699 (1961).

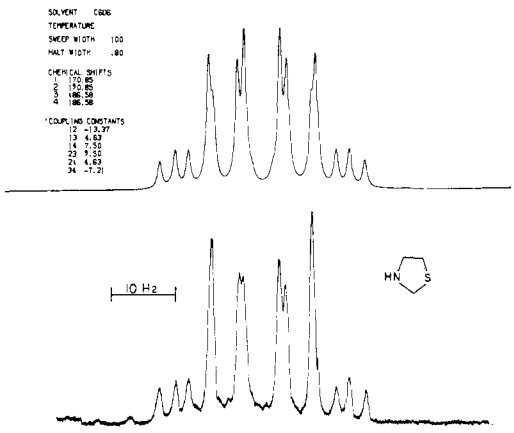


Figure 1. Experimental (bottom) and calculated (top) 60-MHz nmr spectra of 1,3-thiazolidine in benzene-d_6.

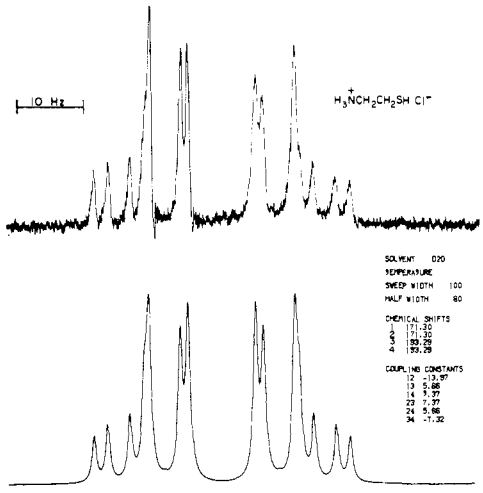


Figure 2. Experimental (top) and calculated (bottom) 60-MHz nmr spectra of cysteamine hydrochloride in D_2O.

of *N,N,S*-triacetylcysteamine was solved by the iterative method at 220 MHz, but the geminal coupling constants were maintained equivalent to those obtained at 60 MHz to prevent divergence.

Both the 60-MHz (Figure 5) and 220-MHz (Figure 6) spectra of 2-*tert*-butyl-1,3-thiazolidine were of the ABCD type, and these were solved by iterative computer analysis (Table II).

Assignment of chemical shifts to the CH_2N and CH_2S groups of the thiazolidines and cysteamine derivatives was based on chemical shifts caused by protonation and deprotonation of cysteamine, acylation shifts of cysteamine, and correlation of magnitudes of geminal coupling constants throughout. Thus protonation of nitrogen is expected to deshield the α proton, but deprotonation of the mercaptan is expected to shield the α protons. Acylation shifts for primary amines are known to be greater than 0.5 ppm[15] but those for thiols are *ca.* 0.25 ppm.[16] For the cysteamine derivatives except *N,N,S*-triacetylcysteamine $J_{gem}(CH_2S)$ and $J_{gem}(CH_2N)$ maintain relatively constant values consistent with the theory that an increase in electronegativity produces an algebraic increase in the geminal coupling constant.[17]

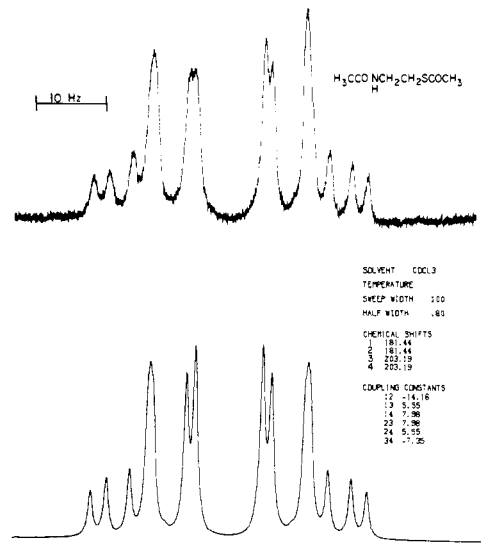
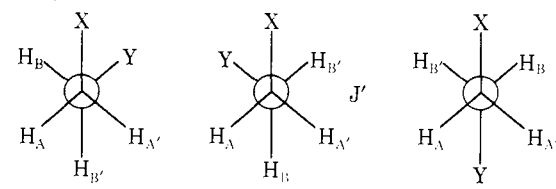


Figure 3. Experimental (top) and calculated (bottom) 60-MHz nmr spectra of *N,S*-diacetylcysteamine in $CDCl_3$.

In 1,3-thiazolidine the upfield multiplet was assigned to the methylene adjacent to sulfur. The chemical shift (2.85 ppm) is compatible with those of CH_2S groups in other compounds and the geminal coupling constant compares favorably with those of the acyclic derivatives. It has been observed[18] that geminal coupling constants in five-membered rings do not differ much from those in six-membered rings or in freely rotating acyclic systems. The geminal coupling constant is also compatible with those found in the dithiolanes[9] though more negative than those found in the oxathiolanes. The geminal coupling constant for the multiplet assigned to the CH_2N function for thiazolidine was in agreement with those observed for the cysteamine derivatives.

Assignments of the resonances for 2-*tert*-butyl-1,3-thiazolidine rests largely on the relative constancy of the geminal coupling constant of the CH_2S group. The algebraic increase in this coupling constant coupled with a decrease in the geminal coupling constant of the CH_2N group relative to thiazolidine probably arises as a result of a conformational change superimposed on the electronegativity effect.[17]

It is impossible to differentiate between J_{cis} and J_{trans} in thiazolidine or other five-membered rings solely on the basis of the spectral data for the ring in question. Assuming rapid interconversion of rotamers and population of only three classical staggered rotamers, the vicinal coupling constants for an ethylene moiety are given by



$$J_{AB'} = J_{A'B} = n_1 J_g + \tfrac{1}{2} n_g (J_t + J_g) = J \quad (1)$$

$$J_{AB} = J_{A'B'} = n_t J_t = n_g J_g = J' \quad (2)$$

(15) L. M. Jackman and S. Sternhell, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry," 2nd ed, Pergamon Press, New York, N. Y., 1969, p 180.

(16) G. E. Wilson, Jr., and T. J. Bazzone, unpublished observation.

(17) R. Cahill, R. C. Cookson, and T. A. Crabb, *Tetrahedron*, **25**, 4681 (1969).

(18) See ref 15, p 276.

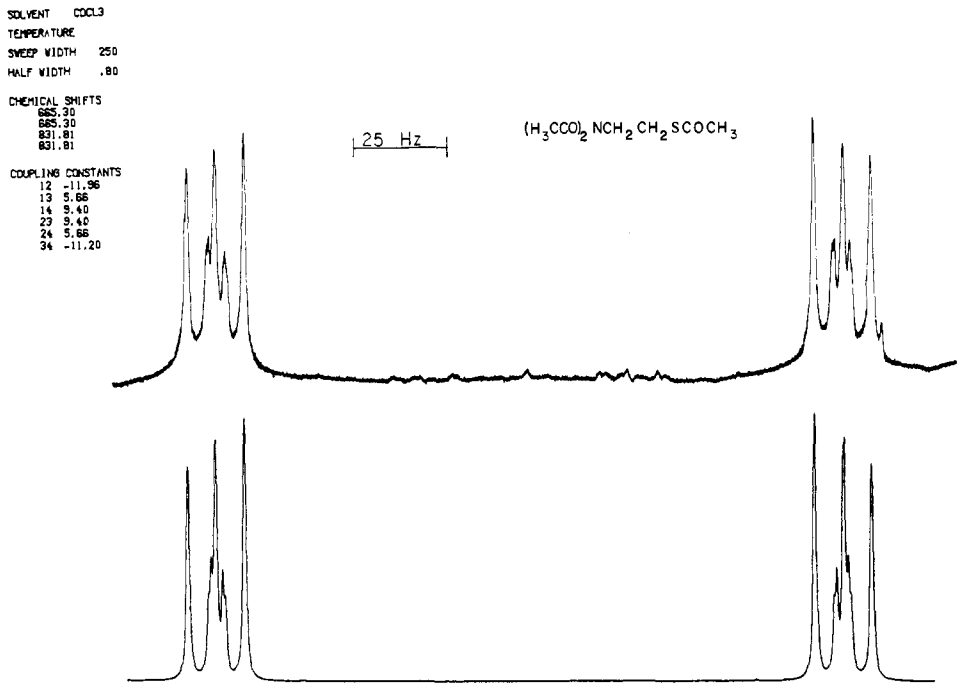


Figure 4. Experimental (top) and calculated (bottom) 220-MHz nmr spectra of *N,N,S*-triacetylcysteamine in $CDCl_3$.

Table I. Chemical Shifts and Coupling Constants for Cysteamine Derivatives and 1,3-Thiazolidine

Compound	Solvent	Freq., MHz	ν_{CH_2S}	ν_{CH_2N}	J	J'	$J_{gem}(CH_2S)$	$J_{gem}(CH_2N)$	RMS[d] error
$H_3N^+CH_2CH_2SH\ Cl^-$	D_2O	60	171.3	193.3	5.66	7.37	−13.97	−7.32	0.037
$H_2NCH_2CH_2S^-Na^+$	D_2O	60	151.3	160.0	5.80	7.97	−13.29	−7.19	0.036
$(H_2NCH_2CH_2S)_2$	D_2O	60	21.3, 178.5	*a*	5.52	7.55	−30.87	−24.21	0.038
$(H_3N^+CH_2CH_2S)_2\ 2Cl^-$	D_2O	60	10.9, 193.85	*a*	5.86	7.40	−13.63	−7.22	0.041
$AcNHCH_2CH_2SH$	$CDCl_3$[b]	60	160.7	206.4	6.5[c]				
	D_2O	60	160.0	203.0	6.5[c]				
$AcNHCH_2CH_2SAc$	$CDCl_3$	60	181.4	203.2	5.55	7.80	−14.16	−7.35	0.033
$Ac_2NCH_2CH_2SAc$	$CDCl_3$	60	182.3	228.3	5.25	9.99	−11.96	−11.21	0.038
	$CDCl_3$	220	665.3	831.8	5.66	9.41	−11.96	−11.21	0.035
	$CDCl_3$	60	168.8	191.0	7.61	4.71	−13.72	−7.24	0.035
	C_6D_6	60	170.9	186.6	7.50	4.63	−13.37	−7.21	0.038

[a] Unambiguous assignments could not be made here. The values reported are the chemical shifts in Hz between the A and B proton sets followed by the midpoints of the AA'BB' pattern. [b] Amide and thiol protons exchanged with D_2O. [c] Average value $(J + J')/2$ obtained from deceptively simple spectra. [d] Rms error of spectral lines, in Hz.

Table II. Chemical Shifts and Coupling Constants for 2-*tert*-Butyl-1,3-thiazolidine at 60 MHz and 220 MHz

Solvent	Freq., MHz	CH_2S ν_A	CH_2S ν_B	CH_2N ν_C	CH_2N ν_D	J_{AB}	J_{AC}	J_{AD}	J_{BC}	J_{BD}	J_{CD}	RMS[a] error
$CDCl_3$	60	173.5	215.4	161.7	178.1	−12.32	9.73	6.38	6.42	2.03	−9.96	0.047
$CDCl_3$	220	635.0	793.4	592.0	655.4	−12.32	9.77	6.49	6.34	1.93	−10.06	0.040

[a] RMS error of spectral lines, in Hz.

where the mole fractions of the gauche and trans rotamers are given by n_g and n_t; the coupling constants for gauche- and trans-related protons are J_g and J_t, respectively. According to these equations for $n_t < 1/3$, J will be greater than J' if $J_t > J_g$ as is normally the case. Thus in cyclic compounds such as six-membered rings where the classical staggered conformations are those populated one finds that $J_{trans} > J_{cis}$. In five-membered rings, however, some deviation from pseudotrigonal projection symmetry exists and deviations from 60° dihedral angles are large with the consequence that the approximation of equivalent J_g's used in obtaining eq 1 and 2 is not valid.

The basic equations may be altered to allow deviation of dihedral angles from 60° and deviation from pseudotrigonal projection symmetry. One then obtains

$$J_{AB'} = J_{A'B} = n_t J_{(\psi-\phi)} + {}^1/_2 n_g (J_{\psi+\phi} + J_{\psi}) = J \quad (3)$$

$$J_{AB} = J_{A'B'} = n_t J_{(\psi+\phi)} + n_g J_{\psi} = J' \quad (4)$$

where ψ and ϕ are the NCCS dihedral angle and the HCH geminal projection angle, respectively. For reasonable values of ϕ it can be shown that for ψ near 30° $J \approx J'$. Since dihedral angles of ethylene units in some five-membered rings are known to fall in this range (*vide infra*), this leads to the conclusion that assignment of J and J' for five-membered rings by inspection

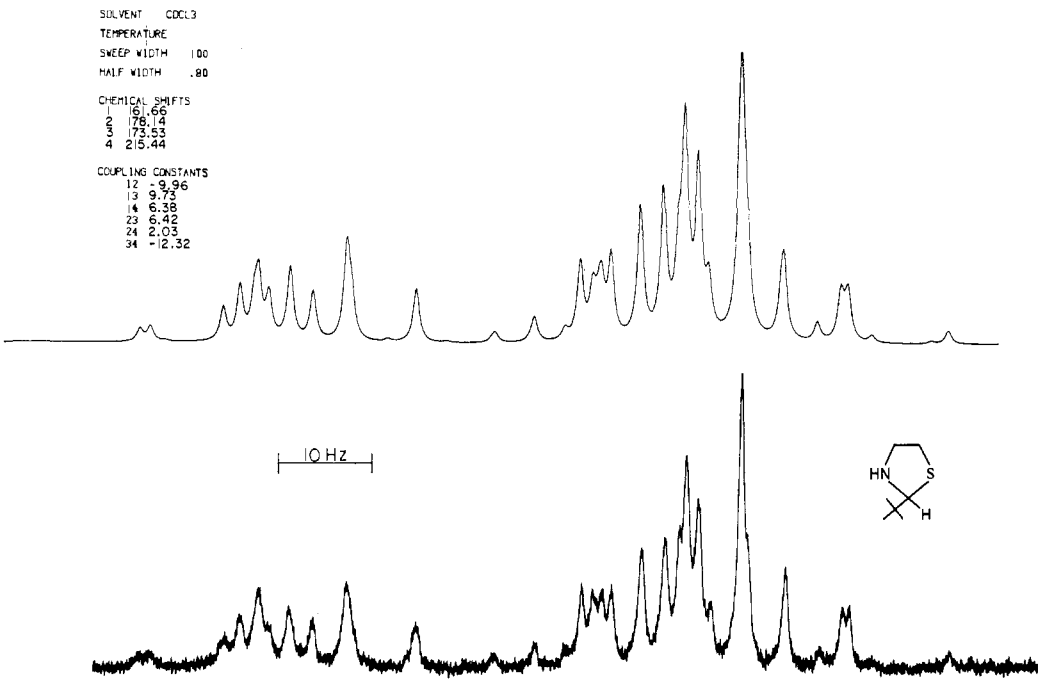


Figure 5. Experimental (bottom) and calculated (top) 60-MHz nmr spectra of 2-*tert*-butyl-1,3-thiazolidine in $CDCl_3$.

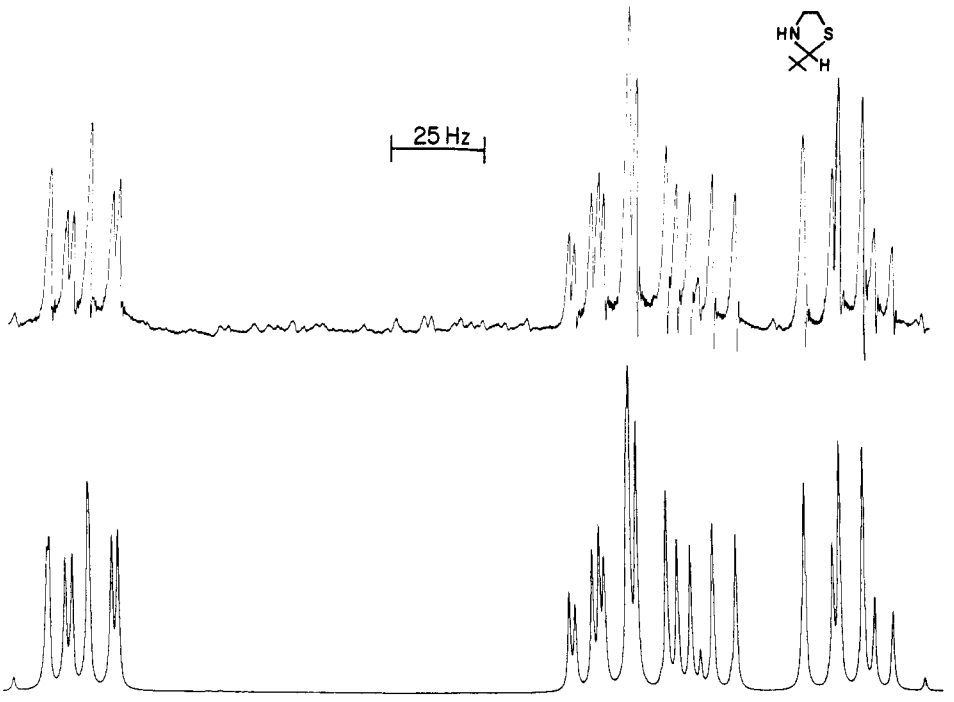


Figure 6. Experimental (top) and calculated (bottom) 220-MHz nmr spectra of 2-*tert*-butyl-1,3-thiazolidine in $CDCl_3$.

necessitates knowledge of the average ring torsional angles. We have obtained the relative magnitudes of J and J' by employing a relationship (eq 5) developed by Abraham and Pachler[19] which relates the average

$$17.97 - 0.8\sum E_i = {}^1/_3(2J + J') \qquad (5)$$

coupling constant $(2J + J')$ to the sum of the Huggins electronegativities[20] of all atoms attached to the vicinal carbons. Because the value of the average coupling constant $2J + J'$ is expected to be smaller for the gauche rotamer than for the trans rotamer for $60° > \psi > 30°$, the experimental value of ΣE_i is expected to be smaller than that obtained by summing the electronegativities. For thiazolidine eq 5 was best satisfied for $J > J'$, and the expected trend was observed. Thus, we conclude that $J_{trans} > J_{cis}$.

The single large coupling constant for 2-*tert*-butyl-1,3-thiazolidine must be assigned as a J_{trans} involving axial–axial coupling.

Discussion

For convenience of analysis several points along the pseudorotation circuit of 1,3-thiazolidines which define

(19) R. J. Abraham and K. G. R. Pachler, *Mol. Phys.*, 7, 165 (1963).
(20) M. L. Huggins, *J. Amer. Chem. Soc.*, 75, 4123 (1953).

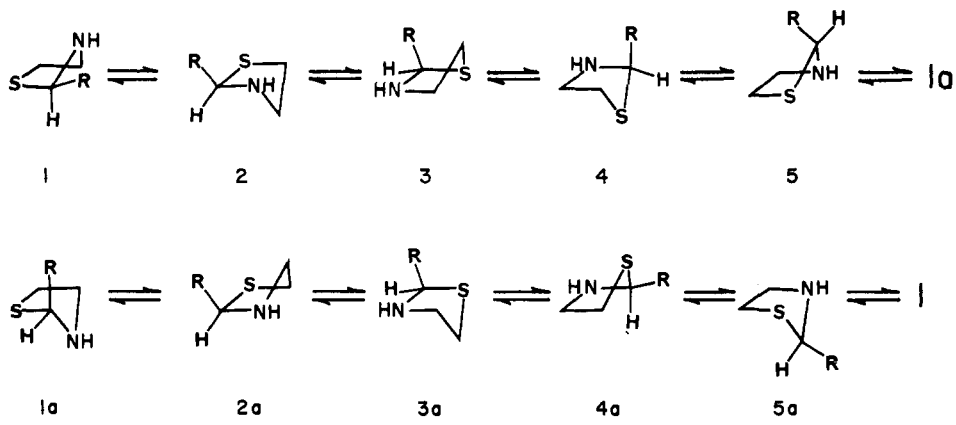


Figure 7. Envelope conformations of pseudorotamers of the 1,3-thiazolidines.

envelope conformations may be singled out for evaluation as preferred conformations (Figure 7). For thiazolidines symmetrically substituted at the 2 position, the enantiomeric ring conformations **1** and **1a**, **2** and **2a**, etc., will be equally populated, although some pairs may be favored due to the reduced symmetry when compared with cyclopentane. Asymmetric substitution at the 2 position results in preferred conformations in which the ring enantiomers are not necessarily equally populated. At the outset the large magnitude of one coupling constant in the 2-*tert*-butyl derivative suggested that pseudorotamers **5** and **5a** are unimportant (*vide supra*). This fact is independent of the validity of the chemical shift assignments of the CH_2N and CH_2S resonances. By analogy to 1,3-oxathiolanes,[10] we believe the major populated conformers will be best represented by **1**, **2**, **3a**, or **4a** as these minimize steric interactions of the *tert*-butyl group with protons across the ring. It is not possible at present to define the relationship between the substituent and that proton α to nitrogen which shows the large trans vicinal coupling constant, but we favor a trans stereochemistry by analogy to the oxathiolanes.[10] Thus, we favor **1** or **2** as the major populated conformers. Other reasoning would also seem to favor conformer **1** or **2** over **3a** or **4a**. The proton on nitrogen is expected to occupy primarily that position which minimizes repulsive forces due to the protons of the α-methylene, the transannular functionality and the substituent. Thus a gauche rotational angle between the *tert*-butyl group and the NH is expected as this will minimize the torsional energy. All these minimizations are incorporated in conformations **1** or **2**. Conformers **3a** and **4a** minimize the transannular interactions of the NH but force the NH and *tert*-butyl groups to be eclipsed.

The geometry of five-membered rings, assuming fixed known bond lengths, is completely determined by any combination of two rotational angles and two bond angles. Because bond angles in five-membered rings are already known with a fair degree of accuracy,[21] knowledge of one rotational angle will often allow an intelligent conclusion to be drawn about the preferred ring conformation. Nmr methods, empirical or theoretical, to provide this information would introduce a powerful tool for the study of conformations in five-membered rings.

(21) See, for example, C. Romers, C. Altona, H. R. Buys, and N. L. Allinger, *Top. Stereochem.*, **4**, 39 (1969).

Among the most useful methods of estimation of torsional angles in six-membered rings has been that of relating the ratio (R)[22-25] of the average trans to the average cis coupling constant to the dihedral angle ψ using a simplified version of eq 6 assuming pseudotrigonal projection symmetry ($\phi = 120°$). This method

$$\cos \psi = \left[\frac{1 - \cos 2\phi}{2(R - \cos 2\phi)}\right]^{1/2} \qquad (6)$$

was found to give only a confirmation of the trend in dihedral angles when applied to 1,3-dioxolanes and 1,3-dithiolanes.[9]

We have attempted correlation of coupling constants with rotational angles of ethylene units obtained by X-ray methods (Table III) utilizing eq 6 and including

Table III. Coupling Constants, "R" Values and Rotational Angles of Some Heterocycles

Ring	R	J(av), Hz Cis	J(av), Hz Trans	"R"	ψ_{calcd}	$\psi_{X\text{-ray}}$
	H	7.3	6.0	0.82	41	21[a]
	CH_3	7.20	6.06	0.84	42	
	Ph	7.16	6.19	0.86	42	
	H	5.58	6.12	1.10	47	34[b]
	Et	4.63	7.17	1.55	52	
	n-Pr	4.82	6.97	1.45		
	H	5.30	6.39	1.21	48	45[c]
	CH_3	5.49	6.62	1.21	49	
	Ph	5.21	6.55	1.26	49	
	H	4.71	7.61	1.62	53	
	t-Bu	5.85	6.40	1.09	47	

[a] The value is that for 2,2'-bis-1,3-dioxolane: S. Furberg and D. Hassel, *Acta Chem. Scand.*, **4**, 1584 (1950). [b] The value is that for cholestan-4-one-3-spiro(2,5-oxathiolane): A. Cooper and D. A. Norton, *J. Org. Chem.*, **33**, 3535 (1968). [c] The value is that for 2,2'-bis-1,3-dithiolane: L. B. Brahde, *Acta Chem. Scand.*, **8**, 1145 (1954).

nmr data for 1,3-thiazolidine obtained in these laboratories. We find the expression for cos ψ relatively insensitive to changes in the projected geminal angle for $\phi \approx 120°$. Changing ϕ to agree with the data for oxathiolanes produced only a slight displacement of the

(22) J. B. Lambert, *J. Amer. Chem. Soc.*, **89**, 1836 (1967).
(23) J. B. Lambert and R. G. Keske, *Tetrahedron Lett.*, 4755 (1967).
(24) J. B. Lambert, R. G. Keske, and D. K. Weary, *J. Amer. Chem. Soc.*, **89**, 5921 (1967).
(25) J. B. Lambert, *Accounts Chem. Res.*, **4**, 87 (1971).

calculated rotational angle. Thus we conclude, in agreement with others, that the form of the relationship between dihedral angle and coupling constant for five-membered rings must be better defined in order to obtain reliable torsional angles.[2,3]

For five-membered rings containing identical heteroatoms in the 1,3 positions, substitution of the 2 position appears to effect little alteration of the conformational populations observed for the unsubstituted ring. On the other hand, for rings containing different heteroatoms at the two sites, substitution appears to alter the conformational populations in favor of one ring enantiomer. These trends were made apparent by the observation of a relatively constant value of "R" in substituted 1,3-dioxolanes, 1,3-dithiolanes, and the parents contrasting strongly with the variation of "R" in the 1,3-oxathiolanes[26] and 1,3-thiazolidines. Changes in the conformations for substituted oxathiolanes and thiazolidines produce opposing changes in the dihedral angle (ψ) of the ethylene unit. Apparently the effect of the proton on nitrogen in the unsubstituted thiazolidine is to introduce a new torsional potential in the RC_2NH fragment which in turn forces reduction of the NCCS torsional angle.

In substituted oxathiolanes, on the other hand, the interaction of the substituent and the transannular protons is the dominant effect, and its minimization results in an increase of the OCCS torsional angle. For the unsubstituted heterocycles, the balancing of the HNC_2H and HNC_5H potentials results in a significant increase of the NCCS dihedral angle but the absence of such interactions in 1,3-oxathiolanes allows the interactions in the OCCS system to control the conformation as in the dioxolanes and dithiolanes.

Experimental Section[28]

Acetylation of Cysteamine. Method A.[29] Acetic anhydride (39.8 g, 0.39 mol) and 15 ml of 8 M potassium hydroxide solution were simultaneously dripped into a stirred, ice bath cooled solution of 10 g (0.13 mol) of cysteamine in 24 ml of water at such a rate that the temperature remained below 20°. When the addition was complete, the ice bath was removed but stirring was continued for 40 min. The crude product mixture was extracted with ether, and the ether extract was dried over sodium sulfate and concentrated at reduced pressure on a rotary evaporator. Distillation of the residue yielded 5 g of a fraction (bp 119–124° (0.6–0.8 mm)) which was shown by vpc analysis to be a 7:1 mixture of *N,N,S*-triacetylcysteamine and *N,S*-diacetylcysteamine.

Method B. Acetic anhydride (44.9 g, 0.44 mol) was added dropwise to an ice bath cooled solution of 25 g (0.22 mol) of cysteamine hydrochloride in 100 ml of water immediately after which a saturated aqueous solution of 36.1 g (0.44 mol) of sodium acetate was added. The ice bath was removed, and stirring was continued for 1 hr. The ether extract of the crude reaction mixture was washed with three 100-ml portions of water, dried over sodium sulfate, and concentrated under vacuum on a rotary evaporator. Vacuum distillation of the residue afforded 19.5 g of material, bp 112–121° (0.7 mm), consisting of *N*-acetylcysteamine; ir (neat) 3290, 3098, 2977, 1654, 1548 cm^{-1}; *N,S*-diacetylcysteamine, ir (neat) 3290, 3078, 2981, 1688, 1653, 1545 cm^{-1}; and *N,N,S*-triacetylcysteamine, ir (neat) 3017, 2929, 1692, 1420 cm^{-1}.

Anal. Calcd for $C_8H_{13}NO_3S$: C, 47.27; H, 6.45; N, 6.88; S, 15.77. Found: C, 47.13; H, 6.60; N, 6.69; S, 15.83.

Attempted separation of the components in the combined products from methods A and B by fractional vacuum distillation on an annular still was not successful. Separation of a 2.5-g sample was successful by elution chromatography on a column of Brinkmann silica gel (75 × 25 mm) using chloroform–methanol (7:1) as an eluent. A total of 83 15-ml fractions were collected on a Buchler Fractomette Model V-200, and a clean separation was obtained with *N,N,S*-triacetylcysteamine in fractions 16–19, *N,S*-diacetylcysteamine in fractions 22–24, and *N*-acetylcysteamine in fractions 32–37. Purity was checked by tlc on silica gel using 9:1 chloroform–methanol as eluent.

2-*tert*-Butyl-1,3-thiazolidine. Pivaldehyde (12.9 g, 0.15 mol) was added dropwise to 5 g (0.065 mol) of solid cysteamine with water bath cooling and stirring. After having been stirred overnight, the mixture was diluted with 50 ml of dry benzene. Water was removed as a benzene azeotrope at reduced pressure on a rotary evaporator, and subsequent vacuum distillation afforded 4.87 g (52%) of 2-*tert*-butyl-1,3-thiazolidine: bp 50° (0.3 mm); ir (neat) 3295, 2958, 1474, 1364, 1393, 1169, 1108 cm^{-1}.

Anal. Calcd for $C_7H_{13}NS$: C, 57.88; H, 10.41; N, 9.64; S, 22.07. Found: C, 57.90; H, 10.30; N, 9.75; S, 22.29.

Procedure for Determination of Nmr Spectra. All 60-MHz spectra were determined for 15–20% w/w solutions on a Varian Associates Model A-60 spectrometer unless otherwise specified. Calibration of the spectra solved by computer-assisted analysis was accomplished using a Hewlett-Packard Model 200 CD wide range oscillator and a Monsanto Model 100A frequency counter. The 220-MHz spectra were determined on a Varian Associates Model HR-220 spectrometer. Chemical shifts for D_2O solutions are reported relative to the trimethylsilyl protons of internal 2,2-dimethylsilapentane-5-sulfonic acid sodium salt, while those for solutions in $CDCl_3$ or DMSO-d_6 are reported relative to internal TMS.

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(26) We have observed distorted triplet nmr patterns for a number of symmetrically 2,2-disubstituted 1,3-oxathiolanes as well as the parent. Considering a condition, $|L^2/2M| < \Delta\nu_{1/2}$, for observation of such "deceptively simple" spectra[27] together with values of M for other oxathiolanes,[10] *ca.* 0.8 Hz, and an estimated line width of 0.8 Hz leads to the conclusions that $L < 1.13$ Hz and $R < 1.22$. The coupling constant values of Pasto and coworkers[11] for 1,3-oxathiolane, which are probably accurate to only ±0.4 Hz, have been adopted for our purposes.

(27) R. J. Abraham and H. J. Bernstein, *Can. J. Chem.*, **39**, 216 (1961).

(28) Infrared spectra were recorded on a Perkin-Elmer Model 521 spectrometer. Nmr spectra were recorded on Varian A60 and HR220 spectrometers. Chemical shifts in D_2O are reported relative to the trimethylsilyl peak of internal DSS; chemical shifts in $CDCl_3$ are relative to internal TMS. Microanalyses were performed by Galbraith Laboratories, Inc., Knoxville, Tenn.

(29) J. Gerstein and W. P. Jencks, *J. Amer. Chem. Soc.*, **86**, 4655 (1964).