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SYNTHESIS, MOLECULAR, AND CRYSTALLINE STRUCTURE OF 3-BENZOYL-1,2-DI(ETHYLSULFONYL)INDOLIZINE

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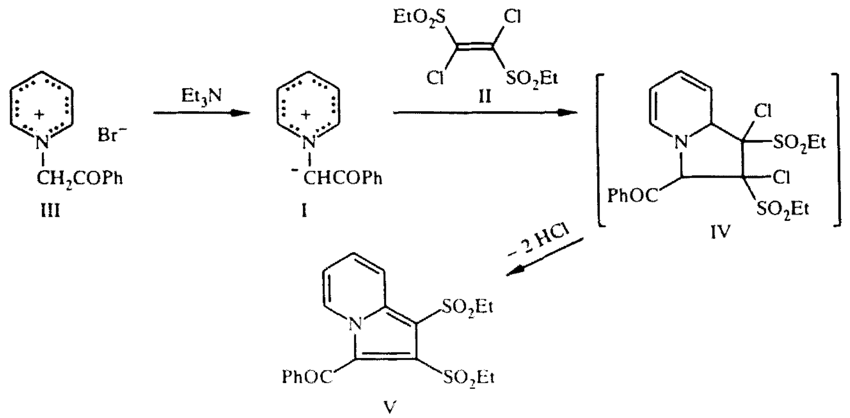
Reaction of pyridiniumbenzoyl methylide with (E)-1,2-di(ethylsulfonyl)-1,2-dichloroethene (which has four nucleophilic groups) occurs via a 1,3-dipolar stereo- and regio directed cycloaddition to give 3-benzoyl-1,2-di(ethylsulfonyl)indolizine the structure of which was established using x-ray crystallography. The rotation of the phenyl substituent by 72.6° relative to the indolizine ring plane and the geometry of the ethylsulfonyl groups can be explained by steric hindrance due to shortened intramolecular non-valence contacts.

By studying the 1,3-dipolar cycloaddition of pyridinium ylids with electron-deficient ethylenes, it has been shown that the regio- and stereo direction of these reactions depend on the structure of the starting materials. Reaction of pyridinium ylids with ethylenes not containing nucleophilic groups leads to tetrahydroindolizines [2] but, when nucleophilic substituents are present, the reaction is accompanied by elimination reactions giving aromatized indolizines [1].

In this work we studied the reaction of methylide I (prepared from the 1-phenacylpyridinium salt III) with (E)-1,2-di(ethylsulfonyl)-1,2-dichloroethene (II), which has four nucleophilic groups, and defined its regioselectivity. Ylid I was generated *in situ* by treatment of salt III with triethylamine.



Reaction of ylid I with dichloroethene II evidently occurs by a 1,3-dipolar cycloaddition via intermediate (IV) with subsequent dehydrochlorination and formation of 3-benzoyl-1,2-di(ethylsufonyl)indolizine (V) in 85% yield. It is known that 1,3-dipolar cycloadditions are reversible and often accompanied by migration of functional groups [1, 2], and it was quite difficult to be certain of the regio directivity from spectral data (see Experimental section). Hence the structure of V was determined by x-ray crystallography. The overall view of V with bond lengths are shown on Fig. 1 and valence angles are given in Table 1. The geometrical parameters for V are in line with reported structural values [3].

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*Deceased.

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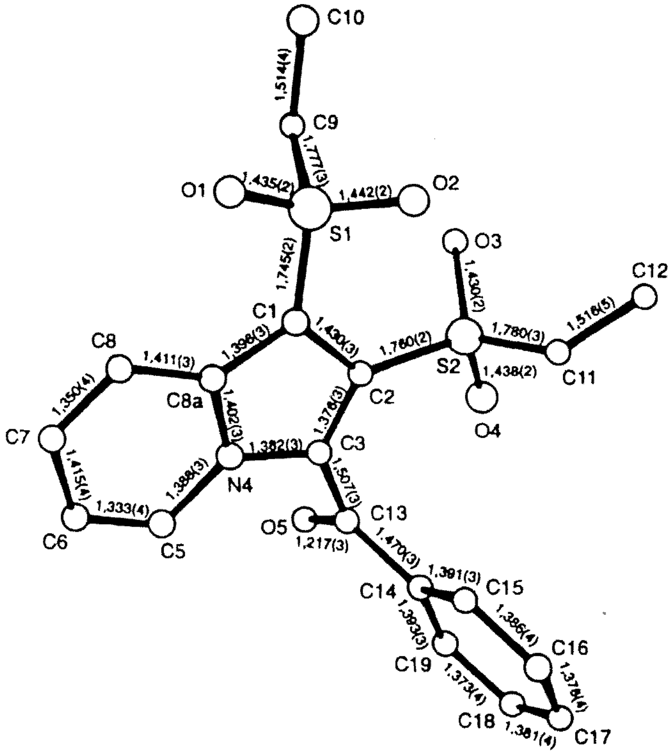

Fig. 1. Overall view and bond lengths in indolizine V.

The indolizine part of V has a planar structure in which the deviation of atoms from the mean plane does not exceed ± 0.065 Å. Steric hindrance due to shortening of intramolecular nonvalence contacts (Table 2) not only causes rotation of the the Ph substituent by 72.6° relative to the indolizine plane, but also has an effect on the geometry of the ethylsulfonyl substituents (torsional angles $C_1S_1C_9C_{10}$ and $C_2S_2C_{11}C_{12}$ are -178.5 and $-164.3°$ respectively) and hinders the conjugation of the C═O group with the indolizine system and the phenyl ring (torsional angles $C_2C_3C_{13}O_5$ -109.9 and $O_5C_{13}C_{14}C_{15}$ $-170.8°$ respectively). This is also apparent in the bond lengths C_3-C_{13} 1.507(3) and $C_{13}-C_{14}$ 1.470(3) Å, where a standard $C_{arom}-C_{sp^2}$ (C═O) is 1.480 Å [3].

The observed distortion from a tetrahedral configuration at sulfurs S_1 and S_2 (valence angles 105.9-117.4(1) and 106.1-118.0(1)°) is common for arylsulfonyl derivatives [4]. An increase in the valence angles $O_1S_1O_2$ and $O_3S_2O_4$ to 117.4(1) and 118.0(1)° respectively is typical for sulfonyl compounds [5].

In the indolizine V the $C_{sp^2}-S$ bond lengths are different. Hence although the C_2-S_2 bond length of 1.760(2) Å agrees with the standard value for $C_{sp^2}-S$ (1.763 Å, [3]) the bond C_1-S_1 is slightly shorter (1.745(2) Å). Such differences in these bonds can be explained by changes in the degree of participation of the sulfonyl groups in the conjugated π-system of the indolizine ring and is probably linked to the extent of deviation of the sulfur atoms from the indicated plane. In fact, atom S_1 lies close to the plane of the heterocycle (deviation not exceeding ±0.025 Å), whereas S_2 is 0.173 Å outside the plane. The greater deviation of S_2 is evidently due to shortening of the intramolecular nonvalence contacts (Table 2) as viewed from both the neighboring ethylsulfonyl group and the benzoyl substituent.

There is an interesting intramolecular nonvalence contact O_1-H_8 (2.39(5) Å) which, according to work in [6], can be considered as an O-H−C type hydrogen bond with quite normal geometrical parameters O_1-C_8 2.986(3), C_8-H_8 0.91(5) Å, and angles S_1-O_1-H_8 108° and C_8-H_8-O_1 123°.

EXPERIMENTAL

IR spectra were recorded on a Specord M-80 spectrometer using KBr tablets and PMR spectra on a Jeol FX-90Q instrument in $CDCl_3$ using TMS internal standard.

TABLE 1. Valence Angles ω (deg.) in the Molecule V

Angle	ω	Angle	ω
$O_{(1)}—S_{(1)}—O_{(2)}$	117,4(1)	$N_{(4)}—C_{(3)}—C_{(13)}$	119,5(2)
$O_{(1)}—S_{(1)}—C_{(1)}$	107,5(1)	$C_{(2)}—C_{(3)}—C_{(13)}$	132,6(2)
$O_{(2)}—S_{(1)}—C_{(1)}$	108,4(1)	$N_{(4)}—C_{(5)}—C_{(6)}$	119,2(2)
$O_{(1)}—S_{(1)}—C_{(9)}$	107,9(1)	$C_{(5)}—C_{(6)}—C_{(7)}$	121,2(3)
$O_{(2)}—S_{(1)}—C_{(9)}$	109,2(1)	$C_{(6)}—C_{(7)}—C_{(8)}$	120,4(3)
$C_{(1)}—S_{(1)}—C_{(9)}$	105,9(1)	$C_{(7)}—C_{(8)}—C_{(8a)}$	119,9(2)
$O_{(3)}—S_{(2)}—O_{(4)}$	118,0(1)	$N_{(4)}—C_{(8a)}—C_{(1)}$	106,9(2)
$O_{(3)}—S_{(2)}—C_{(2)}$	107,5(1)	$N_{(4)}—C_{(8a)}—C_{(8)}$	117,9(2)
$O_{(4)}—S_{(2)}—C_{(2)}$	106,1(1)	$C_{(1)}—C_{(8a)}—C_{(8)}$	135,2(2)
$O_{(3)}—S_{(2)}—C_{(11)}$	109,3(1)	$S_{(1)}—C_{(9)}—C_{(10)}$	111,0(2)
$O_{(4)}—S_{(2)}—C_{(11)}$	109,0(1)	$S_{(2)}—C_{(11)}—C_{(12)}$	109,7(2)
$C_{(2)}—S_{(2)}—C_{(11)}$	106,3(1)	$O_{(5)}—C_{(13)}—C_{(3)}$	117,6(2)
$C_{(3)}—N_{(4)}—C_{(5)}$	128,7(2)	$O_{(5)}—C_{(13)}—C_{(14)}$	122,3(2)
$C_{(3)}—N_{(4)}—C_{(8a)}$	109,9(2)	$C_{(3)}—C_{(13)}—C_{(14)}$	119,9(2)
$C_{(5)}—N_{(4)}—C_{(8a)}$	121,4(2)	$C_{(13)}—C_{(14)}—C_{(15)}$	121,9(2)
$S_{(1)}—C_{(1)}—C_{(2)}$	128,5(2)	$C_{(13)}—C_{(14)}—C_{(19)}$	118,9(2)
$S_{(1)}—C_{(1)}—C_{(8a)}$	124,3(2)	$C_{(15)}—C_{(14)}—C_{(19)}$	119,1(2)
$C_{(2)}—C_{(1)}—C_{(8a)}$	107,2(2)	$C_{(14)}—C_{(15)}—C_{(16)}$	120,1(2)
$S_{(2)}—C_{(2)}—C_{(1)}$	128,4(2)	$C_{(15)}—C_{(16)}—C_{(17)}$	119,9(2)
$S_{(2)}—C_{(2)}—C_{(3)}$	122,7(2)	$C_{(16)}—C_{(17)}—C_{(18)}$	120,3(2)
$C_{(1)}—C_{(2)}—C_{(3)}$	108,5(2)	$C_{(17)}—C_{(18)}—C_{(19)}$	120,1(2)
$N_{(4)}—C_{(3)}—C_{(2)}$	107,6(2)	$C_{(14)}—C_{(19)}—C_{(18)}$	120,4(2)

TABLE 2. Shortened Non Valence Distances in the Indolizine Molecule V*

Distance	d, Å	Distance	d, Å
$S_{(1)}...C_{(8)}$	3,410(2)	$O_{(3)}...C_{(9)}$	3,136(3)
$S_{(2)}...C_{(13)}$	3,368(2)	$O_{(3)}...C_{(12)}$	2,991(3)
$O_{(1)}...C_{(8)}$	2,986(3)	$O_{(4)}...C_{(3)}$	2,915(3)
$O_{(1)}...C_{(8a)}$	2,989(3)	$O_{(4)}...C_{(13)}$	2,818(3)
$O_{(1)}...C_{(10)}$	3,156(3)	$O_{(4)}...C_{(14)}$	3,074(3)
$O_{(1)}...H_{(8)}$	2,39(5)	$O_{(5)}...N_{(4)}$	3,000(3)
$O_{(2)}...C_{(2)}$	3,205(3)	$O_{(5)}...C_{(5)}$	3,185(3)
$O_{(2)}...C_{(10)}$	3,140(3)	$O_{(5)}...C_{(19)}$	2,806(3)
$O_{(2)}...C_{(11)}$	3,193(3)	$C_{(3)}...C_{(15)}$	2,964(4)
$O_{(3)}...C_{(1)}$	3,185(3)	$C_{(5)}...C_{(13)}$	3,001(4)

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*Sum of van der Waal radii of S and C 3.50, O and C 3.22, O and H 2.72, O and N 3.07 Å, doubled radius for C 3.40 Å [7].

X-Ray Structural Investigation of V. Crystals of V are monoclinic, at 20°C a = 9.169(2), b = 21.901(3), c = 9.329(4) Å, β = 92.98(2)°, V = 1871(2) Å^3, d_{calc} = 1.440 g/cm^3, Z = 4, space group $P2_1/n$. Unit cell parameters and intensities of 3624 independent reflections were measured on a Siemens P3/PC four circle automatic diffractometer (λ MoK_α, graphite monochromator, $\theta/2\theta$ scanning to θ_{max} = 30°). The structure was solved by a direct method using the SHELXTL program and refined in a full matrix, least squares method in the anisotropic approximation for non-hydrogen atoms for 3283 reflections with $I > 3\sigma(I)$. All hydrogen atoms were directly revealed by difference synthesis and included in the refinement in the isotropic approximation. Final difference factors were $R = R_w = 0.036$. All calculations were carried out using the SHELXTL PLUS program (version PC) [8]. Atomic coordinates are given in Table 3. Atomic thermal parameter data can be obtained from the authors.

3-Benzoyl-1,2-di(ethylsulfonyl)indolizine (V). Triethylamine (1.7 ml, 8 mmole) was added to a mixture of 1-phenacylpyridinium bromide (III, 1.2 g, 4 mmole) and the ethene II (1.2 g, 4 mmole) in alcohol (20 ml) and the product was held at

TABLE 3. Atomic Coordinates (× 10^4; for H × 10^3) in Molecule V

Atom	x	y	z
$S_{(1)}$	2538(1)	781(1)	8839(1)
$S_{(2)}$	3881(1)	1031(1)	12503(1)
$O_{(1)}$	2606(2)	730(1)	7310(2)
$O_{(2)}$	2531(2)	222(1)	9655(2)
$O_{(3)}$	2327(2)	1084(1)	12336(2)
$O_{(4)}$	4622(2)	1366(1)	13650(2)
$O_{(5)}$	6598(3)	2525(1)	12258(2)
$N_{(4)}$	5946(2)	1859(1)	9490(2)
$C_{(1)}$	4030(2)	1219(1)	9463(2)
$C_{(2)}$	4608(2)	1294(1)	10906(2)
$C_{(3)}$	5779(2)	1687(1)	10896(2)
$C_{(5)}$	6982(3)	2246(1)	8948(3)
$C_{(6)}$	6966(4)	2347(1)	7539(3)
$C_{(7)}$	5910(3)	2068(1)	6591(3)
$C_{(8)}$	4897(3)	1690(1)	7101(2)
$C_{(8a)}$	4886(2)	1572(1)	8587(2)
$C_{(9)}$	962(3)	1216(1)	9199(3)
$C_{(10)}$	-421(3)	875(2)	8738(4)
$C_{(11)}$	4365(3)	246(1)	12658(3)
$C_{(12)}$	3446(4)	-60(2)	13756(4)
$C_{(13)}$	6721(3)	1978(1)	12079(3)
$C_{(14)}$	7800(2)	1608(1)	12915(2)
$C_{(15)}$	8077(3)	1002(1)	12571(3)
$C_{(16)}$	9107(3)	670(1)	13382(3)
$C_{(17)}$	9868(3)	942(1)	14524(3)
$C_{(18)}$	9604(3)	1544(1)	14867(3)
$C_{(19)}$	8586(3)	1876(1)	14067(3)
$H_{(5)}$	760(3)	242(1)	966(3)
$H_{(6)}$	760(3)	258(1)	720(3)
$H_{(7)}$	591(3)	218(1)	557(3)
$H_{(8)}$	419(3)	151(1)	652(3)
$H_{(91)}$	108(3)	159(1)	865(3)
$H_{(92)}$	104(3)	130(1)	1017(3)
$H_{(101)}$	-129(4)	113(2)	903(4)
$H_{(102)}$	-42(4)	80(2)	772(5)
$H_{(103)}$	-44(3)	52(2)	931(3)
$H_{(111)}$	420(3)	10(1)	1175(3)
$H_{(112)}$	544(3)	25(1)	1288(3)
$H_{(121)}$	356(4)	19(2)	1464(4)
$H_{(122)}$	380(4)	-45(2)	1393(4)
$H_{(123)}$	239(4)	-7(2)	1343(3)
$H_{(15)}$	757(3)	82(1)	1180(3)
$H_{(16)}$	929(3)	24(1)	1314(3)
$H_{(17)}$	1058(3)	71(1)	1507(3)
$H_{(18)}$	840(3)	228(1)	1429(1)

20°C for 0.5 h. After removal of alcohol, the residue was dissolved in chloroform, washed with water, and dried over $MgSO_4$. Chloroform was removed and the residue was triturated with alcohol. The precipitated product was filtered off to give (1.0 g, 81.6%) with mp 161-162°C (from chloroform). IR spectrum: 1148, 1156, 1308, 1316 (SO_2), 1654 cm^{-1} (CO). PMR spectrum: 1.25 (3H, t, CH_3), 1.35 (3H, t, CH_3), 3.60 (4H, q, $2CH_2$), 6.78-7.85 (8H, m, Ph, 6,7,8-H), 8.40 ppm (1H, d, 5-H). Found, %: C 42.00, H 6.02, N 5.05, S 21.03. $C_{19}H_{19}NS_2O_5$. Calculated, %: C 41.97, H 6.27, N 4.58, S 20.99.

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