CYCLOPROPANES OF 5-NITROFURANE SERIES. REACTIONS OF DIAZOMETHANE WITH 1-(5-NITRO-2-FURYL)-1-TRICHLOROMETHYL-SULPHONYL-2-R-ETHYLENES

Josef PROUSEK, Adolf JURÁŠEK and Jaroslav KOVÁČ

Organic Chemistry Department,
Slovak Institute of Technology, 880 37 Bratislava

Received July 18th, 1979

Diazomethane reacts with trisubstituted ethylenes of 5-nitrofurane series within the temperature range −60°C to +20°C with direct formation of cyclopropane derivatives *IV* without pyrazoline intermediates. This reaction does not proceed as a 1,3-dipolar cycloaddition but goes *via* a non-finished stepwise mechanism discussed in the present paper. The cyclopropane derivative *IVa* has been prepared as a model substance *via* the new reaction from 5-nitrofurfuryltrichloromethyl sulphone (*I*) and paraformaldehyde. The synthetized derivatives were identified by IR, UV, ^{1}H-NMR and mass spectra.

Activated double bond is known to react with diazomethane by 1,3-dipolar cycloaddition to give pyrazoline adduct[1,2]. So far this reaction has been studied with 5-nitrofurylethylenes.[3] Sasaki[4] prepared the respective pyrazoline derivative by reaction of diazomethane with 3-(5-nitro-2-furyl)acrylic acid and submitted it to therma decomposition to the cyclopropane derivative. Similar thermal decomposition of pyrazolines served for preparation of further 5-nitrofurylcyclopropanes[5,6]. Pyrazoline adducts are also formed in reactions of diazomethane with α,β-unsaturated sulphones[7,8]. Jurášek and coworkers[9] studied the reaction of diazomethane with 1-(5-nitro-2-furyl)-1-phenylsulphonyl-2-(4-X-phenyl)ethylenes (X = NO_2, F, H, OCH_3, $N(CH_3)_2$). All these reactions gave Δ^1-pyrazolines. The pyrazolines having electron-acceptor substituents in the benzene ring only were stable, those with electron-donor substituents being unstable in air (resinification)[9].

Our previous paper[10] dealt with the reaction of diazomethane with 1-(5-nitro-2-furyl)-1-trichloromethylsulphonyl-2-(5-nitro-2-furyl)ethylene. The reaction was found to give direct the cyclopropane derivative. In the present paper this reaction is studied more extensively. For this purpose we synthetized the strongly polarized trisubstituted ethylenes *IIIa*–*IIIo* by the condensation reaction of 5-nitrofurfuryltrichloromethyl sulphone (*I*) with aromatic and heterocyclic aldehydes *IIa*–*IIo* using the known method[11]. Character of the reaction of diazomethane with the olefins *IIIa*–*IIIo* was investigated with respect to effect of the substituents R (Table I), effect of light and reaction temperature. Reactions of 1-(5-nitro-2-furyl)-1-trichloromethylsulphonyl-

TABLE I

1-(5-Nitro-2-furyl)-1-trichloromethylsulphonyl-2-R-cyclopropanes *IVa*—*IVo*

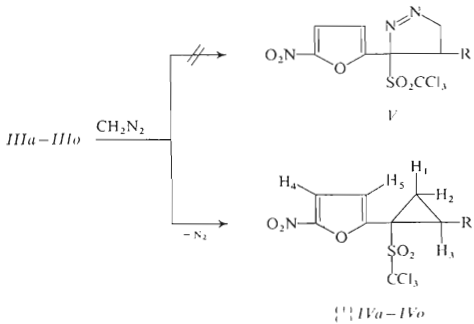
Compound R	Formula (mol. mass)	M.p., °C (yield, %)	Reaction time, days React. temperature °C	Calculated/Found % Cl	% N	% S
IVa 5-Nitro-2-furyl	$C_{12}H_7Cl_3N_2O_8S$ (445·6)	212 (92)	1 −3 to 0	23·87 23·72	6·28 6·25	7·19 7·37
IVb 5-Iodo-2-furyl	$C_{12}H_7Cl_3JNO_6S$ (526·5)	140—160 (34)	10 0 to 20	20·20 21·12	2·66 2·82	6·09 —
IVc 5-Methyl-2-furyl	$C_{13}H_{10}Cl_3NO_6S$ (114·6)	125 (17)	10 20	25·65 24·83	3·38 3·41	7·73 7·76
IVd 5-Carbmethoxy-2-furyl	$C_{14}H_{10}Cl_3NO_8S$ (458·7)	153 (94)	3 −30 to 0	23·19 23·06	3·05 3·15	6·99 7·09
IVe 2-Thienyl	$C_{12}H_8Cl_3NO_5S_2$ (416·7)	126 (44)	10 20	25·46 24·65	3·35 3·39	15·35 14·61
IVf 5-Nitro-2-thienyl	$C_{12}H_7Cl_3N_2O_7S_2$ (461·7)	211 (81)	2 −30 to 0	23·03 22·84	6·06 5·96	13·89 13·72
IVg 5-(2-Nitrophenyl)-2-furyl	$C_{18}H_{11}Cl_3N_2O_8S$ (521·7)	140—150 (74)	2 −20 to 0	20·38 20·25	5·37 5·23	6·14 6·23
IVh 5-(4-Nitrophenyl)-2-furyl	$C_{18}H_{11}Cl_3N_2O_8S$ (521·7)	175 (47)	2 −3 to 20	20·38 19·77	5·37 5·36	6·14 6·20
IVi 3-Chromonyl	$C_{17}H_{10}Cl_3NO_7S$ (478·7)	192—198 (98)	2 0	22·22 21·98	2·92 3·23	6·69 6·33
IVj Phenyl	$C_{14}H_{10}Cl_3NO_5S$ (410·7)	153—155 (46)	10 20	25·90 25·02	3·41 3·46	7·80 7·69
IVk 3-Nitrophenyl	$C_{14}H_9Cl_3N_2O_7S$ (455·7)	174 (66)	2 0	23·34 23·19	6·15 6·13	7·03 7·00
IVl 4-Nitrophenyl	$C_{14}H_9Cl_3N_2O_7S$ (455·7)	234 (84)	1 −3	23·34 23·40	6·15 6·27	7·03 7·03
IVm 2-Fluorophenyl	$C_{14}H_9Cl_3FNO_5S$ (428·7)	166 (89)	1 0	24·81 24·58	3·26 3·19	7·48 7·46
IVn 2-Chlorophenyl	$C_{14}H_9Cl_4NO_5S$ (445·1)	215 (73)	2 −60	31·86 31·70	3·14 3·13	7·20 7·24
IVo 3-Chlorophenyl	$C_{14}H_9Cl_4NO_5S$ (445·1)	166 (44)	11 20	31·86 31·49	3·14 3·14	7·20 7·15

TABLE II

UV and IR Spectra of Cyclopropane Derivatives *IVa*–*IVo*

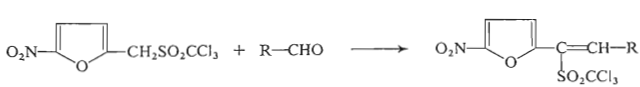
Compound	λ_{max}, nm (log ε)	$\tilde{\nu}$, cm^{-1}				
		cyclopropane ring	$(NO_2)_{as}$	$(NO_2)_s$	SO_2	$(C—O—C)_f$
IVa	209(4·32) 305(4·36)	3 135, 3 050 1 085	1 538 1 505	1 360	1 297 1 160	1 035
IVb	—	3 130, 3 025 1 090	1 545 1 510	1 358	1 297 1 155	1 029
IVc	216(4·22) 311(4·07)	3 135 1 085	1 540 1 510	1 360	1 300 1 160	1 027
IVd	207(4·14) 311(3·98)	3 135, 3 058 1 090	1 535 1 500	1 350	1 305 1 155	1 030
IVe	212(4·12) 312(4·10)	3 132, 3 020 1 092	1 540 1 500	1 362	1 292 1 157	1 029
IVf	207(4·22) 312(4·34)	3 112, 3 020 1 093	1 535 1 510	1 358	1 295 1 159	1 025
IVg	207(4·43) 325(4·02)	3 138, 3 090 1 088	1 540 1 505	1 356	1 295 1 157	1 035
IVh	207(4·30) 356(4·30)	3 130 1 089	1 545 1 505	1 358	1 289 1 153	1 030
IVi	206(4·25) 325(3·80)	3 140, 3 090 1 085	1 539 1 505	1 360	1 300 1 160	1 029
IVj	207(4·27) 312(4·05)	3 133, 3 033 1 078	1 541 1 502	1 362	1 294 1 158	1 029
IVk	210(4·50) 308(4·07)	3 142, 3 022 1 085	1 538 1 503	1 359	1 298 1 145	1 029
IVl	203(4·41) 316(4·10)	3 153, 3 080 1 085	1 530 1 504	1 360	1 293 1 160	1 023
IVm	206(4·02) 312(3·72)	3 141, 3 045 1 088	1 538 1 505	1 355	1 295 1 160	1 030
IVn	204(4·46) 312(3·97)	3 131, 3 027 1 093	1 538 1 505	1 370	1 300 1 160	1 029
IVo	205(4·63) 312(4·10)	3 135, 3 025 1 090	1 535 1 500	1 360	1 297 1 158	1 025

-2-R-ethylenes *IIIa–IIIo* with diazomethane gave, instead of the expected pyrazoline derivatives, always immediately the cyclopropane derivatives *IVa–IVo* with high yields in most cases. All the derivatives were isolated as racemic mixtures (Scheme 1).



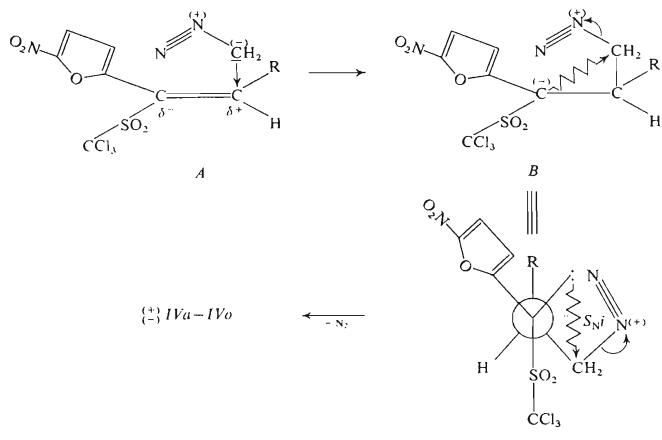
SCHEME 1

The presumed pyrazoline adduct could not be isolated in any case. With the aim to detect the labile pyrazoline intermediates in the reaction we carried out the reaction of *IIIn* with diazomethane in tetrahydrofurane at −60°C in dark, but even under these conditions the cyclopropane derivative *IVn* was the only product. Therefrom it follows that probability of formation of the pyrazolines is even smaller at the higher temperatures used for preparation of the other cyclopropane derivatives (−40°C to +20°C). Comparison of reactivity of diazomethane with 1-(5-nitro-2-furyl)-1-phenylsulphonyl--2-(4-X-phenyl)ethylenes[9] and that with 1-(5-nitro-2-furyl)-1-trichloromethylsulphonyl-2-R-ethylenes *IIIa–IIIo* as well as the experimental facts found led us to suggestion of a non-finished stepwise mechanism. The stepwise mechanism of cycloaddition



I *IIa–IIo* *IIIa–IIIo*

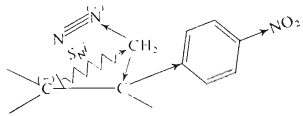
is defined as follows: The reaction goes through a reaction intermediate characterized by a minimum at the reaction coordinate which must be lower than contribution of the zero point energy (0·5 $h\nu$), the life time of this intermediate being at least 10^{-12} s (ref.[12]). This intermediate has a structure of zwitterion or diradical[13]. The non-finished stepwise mechanism has the following meaning here: the reaction intermediate does not finish the cycloaddition, and the final products are not formed *via* the cycloadducts (Scheme 2). Nucleophilic attack of diazomethane on the polarized



SCHEME 2

double bond of trisubstituted ethylenes produces the carbanion *B* which undergoes a cyclopropane-forming S_Ni reaction with simultaneous elimination of nitrogen. Cyclization to pyrazoline ring *via* the stepwise mechanism cannot take place due to the competition of the S_Ni reaction. This reaction produces but one geometrical isomer. The Newman projection formula of the carbanion *B* shows the antiperiplanar arrangement of the bulky substituents R and SO_2CCl_3 to be the most favourable. Configuration of the starting trisubstituted ethylenes being known[14] (*E*-configuration), we presume on the basis of the Curtin–Hammett principle and mutual influence

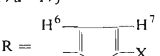
of the bulky substituents (*cis*-effect) that this configuration will be retained in both the transition state and the final cyclopropane derivatives. Formation of the pyrazoline adduct is contradicted also by the fact that the desactivating substituents, which increased stability of the formed pyrazoline in the case of 1-(5-nitro-2-furyl)-1-phenylsulphonyl-2-(4-X-phenyl)ethylenes[9], accelerate formation of cyclopropanes (Scheme 3) in the case of the trichloromethylsulphonyl derivatives.



SCHEME 3

TABLE III

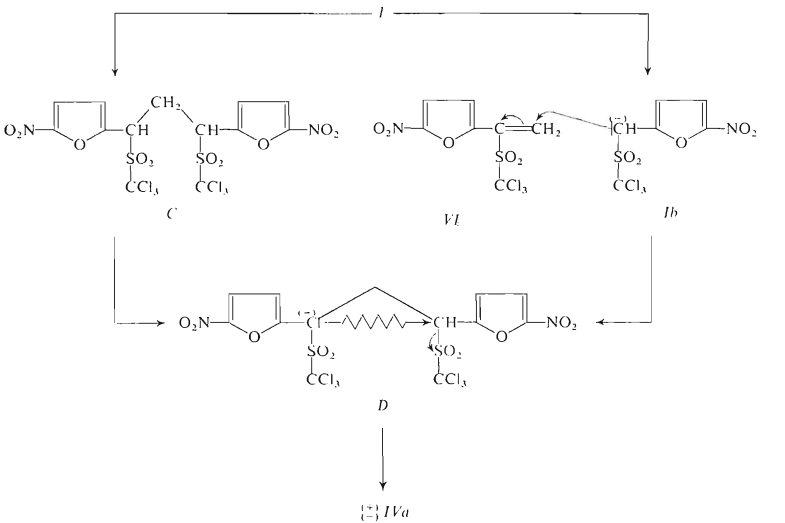
^{1}H-NMR Spectra of the Derivatives *IVa*–*IVf*

R = 

No	Y X	H_1 $J_{1,2}$	H_2 $J_{2,3}$	H_3 $J_{1,3}$	H_4 $J_{2,5}$	H_5	H_6 $J_{6,7}$	H_7
IVa	O	2·91 t	2·69 dd	3·97 dd	7·49 d	6·98 d	6·80 d	7·45 d
	NO_2	7·4	10·4	7·4	4·0	—	4·0	—
IVb	O	2·90	2·50 m	3·41 m	7·53 d	6·88 d	6·35 d	6·36 d
	I	—	—	—	4·0	—	3·8	—
IVc	O	2·82	—	2·16 m	7·41 d	6·99 d	5·99 d	5·83 m
	CH_3[a]	—	—	—	3·7	—	3·1	—
IVd	O	2·87 t	2·65 dd	3·89 dd	7·49 d	6·96 d	6·58 d	7·07 d
	CO_2CH_3[b]	7·3	10·4	7·3	3·9	—	3·1	—
IVe	S	2·58 t	2·43 dd	3·08 dd	7·44 d	7·00 d	6·87	6·92 m
	H[c]	—	—	—	3·9	—	—	—
IVf	S	2·98 t	2·70 dd	4·15 dd	7·50 d	6·99 d	7·02 d	7·82 d
	NO_2	7·6	10·2	7·6	4·0	—	4·3	—

[a] 2·16 s (—CH_3), [b] 3·68 s (—CO_2CH_3), [c] 7·22 dd (—H).

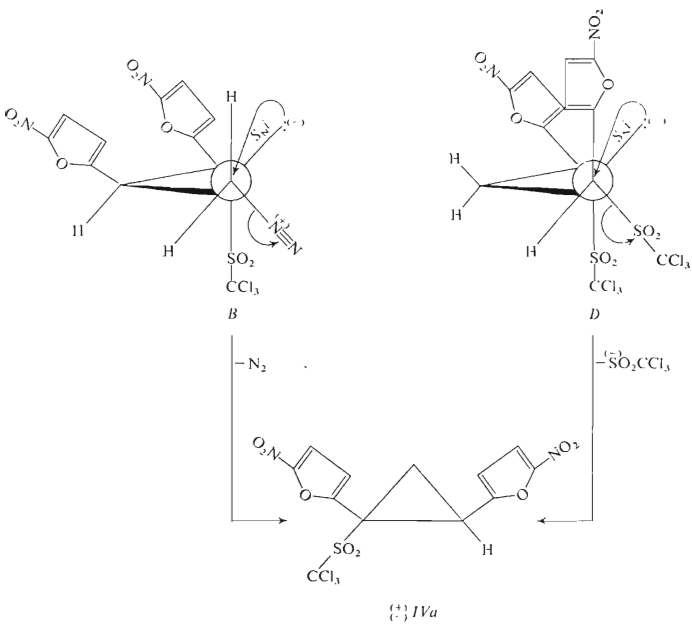
For comparison of configuration of the cyclopropanes prepared by different ways we prepared the cyclopropane *IVa* by the cyclopropane-forming reaction from 5-nitrofurfuryltrichloromethyl sulphone (*I*) and paraformaldehyde in methanol with catalysis by piperidine. Spectral measurements showed that the geometrical isomer obtained was the same as that of the derivative prepared by reaction of the trisubstituted ethylene *IIIa* with diazomethane. Yield of the reaction (9 to 13%) is relatively low. The following mechanism was suggested for the above-mentioned reaction (Scheme 4). The carbanion *D* can be formed through 1-(5-nitro-2-furyl)-



SCHEME 4

-1-trichloromethylsulphonylethylene (*VI*) which was also isolated in the reaction from *C* by action of a base. The cyclopropane-forming reaction produces then the racemate *IVa* from *D*. The same geometrical isomer of the cyclopropane *IVa* prepared by different ways implies obvious similarity of reaction paths of its formation (Scheme 5).

Structure of the derivatives *IVa–IVo* was confirmed by IR, UV and ^{1}H-NMR spectra. All the cyclopropane derivatives *IVa–IVo* showed two common bands in the regions 203–216 nm and 305–356 nm. The compound *IVb* decomposed during



SCHEME 5

the measurement (iodine being set free). The IR spectra contained characteristic absorption bands of cyclopropane vibrations in the regions 3153–3112 cm^{-1}, 3090–3020 cm^{-1} and 1093–1078 cm^{-1}. The ^{1}H-NMR spectra were used, first of all, for analysis of the cyclopropane protons H_1-H_3 (ABX system). Values of chemical shifts of the proton H_1 were within δ = 2·58 to 3·34 ppm, H_2 δ = 2·43 to 2·70 ppm, H_3 δ = 3·08–4·15 ppm. These protons signals are mutually split by

$J_{1,2}$ geminal coupling, $J_{2,3}$ *cis*-coupling and $J_{1,3}$ *trans*-coupling. As in most cases it was $J_{1,2} = J_{1,3}$, signals of the H_1 and H_3 protons showed the consequent multiplicity: a triplet (1 : 2 : 1) of H_1, a doublet of doublets of the proton H_3 due to *cis*- and *trans*-interactions with the protons H_2 and H_1, a doublet of doublets of the proton H_2 due to geminal and *cis*-interactions with the protons H_1 and H_3. The respective values of coupling constants of the geminal, *trans*- and *cis*-interactions are $J_{1,2} = 7{\cdot}3-7{\cdot}9$ Hz, $J_{1,3} = 7{\cdot}3-8{\cdot}5$ Hz and $J_{2,3} = 9{\cdot}9-10{\cdot}6$ Hz, respectively. The mass spectra were used for identification of the derivatives *IVa*–*IVo* (fragmentation of *IVa* is given as an example below).

TABLE IV
^{1}H-NMR Spectra of the Derivatives *IVg*–*IVo*

No	H_1 $J_{1,2}$	H_2 $J_{2,2}$	H_3 $J_{1,3}$	H_4 $J_{4,5}$	H_5
IVg	3·34 m	2·60 dd	3·80 dd	7·44 d	6·76 d
	—	9·9	8·5	4·0	—
IVh	2·98 t	2·68 dd	3·92 dd	7·47 d	6·94 d
	7·5	10·2	7·5	4·0	—
IVi	3·00 m	2·62 m	3·59 m	7·38 d	6·74 d
	—	—	—	4·0	—
IVj	2·95 t	2·55 dd	3·76 dd	7·37 d	6·70 d
	7·5	10·1	7·5	3·8	—
IVk	3·18 t	2·60 dd	4·03 dd	7·45 d	6·85 d
	7·9	10·6	7·9	4·0	—
IVl	3·08 t	2·63 dd	3·95 dd	7·40 d	6·77 d
	7·5	10·0	7·5	4·0	—
IVm	3·10 t	2·58 dd	3·80 dd	7·42 d	6·80 d
	7·40	10·1	7·55	4·0	—
IVn	3·17 dd	2·63 dd	3·86 dd	7·33 d	6·75 d
	7·5	10·0	8·25	4·0	—
IVo	3·02 t	2·53 dd	3·80 dd	7·42 d	6·78 d
	7·7	10·1	8·0	4·0	—

EXPERIMENTAL

The melting points were determined on a Kofler apparatus and are uncorrected. The ^{1}H-NMR spectra were measured in hexadeuteriodimethyl sulphoxide and hexadeuterioacetone at 20°C and 50°C using a Tesla BS 487C apparatus (80 MHz) with tetramethylsilane as internal standard. The IR spectra were measured in KBr discs using a UR-20 spectrophotometer (Zeiss, Jena), the UV spectra were measured in methanol using a Specord UV VIS (Zeiss, Jena). The mass spectra were measured on a MS 902 S apparatus (AEI). All the cyclopropane derivatives *IVa*—*IVo* were obtained in form of racemates.

1-(5-Nitro-2-furyl)-1-trichloromethylsulphonyl-2-R-ethylenes *IIIa*—*IIIo*

Solution of 3·08 g (0·01 mol) sulphone *I*, 1·5 g ammonium acetate and 0·2 ml piperidine in 30 ml glacial acetic acid was treated with 0·01 mol aldehyde *IIa*—*IIo*. The mixture was heated at 50—80°C with stirring for 1—5 h. After cooling the product was collected by suction, washed with acetic acid and with water several times. The obtained ethylenes *IIIa*—*IIIo* were dried in vacuum at 100°C 6 h. Yield 80—90%.

1-(5-Nitro-2-furyl)-1-trichloromethylsulphonyl-2-R-cyclopropanes *IVa*—*IVo*

Solution of the ethylene *IIIa*—*IIIo* in tetrahydrofurane was treated with 3—5 fold excess of diazomethane in ether at 0 to −60°C. After the reaction (1 to 11 days) and evaporation the raw products were purified by chromatography on a 3 × 30 cm column of Al_2O_3 (Brockmann II) using acetone–chloroform 1 : 1 as eluent. Yields 17 to 98%.

1-(5-Nitro-2-furyl)-1-trichloromethylsulphonyl-2-(5-nitro-2-furyl)-cyclopropane (*IVa*)

Mixture of 3·08 g (0·01 mol) sulphone *I* and 0·7 g (0·02 mol) paraformaldehyde in 20 ml methanol was stirred at 20°C and treated with 0·8 ml piperidine during 24 h. The mixture was further stirred 70 h and then left to stand 36 h. After evaporation the raw product was separated on a 3 × 30 cm column (Silicagel 150/250) using chloroform as eluent. The first portions of the eluate gave the compound *IVa* (yield 9—13%, m.p. 210—211°C), further fractions gave the starting sulphone *I* and resins. Mass spectrum, *m/e* (rel. intensity, %): 444 (10) ($C_{12}H_7Cl_3N_2O_8S$, M^+ for ^{35}Cl), 327 (14) ($C_{11}H_7N_2O_8S$, M − CCl_3), 311 (37) ($C_{11}H_7N_2O_7S$, M − $OCCl_3$), 279 (78) ($C_{11}H_7N_2O_7$, M − CCl_3—SO), 263 (12), 140 (100), 115 (69), 89 (43), 63 (53).

The authors are indebted to Professor R. Huisgen for advice and valuable suggestions during the work and to Dr J. Leško for measurements of the mass spectra.

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Translated by J. Panchartek.