CYCLOADDITION REACTIONS

2. REACTION OF SULFENES WITH 1-METHYLTHIO-1-(N,N-DIETHYLAMINO)ETHENE

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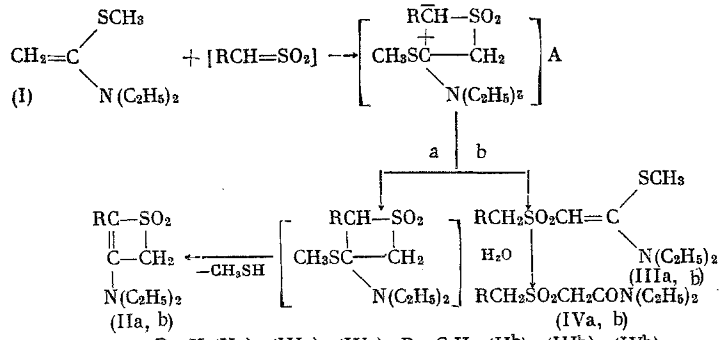
In continuation of studying the 1,2-cycloaddition of sulfenes to unsaturated sulfur-containing compounds [1] we studied their reaction with 1-methylthio-1-(N,N-diethylamino)ethene.

It is known that sulfenes react easily with ketene acetals [2,3] and aminals [4,5]. The cycloaddition of sulfenes to the O,N- or N,N-acetals of ketenes is usually accompanied by the spontaneous β-elimination of alcohol or amine and the formation of thietene dioxide derivatives [5,6]. The 1,2-cycloaddition of sulfenes to the N,S-acetals of ketenes had not been studied previously.

We found that 1-methylthio-1-(N,N-diethylamino)ethene (I) reacts easily with sulfenes. The latter are generated from either methanesulfonyl or α-toluenesulfonyl chloride and Et_3N, taken in an equimolar ratio, at 0-5°C. Here methanethiol is cleaved during the reaction process and dioxythietenes (IIa,b) are formed in 20-50% yields.

Besides the cyclic adducts (IIa,b), acyclic compounds (IIIa,b) are formed, the amount of which depends on the sulfene and solvent used in the reaction (Table 1). An increase in the polarity of the solvent leads to an increase in the amounts of acyclic adducts (IIIa,b) and IVa,b), the total yield of which is 30-60%. Thus, the reaction of (I) with $[CH_2=SO_2]$ in ether gives only dioxythietene (IIa). In a much more polar solvent like CH_3CN the main product becomes 1-methylthio-1-(N,N-diethylamino)-2-methylsulfonyl-1-ethene (IIIa). Both types of compounds were obtained when benzene or $CHCl_3$ was used.



R=H (IIa), (IIIa), (IVa); R=C_6H_5 (IIb), (IIIb), (IVb)

The insertion of a phenyl group into the sulfene molecule also facilitates the formation of acyclic adducts. The reaction of (I) with $C_6H_5CH=SO_2$ even in an ether medium leads to a mixture of the aminodioxythietene (IIb) and β-sulfonylketene N,S-acetal (IIIb). The latter becomes the main product if the process is run in $CHCl_3$ or CH_3CN.

These results can be explained if the intermediate formation of zwitterion A is postulated, as is assumed by many investigators for the cycloaddition reactions with sulfenes [4-7]. A phenyl substituent in the sulfene molecule and a more polar solvent, by favoring a stabilization of the intermediate zwitterion,

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TABLE 1. Ratio of Cyclic (IIa, b) and Acyclic (IIIa, b) + (IVa, b) Adducts (%) when Ketene N, S-Acetals (I) are Reacted with Sulfenes in Various Solvents

Solvent	$CH_2{=}SO_2$		$C_6H_5CH{=}SO_2$	
	(IIa)	(IIIa) + (IVa)	(IIb)	(IIIb) + (IVb)
Ether	100	—	54	46
Benzene	70	30	30	70
$CHCl_3$	25	75	Traces	100
CH_3CN	Traces	100	»	100

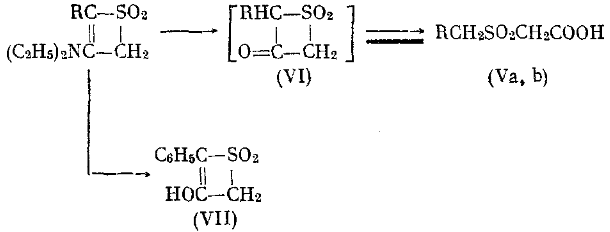
both facilitate the reaction course along direction b, which leads to an increase in the amounts of the acyclic adducts.

The primary acyclic adducts, the β-sulfonylketene N, S-acetals (IIIa, b), are quite labile compounds. When solvents, made absolute by conventional procedures, are used it proves that the amount of water in them is sufficient to partially hydrolyze ketenes (IIIa, b) to amides (IVa, b*). The latter are also detected in the reaction mixtures. The hydrolysis of the reaction mixtures for several days at 20° in the presence of several drops of ~ 1 N HCl solution leads to the complete conversion of ketenes (IIIa, b) to amides (IVa, b). The cycloadducts (IIa, b) remain unchanged under these conditions. The β-sulfonylketene N, S-acetals (IIIa, b) are also hydrolyzed to amides (IVa, b) during the preparative separation of the reaction mixtures by TLC. For this reason the reaction mixtures were analyzed as such by IR and NMR spectroscopy, while the results, obtained by the TLC method, were checked by using as standards the isolated cycloadducts (IIa, b) and authentic specimens of compounds (IIIa) and (IVa, b), which were obtained by counter synthesis.

Besides the frequency of the SO_2 group in the 1110-1120 and 1295-1320 cm^{-1} regions, the IR spectra of the β-sulfonylketene N, S-acetals (IIIa, b) contain the frequency of the C = C bond at 1540-1545 cm^{-1}. Cycloadducts (IIa, b) have the frequency of the C = C bond at 1625-1635 cm^{-1}. It should be mentioned that the frequency of the C = O group of amides (IVa, b) is also found in the 1630-1640 cm^{-1} region, which makes it impossible to quantitatively analyze the mixtures employing IR spectroscopy, as was done by other authors [5].

The ratio of the cyclic (IIa) and acyclic [(IIIa) and (IVa)] compounds was determined by comparing in the NMR spectra the integral intensities of the signals of the H atoms at the double bond [5.15 ppm for the =CH in (IIa), and 5.20 ppm for the =CH in ketene (IIIa)], and of the hydrogens of the SO_2CH_2CO group at 4.16 ppm in amide (IVa). The NMR spectra of the reaction mixtures of compounds (IIb)-(IVb) proved to be complex, and for this reason the ratio of the cyclic and acyclic adducts was established chromatographically, by the preparative separation of the reaction products on plates, which, in harmony with the above said, naturally led to the nearly complete conversion of compound (IIIb) to (IVb).

Together with the IR and NMR spectral data, the structure of cycloadducts (IIa, b) was confirmed by acid hydrolysis at 60-70° to the known β-methyl(benzyl)sulfonic acids (Va, b).



R = H (Va); R = C_6H_5 (Vb), (VII)

In a similar manner, the ring of other aminothietene dioxides is opened via the intermediate formation of cyclic β-ketosulfones [7]. However, we were unable to obtain ketodioxythietane (VI). Together with the starting adduct (IIb), only a small amount of acid (Vb) is detected after 1 h under the conditions used to synthesize analogous compounds in the presence of the acid form of ion-exchange resin Amberlite IR-120 at 20° [5-7], which was isolated in quantitative yield after 3 days.

Dioxythietene (IIb) remains unchanged when kept at 20° for 24 h with 0.1 N HCl solution. Analogous to similar compounds [7], (IIb) is converted to enol (VI) when kept with conc. HCl at 20° for 5 h.

EXPERIMENTAL METHOD

The IR spectra were taken on a UR-10 spectrometer either as KBr pellets or as a thin layer, while the NMR spectra were taken on Varian HA-100 and DA-60-JL spectrometers using HMDS as the internal

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* Taking this into account, the total amount of acyclic adducts (IIIa, b) and (IVa, b) is given in Table 1.

standards. The TLC was run on Woelm neutral Al_2O_3, and the spots were detected with iodine vapors. For the preparative separation we used 20 × 32 cm plates covered with a loose layer of neutral Al_2O_3 (II activity), with a thickness of 2 mm. The GLC was run on an LKhM-8M instrument, using a flame-ionization detector, a 1 m × 4 mm column packed with 10% SKTPT-50 deposited on Chromosorb W (0.18-0.21 mm), and a temperature of 200°. The melting points were determined on a Kofler block. The triethylamine was dried and distilled over KOH. The solvents were made absolute. The methanesulfonyl chloride was distilled, the α-toluenesulfonyl chloride was recrystallized, while the 1-methylthio-1-(N,N-diethylamino)ethene (I) (bp 80.5-81.5° (25 mm), n_D^{20} 1.4940) was synthesized as described in [8] from N,N-diethyl-thioacetamide. Found: C 57.97; H 10.14; N 9.50; S 22.36%. $C_7H_{15}NS$. Calculated: C 57.91; H 10.34; N 9.59; S 22.09%. Infrared spectrum (ν, cm^{-1}): 1580 (C = C). NMR spectrum (neat, δ, ppm): 0.96; 3.04 (C_2H_5); 2.02 s (SCH_3); 4.15 d; 4.04 d (=CH_2).

Cycloaddition of 1-Methylthio-1-(N,N-diethylamino)ethene (I) to Sulfene. a) To a stirred mixture of 2.17 g of (I) and 1.51 g of Et_3N in 100 ml of ether was added in a nitrogen atmosphere, at 0-5°, in 1 h, a solution of 1.72 g of CH_3SO_2Cl in 40 ml of ether in drops. The reaction mixture was kept at 0° for 2 h, and at 20° for 1 h. The triethylamine hydrochloride was filtered and washed with ether [1.85 g (95%), mp 265°]. The combined ether solution was evaporated and several drops of MeOH were added to the residue. Cooling to −5° gave 0.36 g of (IIa) as crystals with mp 76-77.5° (from methanol). Another 0.53 g of (IIa) was isolated from the mother liquor by TLC (in the system hexane:acetone, 2:1). The total yield of 3-(N,N-diethylamino)-1,1-dioxy-2-thietene (IIa) was 0.89 g (32%). Found: C 47.82; H 7.39; N 7.80; S 18.38%. $C_7H_{13}NO_2S$. Calculated: C 47.99; H 7.30; N 7.99; S 18.30%. Infrared spectrum (ν, cm^{-1}): 1627 (C = C), 1100, 1260 (SO_2). NMR spectrum (in $CDCl_3$, δ, ppm): 1.10, 3.13 (C_2H_5N); 4.32 s (CH_2SO_2); 5.15 s = C−H). The IR and NMR spectra of the reaction mixture were identical with the spectra of dioxythietene (IIa). Only compound (IIa) was detected in the reaction mixture by TLC and GLC.

The reaction of (I) with CH_3SO_2Cl in benzene or $CHCl_3$ was run the same as described above. After evaporation of the solvents and removal of the triethylamine hydrochloride, the reaction mixtures were analyzed by TLC, GLC, and IR and NMR spectroscopy. The ratios of the cyclic and acyclic adducts are given in Table 1.

b) Under the above-indicated conditions, from 1 g of (I), 0.9 g of Et_3N, and 0.74 g of CH_3SO_2Cl in 20 ml of CH_3CN we obtained 1.34 g of a mixture. Employing TLC and GLC, it was shown that ketene (IIIa) and amide (IVa) are present by comparison with authentic specimens. Infrared spectrum of the mixture (ν, cm^{-1}): 1115, 1320 (SO_2), 1545 (C=C), 1640 (C=O).

The mixture (1.34 g) was stirred with 10 ml of 1 N HCl solution at 20° for 3 h, extracted with ether, and the ether solution was washed with a little water and then dried over $MgSO_4$. Removal of the ether gave 1.40 g of hydrolyzate, which was purified chromatographically on a plate in the solvent system: hexane−acetone = 15:8. From 0.28 g of the reaction mixture we obtained 0.14 g (43.2%) of amide (IVa), which, based on the TLC and GLC, was identical with the amide (IVa) obtained by counter synthesis. Found: C 43.30; H 7.70; N 7.20; S 16.70%. $C_7H_{15}NO_3S$. Calculated: C 43.53; H 7.79; N 7.25; S 16.58%. Infrared spectrum (ν, cm^{-1}): 1645 (C = O), 1152, 1315 (SO_2). NMR spectrum (in $CHCl_3$, δ, pp,): 1.18, 3.37 (C_2H_5N); 3.18 s (CH_3SO_2); 4.18 s (SO_2CH_2CO).

Cycloaddition Reaction of 1-Methyl-1-(N,N-diethylamino)ethene (I) to Phenylsulfene. a) Under the conditions indicated above for the synthesis of (IIa), from 4.63 g of (I), 3.24 g of Et_3N, and 6.09 g of $C_6H_5CH_2SO_2Cl$ in 75 ml of ether we obtained 7.76 g of a mixture. Infrared spectrum of the mixture (ν, cm^{-1}): 1530 [C = C in (IIIb)], 1643 (C = O and C = C in (IIb)], 1115, 1280, 1320 (SO_2). Several drops of methanol were added to the mixture, and the crystals obtained on cooling to − 5° were filtered. We obtained 1.7 g (21%) of (IIb), mp 132.5-133° (from MeOH). Found: C 61.89; H 6.74; N 5.50; S 12.70%. $C_{13}H_{17}NO_2S$. Calculated: C 62.08; H 6.82; N 5.57; S 12.76%. Infrared spectrum (ν, cm^{-1}): 1640 (C = C), 1115, 1280 (SO_2). NMR spectrum (in $CDCl_3$, δ, ppm): 0.90, 3.20 (C_2H_5N); 4.35 s (CH_2SO_2); 7.20 (C_6H_5).

From 6.1 g of the mother liquor we isolated 0.28 g of substance by TLC in the system: ether−acetone = 40:1. We obtained 0.09 g (33%) of (IIb), mp 132-133° (total yield of (IIb) = 54%), and 0.15 g of (IVb), contaminated with a small amount of (IIIb) (based on the IR spectrum).

The (IIIb) + (IVb) mixture (0.15 g) was stirred with 5 ml of 1 N HCl solution at 20° for 2 h. After the same workup as indicated above for (IVa) we obtained 0.12 g (30%) of amide (IVb), mp 67.5-68° (from methanol), which did not depress the mixed melting point and, based on the TLC, was identical with an authentic specimen of amide (IVb). Found: C 58.02; H 7.09; N 5.10; S 12.02%. $C_{13}H_{19}NO_3S$. Calculated:

C 57.92; H 7.11; N 5.19; S 11.90%. Infrared spectrum (ν,cm^{-1}): 1122, 1320 (SO_2), 1637 (C = O). NMR spectrum (in CCl_4, δ,ppm): 1.02; 3.25 (C_2H_5N), 3.67 s (CH_2SO_2); 4.35 s ($COCH_2SO_2$); 7.3 (C_6H_5).

b) Under the conditions described for the synthesis of (IIa), from 1.70 g of (I), 1.14 g of Et_3N, and 2.22 g of $C_6H_5CH_2SO_2Cl$ in 50 ml of benzene at 0-5° we obtained 3.6 g of a mixture of (IIb) and (IIIb) (based on the TLC and IR spectrum).

The mixture (0.30 g) was separated on a plate in the system: cyclohexane–ethyl acetate = 1:1. We obtained 0.05 g (22.2%) of (IIb) and 0.12 g (53.3%) of amide (IVb).

c) The mixture, obtained as indicated above for (IIa) from 2.31 g of (I), 1.62 g of Et_3N, and 3.04 g of $C_6H_5CH_2SO_2Cl$ in 50 ml of $CHCl_3$, which, based on the TLC and IR spectral data, contained compounds (IIIb), (IVb), and traces of adduct (IIb), was dissolved in a mixture of 30 ml of THF and 3 ml of 1 N HCl solution, and then heated at 60° for 30 min. The THF was evaporated, the residue was extracted with ether, and the ether solution was washed with water and then dried over $MgSO_4$. The residue from the evaporation of the ether (2.96 g) was purified chromatographically on a plate in the system: hexane–acetone = 2 : 1. From 0.36 g of the hydrolyzate we obtained 0.24 g (50.3%) of amide (IVb).

When the cycloaddition was run in CH_3CN, we obtained from 1.70 g of (I), 1.14 g of Et_3N, and 2.22 g of $C_6H_5CH_2SO_2Cl$ a mixture of compounds (IIIb) and (Vb), contaminated with traces of (IIb). After hydrolysis and chromatographic purification, as indicated above, we isolated 1.49 g (59.3%) of amide (IVb).

β-Methyl(benzyl)sulfonylacetic Acid N,N-Diethylamide (IVa,b). Operating in conventional manner, (IVa) and (IVb) were obtained, respectively, from the β-methyl- or β-benzylsulfonylacetic acids. Amide (IVa), bp 100-103° (0.02 mm). Found: C 43.25; H 7.80; N 7.19; S 16.85%. $C_7H_{15}NO_3S$. Calculated: C 43.53; H 7.79; N 7.25; S 16.58%. Infrared spectrum (ν,cm^{-1}): 1645 (C =O), 1152, 1315 (SO_2). NMR spectrum (in $CHCl_3$, δ,ppm): 1.18, 3.37 (C_2H_5N); 3.18 s (CH_3SO_2); 4.18 s (SO_2CH_2CO). Amide (IVb), mp 67.5-68° (from ether). Found: C 57.85; H 7.08; N 5.10; S 11.80%. $C_{13}H_{19}NO_3S$. Calculated: C 57.92; H 7.11; N 5.18; S 11.90%. Infrared spectrum (ν,cm^{-1}); 1121, 1315 (SO_2), 1635 (C=O). NMR spectrum (in CCl_4, δ,ppm): 1.02; 3.26 (C_2H_5N); 3.67 s (CH_2SO_2); 4.35 s ($COCH_2SO_2$); 7.3 (C_6H_5).

1-(N,N-Diethylamino)-1-methylthio-2-methylsulfonylethene (IIIa). From β-methylsulfonylacetic acid N,N-diethylamide, as described in [8], we synthesized (IIIa), bp 108-110° (0.02 mm). Found: C 42.89; H 7.52; N 6.19; S 28.45%. $C_8H_{17}NO_2S_2$. Calculated: C 42.81; H 7.62; N 6.28; S 28.69%. Infrared spectrum (ν,cm^{-1}): 1113, 1300 (SO_2), 1540 (C=C). NMR spectrum (in CCl_4, δ,ppm): 1.16, 3.62 (C_2H_5N); 2.36 s (SCH_3) 3.06 s (CH_3SO_2); 5.22 s (=CH).

Hydrolysis of Adducts (IIa,b). A mixture of 0.2 g of (IIb) and 6 ml of ~ 0.1 N HCl solution was heated at 60-70° for 2 h. The aqueous solution was extracted with CH_2Cl_2. After the usual workup we obtained 0.13 g (77.8%) of acid (Vb), mp 139-140° ($CHCl_3$), which did not depress the mixed melting point with an authentic specimen [9]. Methyl ester (Vb), mp 75-76° (benzene). Found: C 52.54; H 5.01; S 13.98%. $C_{10}H_{12}O_4S$. Calculated: C 52.63; H 5.26; N 14.03%. Infrared spectrum (ν,cm^{-1}): 1145, 1300 (SO_2), 1732 (C=O). In a similar manner, from 0.1 g of (IIa) we isolated 0.6 g (85.7%) of acid (Va), mp 114-115° ($CHCl_3$), which did not depress the mixed melting point with an authentic specimen [10].

A mixture of 0.12 g of (IIb) and 10 ml of water was stirred with Amberlite IR-120 for 3 days at 20°. The ion-exchange resin was filtered and washed with acetone. The aqueous acetone solution was evaporated and the residue was extracted with ether. After evaporation of the ether and recrystallization from $CHCl_3$ we obtained 0.7 g (66.6%) of (Vb).

A mixture of 0.1 g of adduct (IIb) and 3 ml of conc. HCl was kept at 20° for 3 h. After removal of the water the residue was sublimed at 2 mm. We obtained 0.06 g (85.7%) of enol (VI), mp 152-153.5°, which gave a blue color with $FeCl_3$. Found: C 55.14; H 4.39; S 16.18%. $C_9H_8O_3S$. Calculated: C 55.13; H 4.11; S 16.34%. Infrared spectrum (ν,cm^{-1}): 1100, 1290 (SO_2), 1680 (C =C), 3090 (OH).

CONCLUSIONS

1. Methanethiol is cleaved in the 1,2-cycloaddition of 1-methylthio-1-(N,N-diethylamino)ethene to sulfenes and a mixture of 3-(N,N-diethylamino)dioxy-2-thietenes and 1-(N,N-diethylamino)-1-methylthio-2-methyl(benzyl)sulfonylethenes is formed, along with the partial hydrolysis products of the latter.

2. The ratio of the cyclic and acyclic adducts depends on the structure of the employed sulfene and the polarity of the solvent.

LITERATURE CITED

1. E. N. Prilezhaeva, N. P. Petukhova, V. I. Kurilkin, A. U. Stepanyants, and V. P. Lezina, Izv. Akad. Nauk SSSR, Ser. Khim., 1827 (1974).
2. W. E. Truce and J. R. Norell, J. Am. Chem. Soc., 85, 3231 (1963).
3. T. Nagai, H. Namikoshi, and N. Tokura, Tetrahedron Lett., 4329 (1968).
4. R. H. Hasek, P. G. Gott, R. H. Meen, and J. C. Martin, J. Org. Chem., 30, 1495 (1965).
5. G. Opitz and H. Schempp, Ann. Chem., 684, 103 (1965).
6. W. E. Truce, D. J. Abraham, and P. Son., J. Org. Chem., 32, 990 (1967).
7. M. H. Rosen, Tetrahedron Lett., 647 (1969).
8. R. Compper and W. Elser, Ann. Chem., 725, 64 (1969).
9. R. Lesser and A. Mehrländer, Chem. Ber., 56, 1642 (1923).
10. H. Böhme and H. Fischer, Chem. Ber., 76, 92 (1943).