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STEREOCHEMISTRY OF TRI-N-SULPHONYLHEXAHYDRO-*s*-TRIAZINES[1]

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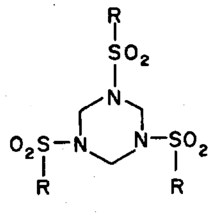
Abstract—X-Ray crystallography showed that the heterocyclic ring of **1a** and **1d** is a chair with the substituents intermediate between axial and equatorial (all *cis*) and diequatorial-monoaxial (two *cis* and one *trans*) positions, respectively. Infrared N–S absorption in solid and solution led to tentative stereochemical assignments for **1a–d**.

The title class of compounds (**1**) is long known;[2] general synthetic methods and a number of new examples have recently been described.[1,3] However, the configuration and conformation for the whole class remained unsettled.

Stereochemical studies on hexahydro-*s*-triazines are difficult due to fast ring reversal and fast inversion of the N-atoms;[4] thus, N,N′,N″-trimethylhexahydro-*s*-triazine has a chair ring and was successively described as triequatorial,[5] as a mixture of mainly mono and diequatorial,[6] and as diequatorial[7] according with NMR or dipole moment data. NMR measurements down to −80° on **1** (R = *p*-tolyl) failed to exhibit any separation between equatorial and axial H-signals; this behaviour was ascribed to a fast ring reversal suggesting that the N-atoms are nearly planar.[8]

We report here our results on **1a–d** using X-ray crystallography[9] and/or IR spectroscopy; the constitution of the compounds was known before starting the present work.[1-3] Crystallographic atom numbering system is used throughout.



1 R
a: CH_3
b: C_2H_5
c: n-C_5H_{11}
d: C_6H_5

RESULTS AND DISCUSSION

By analogy with a variety of known saturated 6-membered homo and heterocyclic compounds, it is safely assumed that the heterocyclic ring of **1** occurs as chair form either in solid or solution.

The sulphonamides used for the preparation[1] of **1a–d** exhibit only one IR absorption in the N–S stretching region (Table 1) which extends[10] approximately from 915 to 815 cm^{-1}. Compound **1a** shows only one band suggesting that it contains three equivalent N–S bonds; therefore, triequatorial (all *cis*) stereochemistry is assigned since the triaxial alternative is unlikely considering non-bonded interactions. On the same grounds this stereochemistry is also attributed to **1b**.

Compound **1c** displays a band near 860 cm^{-1} accompanied by a less intense one at *ca.* 835 cm^{-1} which are ascribed to equatorial (two) and axial N–S bonds respectively, considering the relative band positions;[11] besides, the diaxial-monoequatorial alternative is much less probable. Similarly, compound **1d** is also described as diequatorial-monoaxial (two substituents *cis* and the other *trans*).

The above tentative conclusions refer to solid and solution considering the coincidence of the N–S absorptions in both states.

It is proved by X-ray crystallography that compounds **1a** and **1d** occur as chair conformers in the crystalline state (Fig. 1). In **1a** the three N–S bonds are *cis* and their orientations are intermediate between axial and equatorial; two of them are equivalent and differ slightly from

Table 1. Infrared absorptions (cm^{-1}) in the region 915–815 cm^{-1}

R	$R-SO_2-NH_2$	Compounds 1		
	KBr	Nujol	KBr	Solution[a]
CH_3	881	852	854	863
C_2H_5	901	858	858	861
n-C_5H_{11}	889	858;835	857;833	863;835
C_6H_5	905	880;846	883;848	868;847(sh)[b]

[a] In hexamethylphosphoric triamide.

[b] In *N*,*N*-dimethylacetamide: 870 and 847(sh).

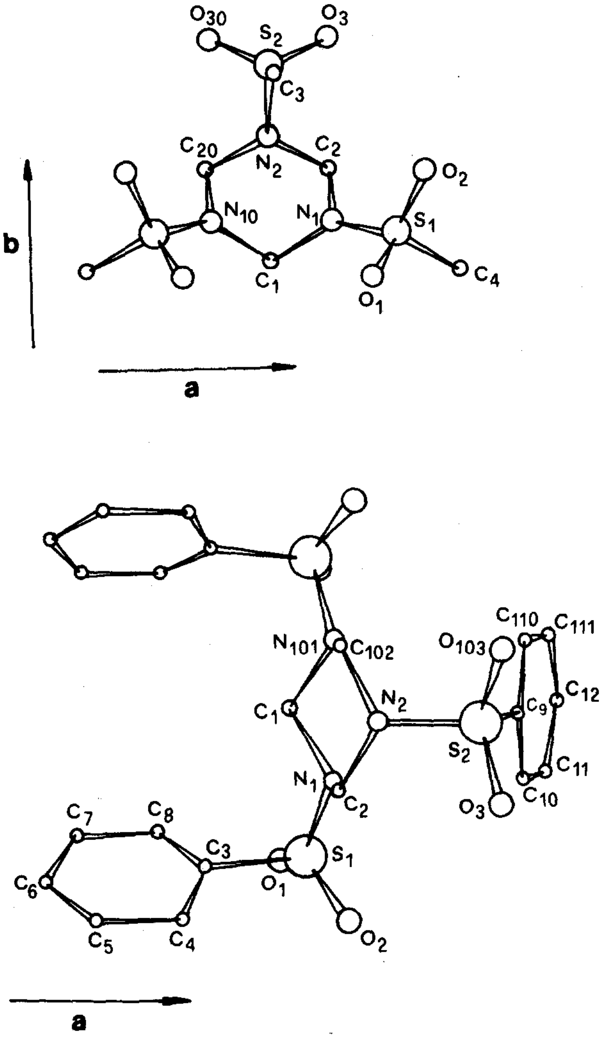


Fig. 1. Perspective views of **1a** (top) and **1d** (bottom).

the other, N(2)–S(2). In **1d** the sulphonyl substituents are diequatorial-monoaxial, two *cis* and one *trans*.

Due to the method used for data collection the accuracy of bond lengths and valency angles is limited (Table 4). Nevertheless, it may be stated that the three N-atoms of **1d** are pyramidal. One of them, N(2), is 0.30 Å out of the plane defined by its three adjacent atoms; the corresponding distance for the two other N-atoms related by symmetry is 0.37 Å.

In **1a**, the N(1) and N(10)-atoms are planar as indicated by the distance (0.002 Å) to the planes of the respective adjacent atoms whilst N(2) is a flattened pyramid 0.13 Å out of the S(2),C(2),C(20) plane. The estimated standard deviation for the values given in this paragraph is 0.05 Å.

The relatively small difference (20°) between the angles formed by non-equivalent N–S bonds with the mean ring plane could account for the appearance of only one infrared N–S band. In **1d**, the spectra of which show two N–S bands, the difference for the corresponding angles (absolute values) is much larger (60°).

In both compounds the puckering changes around the heterocyclic ring as shown by the endocyclic torsion angles (Table 4); the means of the absolute values for the latter in **1a** (58°) and **1d** (55°) are similar and near to the real cyclohexane chair value (56°).[12]

In the crystal of each compound there is only one intermolecular contact shorter than the van der Waals distances: O(2)...C(4')† at 3.25 Å and O(1)...C(2') at 3.15 Å for **1a** and **1d** respectively. The van der Waals radii for the O-atom, methyl and methylene groups are 1.40, 2.0 and 2.0 Å, respectively.[13] Moreover, each compound displays essentially the same IR absorption in the N–S stretching region for solid and solution (Table 1). Both sets of data suggest that the above mentioned ring conformation and N-substituents configuration in **1a** and **1d** may be extrapolated to solution.

EXPERIMENTAL

IR spectra. The region 920–790 cm^{-1} was recorded using a grating spectrophotometer Perkin-Elmer 377E. The samples of **1a** and **1d** were the same as for X-ray diffraction (see below); **1b** and **1c** were crystallised as indicated.[1] The sulphonamides taken as reference compounds were obtained and purified by literature methods. The solid phase spectra were measured in KBr discs and Nujol mulls. The spectra in solution were obtained in hexamethylphosphoric triamide (redistilled *in vacuo* and kept over CaH$_2$), cell of 0.2 mm and compensation with pure solvent; conc. 10 mg/ml for **1a** and 50 mg/ml for **1b–d**.

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†The numbers for atoms of another molecule of the same compound are primed.

Table 2. Fractional co-ordinates[a] of nonhydrogen atoms for **1a** and **1d**

	Atom	x/a	y/b	z/c
1a	S(1)	0.1591(4)	0.1399(4)	0.000(0)
	N(1)	0.081(1)	0.159(1)	-0.193(6)
	O(1)	0.122(1)	0.076(1)	0.162(4)
	O(2)	0.193(1)	0.224(1)	0.076(4)
	O(3)	0.080(1)	0.419(1)	-0.237(4)
	C(2)	0.084(1)	0.237(2)	-0.362(7)
	C(4)	0.249(2)	0.088(2)	-0.150(6)
	S(2)	0.0	0.3801(6)	-0.178(2)
	N(2)	0.0	0.286(2)	-0.325(6)
	C(1)	0.0	0.104(2)	-0.227(8)
	C(3)	0.0	0.356(3)	0.109(8)
1d	S(1)	0.2687(5)	0.0910(3)	0.0266(4)
	N(1)	0.314(1)	0.178(1)	0.083(1)
	C(2)	0.339(2)	0.175(1)	0.196(2)
	O(1)	0.265(1)	0.107(1)	-0.086(1)
	O(2)	0.341(1)	0.029(1)	0.074(1)
	O(3)	0.579(1)	0.172(1)	0.269(1)
	C(3)	0.121(2)	0.081(1)	0.071(1)
	C(4)	0.107(2)	0.042(1)	0.172(2)
	C(5)	-0.010(2)	0.043(1)	0.212(2)
	C(6)	-0.102(2)	0.075(2)	0.151(2)
	C(7)	-0.079(2)	0.110(2)	0.052(2)
	C(8)	0.033(2)	0.111(1)	0.011(2)
	C(10)	0.599(2)	0.177(1)	0.034(2)
	C(11)	0.631(3)	0.175(2)	-0.075(2)
	C(1)	0.242(3)	0.250(0)	0.049(2)
	N(2)	0.397(2)	0.250(0)	0.228(2)
	S(2)	0.5441(7)	0.250(0)	0.2218(7)
	C(9)	0.595(3)	0.250(0)	0.086(3)
	C(12)	0.644(4)	0.250(0)	-0.127(3)

[a] Standard deviations are given in parentheses and refer to the last digit.

Table 3. Anisotropic thermal factors[a] of nonhydrogen atoms for **1a** and **1d** in the form: $\exp[-(\beta_{11}h^2+\beta_{22}k^2+\beta_{33}l^2+2\beta_{12}hk+2\beta_{13}hl+2\beta_{23}kl)]$

	Atom	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
1a	S(1)	0.004(1)	0.002(1)	0.011(2)	0.001(1)	-0.001(2)	-0.004(2)
	N(1)	0.003(1)	0.002(1)	0.069(17)	0.002(2)	-0.019(8)	0.006(7)
	O(1)	0.006(1)	0.004(1)	0.016(9)	-0.002(2)	0.004(5)	0.011(5)
	O(2)	0.006(1)	0.003(1)	0.011(9)	0.002(2)	-0.005(5)	-0.003(4)
	O(3)	0.008(1)	0.003(1)	0.021(9)	0.002(2)	0.005(7)	0.005(5)
	C(2)	0.003(1)	0.003(1)	0.062(16)	0.002(2)	0.021(9)	0.025(8)
	C(4)	0.002(1)	0.003(1)	0.031(12)	0.005(2)	-0.002(7)	0.009(7)
	S(2)	0.003(1)	0.002(1)	0.044(5)	0.0	0.0	0.003(2)
	N(2)	0.002(2)	0.001(1)	0.034(15)	0.0	0.0	0.007(6)
	C(1)	0.003(2)	0.003(2)	0.035(17)	0.0	0.0	0.007(8)
	C(3)	0.003(3)	0.006(2)	0.019(16)	0.0	0.0	-0.006(9)
1d	S(1)	0.0040(6)	0.0015(7)	0.0011(4)	0.0002(4)	-0.0007(5)	0.0003(5)
	N(1)	0.003(1)	0.001(1)	0.001(1)	-0.0004(6)	-0.003(2)	0.0008(10)
	C(2)	0.010(2)	0.004(1)	0.0008(1)	-0.002(2)	-0.004(2)	-0.0008(10)
	O(1)	0.010(1)	0.003(1)	0.001(1)	0.001(1)	-0.0009(8)	-0.004(1)
	O(2)	0.006(1)	0.003(1)	0.002(1)	0.004(1)	-0.002(1)	0.002(1)
	O(3)	0.006(1)	0.004(1)	0.004(1)	0.001(1)	-0.005(2)	0.003(1)
	C(3)	0.001(2)	0.003(1)	0.001(1)	-0.004(2)	0.001(2)	-0.002(1)
	C(4)	0.006(2)	0.001(1)	0.004(1)	-0.004(2)	-0.0004(6)	0.0008(10)
	C(5)	0.011(2)	0.004(1)	0.003(1)	-0.006(2)	0.006(2)	-0.001(2)
	C(6)	0.008(2)	0.005(1)	0.010(2)	-0.006(3)	0.001(3)	-0.007(2)
	C(7)	0.003(2)	0.005(1)	0.008(2)	-0.001(2)	-0.004(3)	-0.004(2)
	C(8)	0.006(2)	0.003(1)	0.003(1)	-0.001(2)	-0.004(2)	-0.001(1)
	C(10)	0.004(2)	0.002(1)	0.004(1)	-0.001(2)	0.006(2)	-0.001(1)
	C(11)	0.009(2)	0.003(1)	0.009(2)	0.001(2)	0.001(3)	-0.002(2)
	C(1)	0.001(2)	0.001(1)	0.007(3)	0.0	0.002(2)	0.0
	N(2)	0.002(2)	0.003(1)	0.002(2)	0.0	0.002(1)	0.0
	S(2)	0.003(1)	0.005(1)	0.004(1)	0.0	0.003(2)	0.0
	C(9)	0.005(3)	0.005(2)	0.003(3)	0.0	0.005(1)	0.0
	C(12)	0.008(3)	0.004(4)	0.007(4)	0.0	0.004(2)	0.0

[a] Standard deviations are given in parentheses and refer to the last digit(s).

Table 4. Bond lengths, valency and torsion angles for **1a** and **1d**

Bond Lengths (Å)[a]

Compound 1a		Compound 1d			
S(1)-N(1)	1.65(3)	S(1)-N(1)	1.67(1)	C(4)-C(5)	1.42(2)
S(1)-O(1)	1.43(2)	S(1)-O(1)	1.42(1)	C(5)-C(6)	1.39(3)
S(1)-O(2)	1.40(2)	S(1)-O(2)	1.44(1)	C(6)-C(7)	1.38(3)
S(1)-C(4)	1.79(3)	S(1)-C(3)	1.77(1)	C(7)-C(8)	1.38(2)
N(1)-C(2)	1.50(4)	N(1)-C(2)	1.44(2)	C(10)-C(11)	1.40(2)
N(1)-C(1)	1.50(3)	N(1)-C(1)	1.49(2)	C(10)-C(9)	1.38(2)
O(3)-S(2)	1.39(2)	C(2)-N(2)	1.45(2)	C(11)-C(12)	1.41(3)
C(2)-N(2)	1.49(3)	O(3)-S(2)	1.46(1)	N(2)-S(2)	1.67(1)
S(2)-N(2)	1.61(3)	C(3)-C(4)	1.42(2)	S(2)-C(9)	1.78(2)
S(2)-C(3)	1.69(5)	C(3)-C(8)	1.35(2)		

Valency Angles (degrees)[a]

Compound 1a		Compound 1d			
N(1)-S(1)-O(1)	105(2)	N(1)-S(1)-O(1)	105(2)	C(3)-C(8)-C(7)	118(2)
N(1)-S(1)-O(2)	109(2)	N(1)-S(1)-O(2)	106(2)	C(11)-C(10)-C(9)	118(2)
N(1)-S(1)-C(4)	108(2)	N(1)-S(1)-C(3)	104(2)	C(10)-C(11)-C(12)	117(3)
O(1)-S(1)-O(2)	121(3)	O(1)-S(1)-O(2)	123(2)	N(1)-C(1)-N(101)	105(2)
O(1)-S(1)-C(4)	110(2)	O(1)-S(1)-C(3)	108(2)	C(2)-N(2)-S(2)	117(2)
O(2)-S(1)-C(4)	104(2)	O(2)-S(1)-C(3)	110(2)	C(2)-N(2)-C(102)	116(2)
S(1)-N(1)-C(2)	123(2)	S(1)-N(1)-C(2)	116(2)	O(3)-S(2)-N(2)	105(2)
S(1)-N(1)-C(1)	127(2)	S(1)-N(1)-C(1)	114(2)	O(3)-S(2)-C(9)	107(2)
C(2)-N(1)-C(1)	110(2)	C(2)-N(1)-C(1)	114(2)	O(3)-S(2)-O(103)	121(2)
N(1)-C(2)-N(2)	104(2)	N(1)-C(2)-N(2)	109(2)	N(2)-S(2)-C(9)	111(2)
O(3)-S(2)-N(2)	103(2)	S(1)-C(3)-C(4)	115(2)	C(10)-C(9)-S(2)	117(2)
O(3)-S(2)-C(3)	109(3)	S(1)-C(3)-C(8)	119(2)	C(10)-C(9)-C(110)	124(2)
O(3)-S(2)-O(30)	123(3)	C(4)-C(3)-C(8)	126(2)	C(11)-C(12)-C(111)	124(3)
N(2)-S(2)-C(3)	109(2)	C(3)-C(4)-C(5)	114(2)		
C(2)-N(2)-S(2)	119(2)	C(4)-C(5)-C(6)	121(2)		
C(2)-N(2)-C(20)	121(4)	C(5)-C(6)-C(7)	120(3)		
N(1)-C(1)-N(10)	113(3)	C(6)-C(7)-C(8)	119(3)		

Endocyclic Torsion Angles (degrees)

Compound 1a		Compound 1d	
C(20)-N(2)-C(2)-N(1)	-60	C(102)-N(2)-C(2)-N(1)	51
N(2)-C(2)-N(1)-C(1)	54	N(2)-C(2)-N(1)-C(1)	-56
C(2)-N(1)-C(1)-N(10)	-60	C(2)-N(1)-C(1)-N(101)	59

[a] Standard deviations are given in parentheses and refer to the last digit.

X-Ray diffraction. Single crystals of **1a** and **1d** were grown from analytically pure samples[1] using nitromethane and tetrahydrofuran as solvent respectively; the density was measured by a flotation procedure.

Compound **1a** ($C_6H_{15}N_3O_6S_3$; mol. wt. 321.4): orthorhombic, $Cmc2_1$; $Z = 4$; $a = 15.36(4)$, $b = 14.55(5)$, $c = 5.74(3)$ Å; $d_{meas.} = 1.67$, $d_{calc.} = 1.66\ g\ cm^{-3}$. Compound **1d** ($C_{21}H_{21}N_3O_6S_3$; mol. wt. 507.6): orthorhombic, Pamn; $Z = 4$; $a = 11.36(4)$, $b = 16.48(3)$, $c = 12.41(3)$ Å; $d_{meas.} = d_{calc.} = 1.45\ g\ cm^{-3}$. In both compounds the molecule is in a special position of point symmetry *m*.

A Phillips equipment and CuK_α radiation were used; reflections intensity was estimated visually by a multi-film Weissenberg technique. For **1a**, from a total of 578 independent reflections 374 were above the background; the corresponding numbers for **1d** were 1226 and 746 respectively. The intensities were corrected for Lorentz and polarization effects but not for absorption or extinction. The programs of Ahmed *et al.* (National Research Council of Canada, 1968) were used to convert intensity data to structure factors.

The heavy atom method was used to determine the coordinates of the two independent S-atoms. Fourier maps were calculated from the observed structure factors with phases calculated from the S-atoms; all the non H-atoms were located in these maps. Isotropic block-diagonal refinements led to R-factors of 13.60 and 13.54% for **1a** and **1d** respectively. Anisotropic refinements, after placing the H-atoms, led to R = 9.57% for **1a** and R = 11.19% for **1d**. Atoms lying at the plane of symmetry *m* were not refined anisotropically.

The final atomic parameters are listed in Tables 2 and 3; bond lengths, valency and torsion angles are collected in Table 4. Values not included result from symmetry (planes *m*, C(1),N(2),S(2) in Fig. 1).

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