Mechanism of the Stereoselective Formation of 1,4-Dithiafulvens from 1,2,3-Thiadiazoles and Base (1)

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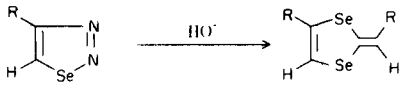
4-Substituted-1,2,3-thiadiazoles were found to react with base to form *cis*-2,ω-disubstituted-1,4-dithiafulvenes. The mechanism for the stereoselective formation of the product is discussed.

Recently we have shown that the base catalyzed decomposition of 1,2,3-selenadiazoles afforded only one of the expected isomeric forms of 1,4-diselenafulvenes (2). (See Scheme I).

Scheme I

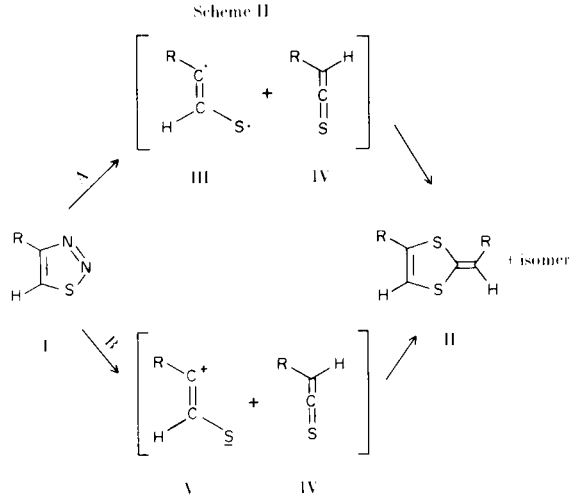


It is noteworthy that the similar base catalyzed reaction of 1,2,3-thiadiazoles (I) had been reported to give a mixture of both isomers of 1,4-dithiafulvene (II) (3). Various mechanisms have been postulated. In broad outline, under the reaction conditions used, one of the two basic mechanisms appears to be operative.

In the first, a photolytic dimerization, it is proposed that the biradical (III) is produced which rearranges to give the thioketene (IV). 1,3-Addition of the biradical to the thioketene would afford (II) (4). (Route A Scheme II). The second mechanism proposes the 1,3-dipolar addition of an intermediate of type (V) to the thioketene (IV) (3,5). (Route B Scheme II).

It was of interest to us to clarify the exact mechanism of this reaction and it seemed that the nmr spectroscopy could be helpful to overcome this problem. The nmr spectra of the more easily obtained dimers from 4-aryl-1,2,3-thiadiazoles were unrevealing, since H_3 and H_ω of the ylidenes had signals in the aromatic region. Useful spectra were obtained from the dimer which was prepared by the addition of the pellets of potassium hydroxide to the alcoholic solution of 4-*t*-butyl-1,2,3-thiadiazole. Figure I shows the nmr spectrum of the di-*t*-butyl substituted dimer. The protons of the *t*-butyl groups are clearly resolved into four peaks centered at 1.15 ppm. In the low field part of the spectrum H_3 and H_ω absorptions appeared as triplets centered at 5.31 and 5.6 ppm. This spectrum could be rationalized by the presence of a mixture of two isomers. In one, the two *t*-butyl groups are in the *cis* and in the other, in the *trans* configurations. Possibly the larger long range coupling constant of the

Scheme II



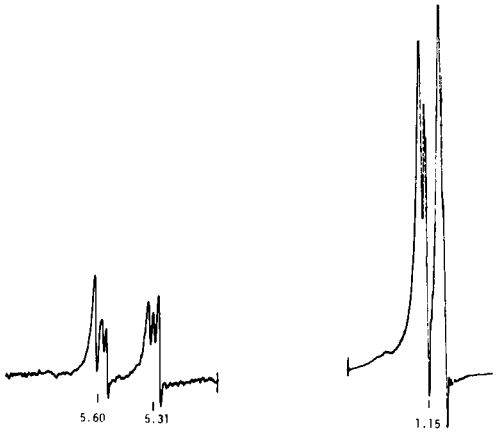


Figure I

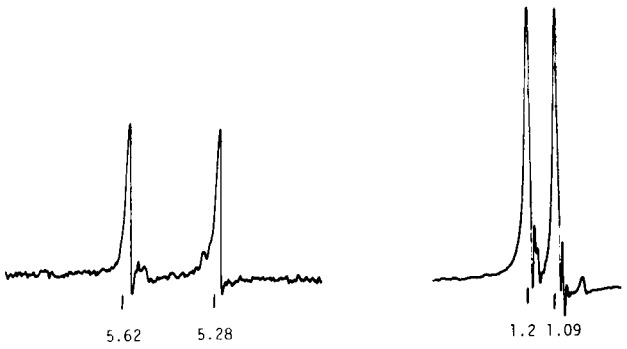


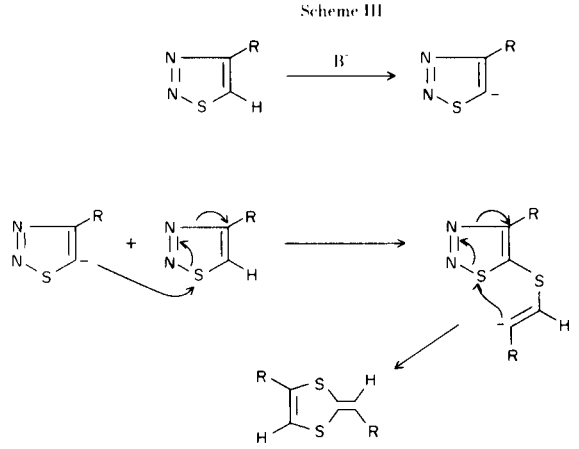
Figure II

two olefinic protons in the *trans* configuration would result in the splitting of H_3 and H_ω, each as a doublet. However, in the *cis* isomer H_3 and H_ω do not couple and consequently, they appear as singlets.

Rapid and careful work-up of the reaction mixture resulted in a product which showed the nmr spectrum shown in Figure II. Both triplets, each integrating for one proton, are reduced to sharp singlets at 5.28 and 5.62 ppm. Also there are two singlets at 1.09 and 1.2 ppm, each integrating for nine protons, for the two *t*-butyl groups. Addition of a trace of trifluoroacetic acid resulted in the reappearance of the former spectrum (Figure I). Clearly the product of the rapid and careful work-up is a single isomer which is isomerized by acid to a mixture of the *cis* and *trans* isomers.

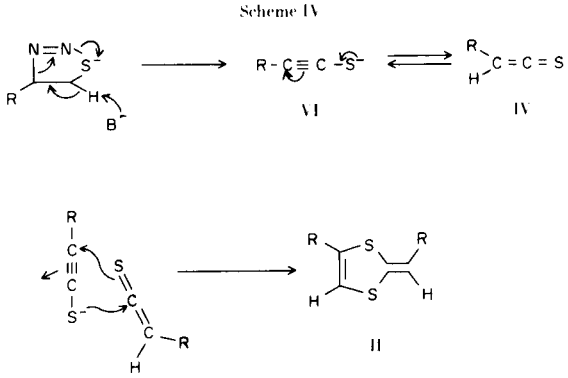
In analogy with the mechanism proposed for the dimerization of isothiazolones (6), a mechanism can be envisaged which would account for the formation of a single isomer. According to this mechanism only the *trans* isomer is formed. (Scheme III).

Scheme III



Another mechanism, which predicts the formation of the *cis* isomer, can also be suggested (Scheme IV). Consistant with this mechanism, the intermediate VI could be obtained as an insoluble potassium salt, when the reaction was carried out in dioxane using alcoholic potassium ethoxide as a base. The ir spectrum of this salt showed carbon carbon triple bond absorption. Dissolving this salt in 95 percent alcohol converted it to the same pure *cis* isomer which could be formed directly from the thiadiazole.

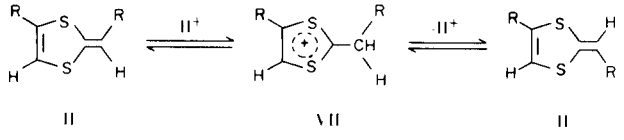
Scheme IV



The factor that controls this stereoselectivity in an apparently symmetrical intermediate is probably steric hindrance of a relatively bulky R group on the thioketene. This could lead to a preferred approach of the thioketene from the hydrogen side.

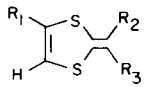
On the basis of the above mechanism, the primary compounds which are formed from 4-aryl-1,2,3-thiadiazoles are also *cis* isomers. All *cis* aryl substituted 1,4-dithiafulvenes are isomerized to the corresponding thermodynamically more stable *trans* isomer through heating. Also, the *trans* isomer could be crystallized from an alcoholic solution of the *cis* isomer to which a trace of an acid was added. It appears that the isomerization happens as shown in Scheme V *via* the dithiolium ion (VII). Evidence for the existance of (VII) in solution was obtained from the nmr spectrum of the pure *cis* or the *trans* isomer of (II, R = Ph) in trifluoroacetic acid. In such a solvent a peak appears at 4.46 ppm for the methylene protons of (VII) integrating for two hydrogens relative to the eleven aromatic hydrogens. The nmr of a pure *cis* or *trans* isomer obtained in DMSO had only aromatic hydrogens.

Scheme V



The physical data of the *cis* and *trans* aryl substituted 1,4-dithiafulvenes are given in Table I.

TABLE I



R_1	R_2	R_3	(a) M.p., °C	Yield %	Formula	C Calcd.	C Found	H Calcd.	H Found	S Calcd.	S Found
C_6H_5	C_6H_5	H	126-128	72	$C_{16}H_{12}S_2$	71.64	71.47	4.47	4.54	23.88	24.01
C_6H_5	H	C_6H_5	203-204	95	$C_{16}H_{12}S_2$	71.64	71.57	4.47	4.57	23.88	23.90
p-FC_6H_4	*p*-FC_6H_4	H	101-103	63	$C_{16}H_{10}F_2S_2$	63.15	63.25	3.28	3.18	21.05	20.93
p-FC_6H_4	H	*p*-FC_6H_4	219-221	96	$C_{16}H_{10}F_2S_2$	63.15	63.04	3.28	3.32	21.05	20.99
p-ClC_6H_4	*p*-ClC_6H_4	H	165-167	66	$C_{16}H_{10}Cl_2S_2$	56.97	56.88	2.96	2.83	18.99	19.05
p-ClC_6H_4	H	*p*-ClC_6H_4	239-241	90	$C_{16}H_{10}Cl_2S_2$	56.97	56.92	2.96	2.99	18.99	18.81
p-BrC_6H_4	*p*-BrC_6H_4	H	190-191	67	$C_{16}H_{10}Br_2S_2$	45.07	45.18	2.34	2.45	15.02	14.89
p-BrC_6H_4	H	*p*-BrC_6H_4	251-253	97	$C_{16}H_{10}Br_2S_2$	45.07	45.01	2.34	2.48	15.02	15.06
p-$CH_3C_6H_4$	*p*-$CH_3C_6H_4$	H	178-180	71	$C_{18}H_{16}S_2$	72.97	72.87	5.40	5.52	21.62	21.49
p-$CH_3C_6H_4$	H	*p*-$CH_3C_6H_4$	228-229	96	$C_{18}H_{16}S_2$	72.97	72.99	5.40	5.48	21.62	21.55
p-$CH_3OC_6H_4$	*p*-$CH_3OC_6H_4$	H	157-159	73	$C_{18}H_{16}O_2S_2$	65.85	65.93	4.87	4.72	19.51	19.39
p-$CH_3OC_6H_4$	H	*p*-$CH_3OC_6H_4$	232-233	92	$C_{18}H_{16}O_2S_2$	65.85	65.89	4.87	4.91	19.51	19.41

(a) All the *cis* isomers were crystallized from ethanol and all the *trans* isomers in DMSO.

EXPERIMENTAL

Melting points were obtained on a Kofler hot stage apparatus and are uncorrected. Nmr spectra were determined using Varian A60A spectrometer. Infrared spectra were obtained from a Leitz model III. Mass spectra were run on a Varian Mat 111 instrument.

Substituted 1,2,3-thiadiazoles were prepared by a known method (7).

2,ω-Di-*t*-butyl-1,4-dithiafulvene.

4-*t*-Butyl-1,2,3-thiadiazole (0.71 g., 5 mmoles) was added to a solution of 50 mmoles of potassium ethoxide in 50 ml. of dioxane containing 2 ml. of ethanol. After the gas evolution had ceased the precipitate was filtered and washed with dry ether to give the white potassium salt; ir (potassium bromide) 2200 cm^{-1}. The salt was treated with 10 ml. of 95% ethanol. The reaction mixture was diluted with water, and extracted with chloroform. The extract was dried, filtered, and evaporated to give 0.51 g. (90%) of an oil; nmr (carbon tetrachloride), δ 5.62 (s, 1H, H_3), 5.28 (s, 1H, H_ω), 1.2 (s, 9H, *t*-Bu), 1.09 ppm (s, 9H, *t*-Bu); m.w. (by mass spectrum): 228 m/e. Upon addition of a trace of trifluoroacetic acid to nmr tube: δ 5.62 (s, H_3, *cis*), 5.59 (d, H_3, *trans*, $J_{3,\omega}$ = 1.3 Hz), total integration 1H, 5.32 (d, H_ω *trans*), 5.28 (s, H_ω *cis*), total integration 1H, 1.05-1.25 ppm (4 peaks, 18H, *t*-Bu).

2,ω-Diaryl-1,4-dithiafulvenes.

4-Aryl-1,2,3-thiadiazole (5 mmoles) was dissolved in 20 ml. of 95% ethanol and a few pellets of potassium hydroxide were added. Upon slight heating gas evolution commenced. After gas evolution has ceased, 10 ml. of water was added. The crystals were filtered and recrystallized (see Table I). The *cis* compounds were isomerized to the *trans* configuration through heating above the melting points or addition of a trace of an acid to the corresponding ethanolic solution (see Table I).

2,ω-Diphenyl-1,4-dithiafulvenes.

cis-2,ω-Diphenyl-1,4-dithiafulvene prepared according to the above procedure had m.p. 126-128°; ir ν max (potassium bromide) 1565s, 1550m, 1480m, 1430s, 1333w, 1183w, 925m, 895m, 806s, 740s, 731vs, 680s cm^{-1}. Upon heating to 220° and cooling the *trans* compound was formed which melted at 203-204°; ir ν max (potassium bromide) 1565s, 1550m, 1480m, 1430s, 1333w, 1183w, 925m, 895m, 809s, 739vs, 735s, 680s cm^{-1}; m.w. (by mass spectrum): m/e 268.

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