REACTIONS OF 2,4,4,6-TETRAARYL-4*H*-THIOPYRANS WITH CHLORINE: AN UNUSUAL REACTION ROUTE

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2,4,4,6-Tetraaryl-4*H*-thiopyrans *Ia – Ig* react smoothly with carbon disulfide solution of chlorine already at 0 °C yielding the corresponding 3,5-dichloro derivatives *IIa – IIg*. With longer reaction time and temperature raised to 20 °C, the 4*H*-thiopyrans *Ia – Ie* gave exclusively the trichloro derivatives *IIIa – IIIe* whereas *If* and *Ig* underwent a nonselective chlorination leading to multicomponent mixtures of products. Isolation of sulfoxides *IVa* and *IVe* from the chlorination of *Ia* and *Ie* (upon hydrolysis of the reaction mixture) allowed us to formulate the reaction mechanism for the formation of compounds type *III*. ^{1}H, ^{13}C NMR, and mass spectra of the prepared compounds are discussed in detail.

Studies of electrophilic substitution of π-electron-donating 4*H*-thiopyrans are relatively scarce[1]. During halogenation experiments with easily available 2,4,4,6-tetraaryl-4*H*-thiopyrans of the type *I*, we observed[2] that the formation of 3,5-dichloro derivatives *II* strongly depends on the reaction conditions and is accompanied by formation of other chloro derivatives[3], on the contrary to highly selective 3,5-bromination. Preliminary examination of the reaction products obtained from 4*H*-thiopyrans *Ia* and *IIa* confirmed a surprising presence of 2-thiabicyclo[3.2.1]octane skeleton in the trichloro derivatives *IIIa* and *IIIb* (ref.[4]). Now we tried to prove the supposed formation of compounds of this type (*III*) with another 4*H*-thiopyrans *IIIc – IIIg* and eventualy to capture the reaction intermediates. Our results are the subject of this communication.

All investigated 4*H*-thiopyrans *Ia – Ig* react readily with chlorine excess (2.2 mol) in carbon disulfide at 0 °C; no starting material was present in the reaction mixture after

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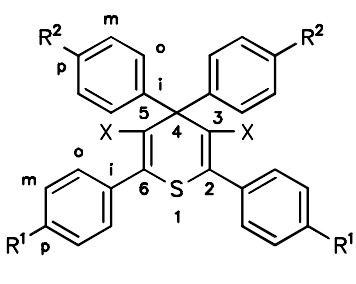
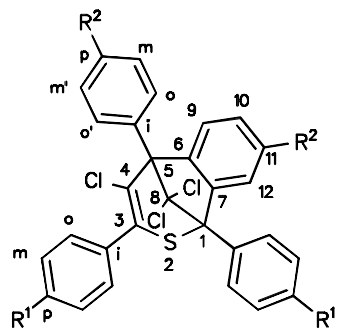
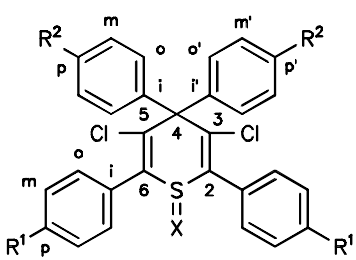
1 min according to HPLC. Preparative runs afforded 3,5-dichloro derivatives *IIa* – *IIg* in 57 – 71% yields (Table I). Using larger Cl_2 excess (10 – 12 mol), prolonging the reaction time to 5 min and decomposing the reaction mixture with aqueous sodium sulfite, the 4*H*-thiopyrans *Ia* and *Ig* gave besides simple 3,5-dichloro derivatives *IIa* and *IIe* also the corresponding 3,5-dichloro-1-oxides *IVa* and *IVe*. However, these compounds are artifacts formed from other secondary products of chlorination. When the reaction time was further prolonged and the temperature was raised to 20 °C, the above mentioned compounds disappeared and with 4*H*-thiopyrans *Ia* – *Ie* the corresponding 4,8,8-trichloro-2-thiabicyclo[3.2.1]octanes *IIIa* – *IIIe* (yields 53 – 89%, Table I) were indentified as the only products. On the contrary, the parent compounds *If* and *Ig* provided under comparable conditions complex mixtures of chlorination products from which only a small amount of trichloro derivative *IIIf* was isolated. The decreased selectivity of chlorination in *If* is probably related to possible halogen exchange; with *Ig* it is undoubtedly due to an increased reactivity of 2,6-aryl substituents activated by methoxyl groups.



I, X = H
II, X = Cl



III



IV, X = O
V, X = Cl_2

	R^1	R^2
a	H	H
b	F	H
c	*t*-Bu	H
d	H	F
e	H	*t*-Bu
f	Br	H
g	OMe	H

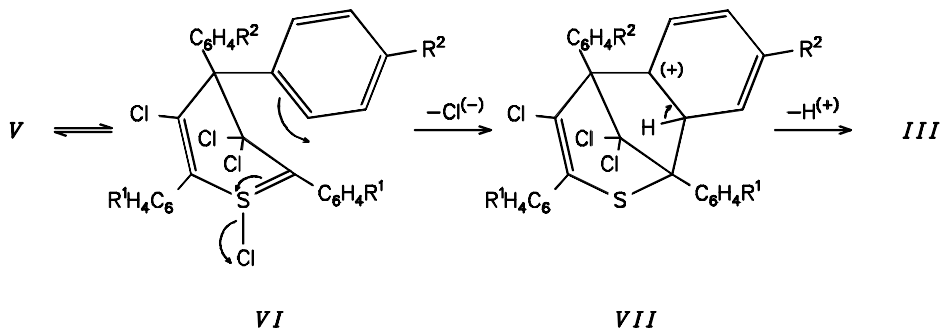
TABLE I
Reaction times, yields, and physical properties of compounds *II* and *III*

Compound	Reaction time Yield, %	M.p., °C (solvent)	Formula (M.w.)	Calculated/Found			
				% C	% H	% Cl	% S
IIa	1[a]	197 – 198	$C_{29}H_{20}Cl_2S$	73.89	4.28	15.03	6.80
	68	(heptane)	(471.5)	74.15	4.32	14.90	6.67
IIb	1[a]	214 – 215	$C_{29}H_{18}Cl_2F_2S$[b]	68.64	3.57	13.98	6.31
	65	(ethanol)	(507.4)	68.51	3.61	14.30	6.52
IIc	1[a]	185 – 186	$C_{37}H_{36}Cl_2S$	76.13	6.22	12.15	5.49
	65	(ethanol)	(583.7)	76.39	6.33	12.52	5.50
IId	1[a]	142 – 143	$C_{29}H_{18}Cl_2F_2S$[b]	68.64	3.57	13.98	6.31
	60	(heptane)	(507.4)	68.74	3.65	13.99	6.51
IIe	1[a]	233 – 234	$C_{37}H_{36}Cl_2S$	76.13	6.22	12.15	5.49
	71	(ethanol)	(583.7)	76.43	6.42	12.40	5.22
IIf	1[a]	167 – 168	$C_{29}H_{18}Br_2Cl_2S$[c]	55.35	2.88	11.27	5.09
	67	(ethanol)	(629.3)	55.37	2.89	11.09	4.74
IIg	1[a]	136 – 138	$C_{31}H_{24}Cl_2O_2S$	70.05	4.55	13.34	6.03
	57	(ethanol)	(531.5)	70.10	4.52	13.23	5.83
IIIa	5[d]	240 – 241	$C_{29}H_{19}Cl_3S$	68.86	3.79	21.03	6.34
	89	(acetone)	(505.9)	68.53	3.78	21.28	6.52
IIIb	5[d]	258 – 260	$C_{29}H_{17}Cl_3F_2S$[e]	64.29	3.17	19.62	5.91
	71	(acetone)	(541.9)	64.56	3.23	19.31	5.81
IIIc	1.5[d]	294 – 296	$C_{37}H_{35}Cl_3S$	71.90	5.71	17.20	5.19
	60	(acetone)	(618.1)	71.65	5.96	17.69	5.46
IIId	20[d]	244 – 246	$C_{29}H_{17}Cl_3F_2S$[e]	64.29	3.17	19.62	5.91
	55	(acetone)	(541.9)	64.59	3.12	19.39	5.97
IIIe	3[d]	247 – 249	$C_{37}H_{35}Cl_3S$	71.90	5.71	17.20	5.19
	53	(ethanol)	(618.1)	71.96	5.75	17.68	5.03

[a] Reaction time in min; [b] fluorine content was not determined; [c] % Br: calculated: 25.40, found: 25.28; [d] reaction time in h; [e] fluorine content determined by high-resolution MS (see Table VI).

Formation of trichloro derivatives of type *III* is evidently caused by Cl_2 molecules acting as chlorination agens. This assumption is supported by reaction of 4*H*-thiopyran *Ia* with 12 molar excess of *t*-BuOCl yielding exclusively 3,5-dichloro derivative *IIa*. Bromine excess leads to analogous 3,5-disubstitution, too[2].

A probable mechanism of the formation of isolated products type *II*, *III*, and *IV* might be described by following steps: the substitution of protons in 3,5-positions takes place first (*I* + 2 Cl_2 → *II* + 2 HCl); then (in analogy with similar reactions of acyclic sulfides[5–7]) is the Cl_2 molecule added to sulfur S1 (*II* + Cl_2 → *V*). However, the 1,1-dichloro adduct *V* undergoes transformation to corresponding 1-oxide *IV* during hydrolysis (*V* + H_2O → *IV* + 2 HCl) but it could be also a key intermediate for the formation of trichloro derivatives *III* (Scheme 1). The appearence of the end product *III* might be explained by the isomerization of *V* to 1,3,3,5-tetrachloro derivative *VI* followed by an intramolecular Friedel–Crafts type C-substitution of one 4,4-aryl groups (involving the carbocation *VII*).



SCHEME 1

Molecular structure of 4*H*-thiopyran derivatives *IIa* – *IIg* was determined on the basis of the interpretation of their ^1H and ^{13}C NMR spectra and characteristic skeletal vibrations in IR spectra employing the analogy with earlier published characteristics of similar compounds[2,8] (Tables II and III). Similarly was also verified the structure of 1-oxides *IVa* and *IVe*. A direct chemical evidence was performed by hydrogen peroxide oxidation of 4*H*-thiopyran *IIa* to the 1-oxide *IVa*.

The starting point for the interpretation of NMR spectra of type *III* compounds was the molecular structure of trichlorodifluoro derivative *IIIb* determined by X-ray diffraction analysis[4,9]. All proton and carbon signals in compounds *IIIa*, *IIIb*, and *IIId* were assigned by a series of homo- and heterocorrelated (^1H,^{13}C) 2D NMR experiments. Compounds *IIIc*, *IIIe*, and *IIIf* were then assigned by analogy (Tables IV and V).

TABLE II
^{1}H NMR and IR data of compounds *II*

Compound	^{1}H NMR δ, ppm; *J*, Hz	IR $\tilde{\nu}_{max}$, cm^{-1}
IIa	7.71 m, 4 H (*o*-Ph); 7.31 – 7.46 m, 16 H (Ph)	1 594, 1 575
IIb	7.68 m, 4 H (*o*-Ph4); 7.44 m, 4 H (*m*-Ph4); 7.34 – 7.39 m, 6 H (*p*-Ph4, *o*-Ar2); 7.06 m, 4 H, *J*(H,F) = 7.7 (*m*-Ar2)	1 598, 1 578
IIc	7.75 m, 4 H (*o*-Ph4); 7.35 – 7.53 m, 14 H (Ph, Ar); 1.34 s, 18 H (Me)	1 598, 1 580
IId	7.64 m, 4 H, *J*(H,F) = 5.2 (*o*-Ar4); 7.32 – 7.39 m, 10 H (Ph2); 7.13 m, 4 H, *J*(H,F) = 7.8 (*m*-Ar4)	1 604, 1 578
IIe	7.64 m, 4 H (*o*-Ph4); 7.30 – 7.48 m, 14 H (Ph, Ar); 1.33 s, 18 H (Me)	1 604, 1 576
IIf	7.67 m, 4 H (*o*-Ph4); 7.52 m, 4 H (*o*-Ar2); 7.46 m, 4 H (*m*-Ph4); 7.38 m, 2 H (*p*-Ph4); 7.29 m, 4 H (*m*-Ar2)	1 605, 1 584
IIg	7.71 m, 4 H (*o*-Ph4); 7.45 m, 4 H (*m*-Ph4); 7.32 – 7.39 m, 6 H (*o*-Ar2, *p*-Ph4); 6.90 m, 4 H (*m*-Ar); 3.81 s, 6 H (Me)	1 608, 1 575

TABLE III
^{13}C NMR data of compounds *II*; δ in ppm, *J*(C,F) in Hz given in parentheses

Carbon	^{13}C NMR						
	IIa	*IIb*	*IIc*[a]	*IId*	*IIe*[b]	*IIf*	*IIg*[c]
2	128.52	127.90	129.73	135.64	128.64	128.30	129.45
3	123.47	124.02	123.91	122.97	124.76	124.15	124.04
4	63.90	63.93	65.08	62.93	64.12	64.86	65.09
Ar-2 (*i*)	135.96	131.67 (3.5)	133.83	135.64	136.97	135.47	129.00
(*o*)	129.15	131.14 (8.6)	129.68	129.04	130.09	131.70	131.29
(*m*)	128.52	115.69 (21.7)	126.25	128.60	129.35	132.72	114.78
(*p*)	128.87	162.83 (249.4)	152.74	128.35	129.64	124.98	160.69
Ar-4 (*i*)	140.76	140.52	141.78	136.43 (3.4)	138.68	141.24	141.76
(*o*)	130.45	130.35	131.34	132.02 (8.0)	130.96	131.20	131.37
(*m*)	127.69	127.74	128.50	114.69 (21.4)	125.35	128.65	128.49
(*p*)	127.31	127.43	128.10	161.95 (247.61)	150.73	128.36	128.10

[a] 35.78 (CMe_3), 32.31 (CH_3); [b] 35.59 (CMe_3), 32.50 (CH_3); [c] 56.28 (OCH_3).

TABLE IV
^{1}H NMR data of compounds *III;* δ in ppm, *J* in Hz given in parentheses

Proton	^{1}H NMR					
	IIIa	*IIIb*	*IIIc*	*IIId*	*IIIe*	*IIIf*
9	7.188 ddd (7.9, 1.9, 1.5)	7.849 ddd (7.8, 1.9, 1.7)	7.842 m	7.442 dd (8.6, 5.1[a])	7.288 – 7.362 m	7.823 m
10	7.424 ddd (7.9, 7.2, 1.9)	7.440 ddd (7.8, 7.3, 1.8)	7.361 – 7.510 m	7.290 ddd (8.6, 8.6[a], 2.5)	7.451 – 7.605 m	7.448 m
11	7.479 ddd (7.5, 7.2, 1.9)	7.518 ddd (7.5, 7.3, 1.9)	7.361 – 7.510 m		[b]	7.468 m
12	7.632 ddd (7.5, 1.9, 1.5)	7.613 ddd (7.5, 1.8, 1.7)	7.681 m	7.374 dd (8.8[a], 2.5)	7.734 d (1.7)	7.483 – 7.545 m
Ar-1 (*o*)	7.984 m	7.970 m (5.1[a])	7.892 m	7.961 m	8.051 m	7.822 m
(*m*)	7.434 – 7.524 m	7.152 m (8.8[a])	7.360 – 7.530 m	7.470 – 7.497 m	7.451 – 7.605 m	7.488 – 7.545 m
(*p*)	7.434 – 7.524 m		[c]	7.470 – 7.497 m	7.451 – 7.605 m	
Ar-3 (*o*)	7.133 m	7.104 m (5.3[a])	7.111 m	7.273 – 7.312 m	7.183 m	6.994 m
(*m*)	7.434 – 7.524 m	6.964 m (8.7[a])	7.278 m	7.273 – 7.312 m	7.451 – 7.605 m	7.396 – 7.435 m
(*p*)	7.434 – 7.524 m		[d]	7.302 m	7.451 – 7.605 m	
Ar-5 (*o*)	7.640 m	7.641 m	7.642 m	7.824 ddd (8.8, 5.3[a], 2.5)	7.824 dd (8.4, 2.1)	7.483 – 7.545 m
(*m*)	7.380 m	7.480 – 7.534 m	7.360 – 7.530 m	7.190 ddd (8.8, 8.6[a], 2.8)	7.288 – 7.362 m	7.396 – 7.435 m

TABLE IV
(*Continued*)

Proton	^{1}H NMR					
	IIIa	*IIIb*	*IIIc*	*IIId*	*IIIe*	*IIIf*
(*p*)	7.434 – 7.524 m	7.480 – 7.534 m	7.360 – 7.530 m		[e]	7.396 – 7.435 m
(*m′*)	7.434 – 7.524 m	7.393 m	7.360 – 7.530 m	7.075 ddd (8.6, 8.6[a], 2.8)	7.288 – 7.362 m	7.396 – 7.435 m
(*o′*)	7.434 – 7.524 m	7.480 – 7.534 m	7.360 – 7.530 m	7.529 ddd (8.6, 5.2[a], 2.5)	7.419 dd (8.3, 2.1)	7.396 – 7.435 m

[a] *J*(H,F); [b] 1.42 (CH_3); [c] 1.26 (CH_3); [d] 1.35 (CH_3); [e] 1.44 (CH_3).

From the ^{1}H and ^{13}C NMR spectra of compounds type *III* it is evident that one phenyl group is lacking the expected local symmetry. The presence of fluorine in compounds *IIIb* and *IIId* allowed us to assign the protons and carbons in the fluorine substituted rings on the basis of spin-spin couplings *J*(H,F) and *J*(C,F). Using this assignment, it was proved by COSY and 2D J-resolved spectra that the responsible phenyl group is that at position 5. Its carbons account for six signals, its protons for five. The evidence for a *para*-substituted phenyl ring in *IIId* follows from the magnitudes of proton-proton couplings: each proton *ortho*-situated to fluorine exhibits one *ortho* and one *meta* H,H coupling; each of the *meta*-oriented to fluorine, too. A probable source of the observed magnetic nonequivalence is the hindered rotation of this phenyl group at room temperature. The remaining quaternary carbons devoid of any couplings to protons were assigned to C10 (≈ 99 ppm, see ref.[10] for chemical shifts in CCl_2 fragment) and to C4 (≈ 120 ppm) on the basis of their chemical shifts.

Mass spectra of compounds *IIIa*, *IIIb*, *IIId*, *IIIf*, and *IVa* were also studied. With compound *IIIf*, obtained in a very small amount by preparative HPLC, it was the main approach to its structure verification. All compounds of type *III* exhibit in electron impact mass spectra besides the intense molecular cation-radicals also stable ions corresponding to a loss of individual chlorine atoms combined with the elimination of $R^1C_6H_4$, $R^2C_6H_4$, and $R^1C_7H_4S$ (Table VI). The nature of the R^1 substituent follows unambiguously from the thioacylium ions of the type $[R^1C_7H_4S]^+$. Fast verification of the proposed structures might be also achieved by linked scans. Scan of neutral losses of 35 amu (Fig. 1, upper part) contains the ions eliminating a radical ^{35}Cl. On the other hand, the daughter ion scan of the molecular cation-radical (Fig. 1, bottom part) determines the most structuraly important ions of the given molecule.

TABLE V
^{13}C NMR data of compounds *III*; δ in ppm, *J*(C,F) in Hz given in parentheses

Carbon	^{13}C NMR					
	IIIa	*IIIb*	*IIIc*	*IIId*	*IIIe*	*IIIf*
1	70.25	69.38	70.00	69.38 (1.5)	70.52	69.93
3	133.82	132.69	133.54	133.99	134.17	132.47
4	120.06	120.73	119.52	119.87	121.36	117.70
5	70.25	70.22	70.33	70.06	71.17	70.24
6	140.22	140.15	140.22	136.26 (2.8)	138.72	140.19
7	136.66	136.56	137.01	138.46 (8.1)	137.03	136.26
8	99.40	99.40	99.69	99.31	100.52	98.93
9	132.05	131.96	132.11	122.99 (8.6)	132.13	131.93
10	128.31	128.43	128.33	116.51 (22.9)	126.43	128.31
11	128.48	126.68	128.21	162.98 (246.8)	151.45[a]	128.78
12	130.51	130.46	130.53	112.57 (24.3)	130.74	130.46
Ar-1 (*i*)	132.12	128.86 (3.3)	130.11	132.49	132.16	132.09
(*o*)	130.62[b]	131.96[b] (8.3)	129.74[b]	129.85[b]	130.71[b]	131.66[b]
(*m*)	128.08[b]	115.19[b] (21.5)	124.98[b]	128.31[b]	128.61[b]	131.60[b]
(*p*)	129.53	163.37 (250.1)	152.40[c]	129.83	129.97	124.15
Ar-3 (*i*)	136.47	132.66 (3.4)	133.99	136.15	137.34	131.60
(*o*)	129.27[b]	132.21[b] (8.4)	128.93[b]	129.23[b]	129.93[b]	131.39[b]
(*m*)	128.29[b]	115.45[b] (21.8)	125.17[b]	120.40[b]	128.82[b]	130.94[b]
(*p*)	128.66	162.74 (249.0)	151.69[d]	128.88	129.11	123.06

TABLE V
(*Continued*)

Carbon	^{13}C NMR					
	IIIa	*IIIb*	*IIIc*	*IIId*	*IIIe*	*IIIf*
Ar-5 (*i*)	134.50	134.29	134.75	130.10 (3.4)	133.90	134.09
(*o*)	125.43	125.19	125.44	133.68 (8.2)	122.92	125.17
	121.71	121.84	121.63	132.01 (8.1)	121.87	121.89
(*m*)	126.80	126.90	126.74	114.70 (21.7)	124.06	126.91
	127.29	127.36	127.24	113.79 (21.4)	124.85	127.38
(*p*)	128.80	129.02	128.62	162.81 (248.1)	152.14[e]	129.11

[a] 35.36 (CMe_3), 32.17 (CH_3); [b] 2 C; [c] 34.61 (CMe_3), 31.19 (CH_3); [d] 34.68 (CMe_3), 31.27 (CH_3); [e] 35.83 (CMe_3), 32.24 (CH_3).

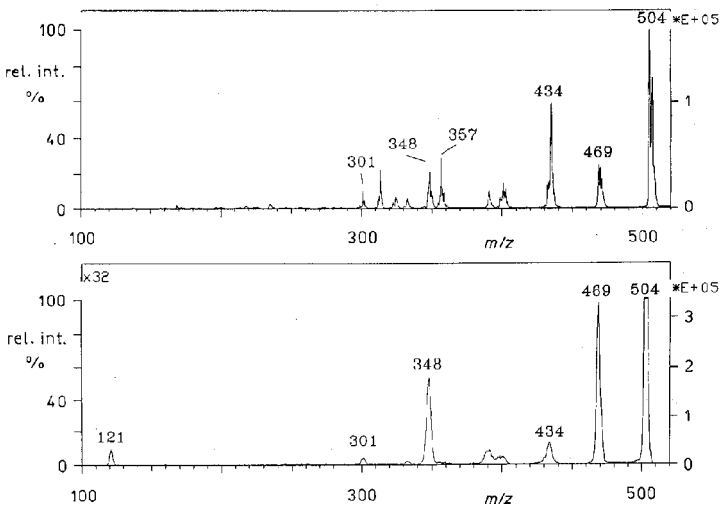
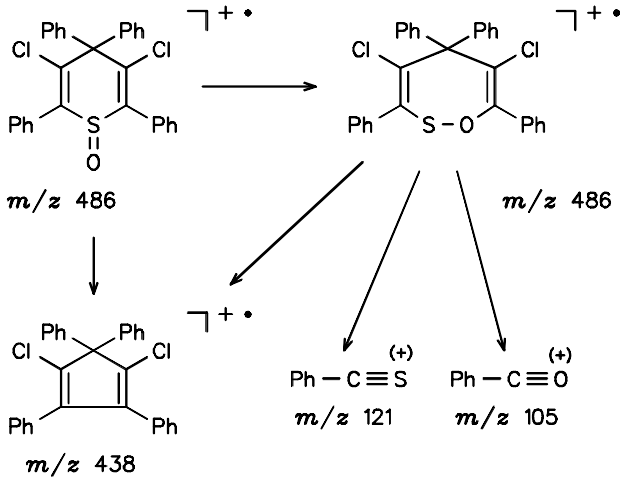


FIG. 1
Mass spectrum of neutral losses of 35 amu (top) and daughter ions of the molecular ion-radical of compound *IIIa* (bottom). Electron impact ionization, second field-free region of the spectrometer

Electron impact mass spectrum of compound *IVa* does not provide the molecular information (for the list of ions, see Experimental). The first reaction is the elimination of a SO fragment yielding a stable ion *m*/*z* 438. The decomposition of molecular cation-radicals of organic S-oxides is usually accompanied by an intramolecular rearrangement[11], as illustrated on the fragmentation of compound *IVa (*Scheme 2).



SCHEME 2

TABLE VI
Mass spectrometric data of compounds *IIIa*, *IIIb*, *IIId*, and *IIIf* (electron impact, positive ions)

Ion[a]	*m*/*z* (% rel. int.)			
	IIIa	*IIIb*	*IIId*	*IIIf*
$M^{+\bullet}$	504 (65)	540 (71)	540 (97)	659 (25)
$[M–Cl]^+$	469 (36)	505 (34)	505 (77)	625 (12)
$[M–2Cl]^{+\bullet}$	434 (65)	470 (42)	470 (99)	590 (10)
$[M–3Cl]^+$	399 (100)	435 (96)	435 (91)	555 (22)
$[M–{}^1RC_6H_4–2Cl]^+$	357 (55)	375 (56)	393 (40)	435 (10)
$[M–{}^2RC_6H_4–2Cl]^+$	357 (55)	393 (41)	375 (12)	513 (11)
$[M–{}^1RC_7H_4S–Cl]^{+\bullet}$	348 (37)	366 (42)	384 (21)	426 (33)
$[{}^1RC_7H_4S]^+$	121 (68)	139 (100)	121 (100)	199 (97)

High-resolution results (measured/found): *IIIa* 504.0268/504.0273; *IIIb* 540.0083/540.0085; *IIId* 540.0084/540.0085; *IIIf* 659.8480/659.8484. [a] All reported ions contain isotopes ^1H, ^{12}C, ^{32}S, ^{35}Cl, and ^{79}Br only; for this reason the base peak in the mass spectrum of *IIIf* *m*/*z* 201 is missing – it is the ion $^{81}BrC_7H_4S^+$.

EXPERIMENTAL

Temperature data were uncorrected. Melting points were determined using a Boetius apparatus. NMR spectra were measured on spectrometers Varian VXR-400 and Bruker AM-400 (400 MHz for ^{1}H, 100 MHz for ^{13}C) in $CDCl_3$ at 298 K, using digital resolution 0.02 and 0.3 Hz, respectively. Internal TMS was used as a standard. 2D NMR experiments – COSY, delayed COSY (ref.[12]), J-resolved[13], (^{1}H,^{13}C)-COSY, and its variant optimized for long-range couplings[14] – were realized using the manufacturer's software. Infrared spectra (ν, cm^{-1}) were measured by a FTIR Nicolet 740 spectrometer in chloroform solutions. Chemical reactions were monitored by HPLC on a Separon SGX C18 column (3 × 150 mm, particle size 5 μm, Tessek, The Czech Republic) in the system methanol–water; UV detection at 254 nm was employed. Mass spectra were measured on a Finnigan MAT-90 instrument (BE geometry, accelerating voltage +5 kV, ion source temperature 250 °C, emission current 1 mA, energy of ionizing electrons 70 eV, direct inlet in microgram amounts). Elemental compositions of ions was calculated from the high-resolution scans (R: 10 000), perfluorokerosene was used as an internal standard. Products of unimolar decompositions in the second field-free region of the spectrometer (no collision activation was used) were detected by appropriate linked scans: daughter ions (B = const), neutral losses (B^2 ($E_0 - E$) = const).

2,4,4,6-Tetraaryl-4*H*-thiopyrans *Ia – If* were prepared as described earlier[8].

2,4,4,6-Tetraaryl-3,5-dichloro-4*H*-thiopyrans *IIa – IIg*

Carbon disulfide solution of Cl_2 (5 ml, 2.98 mmol) was added at 0 °C to the solution (10 ml) of the respective 4*H*-thiopyran (1.24 mmol) in the same solvent. The reaction mixture was stirred 1 min and then decomposed with saturated aqueous solution of sodium sulfite. Organic layer was separated, dried over magnesium sulfate and the solvent was removed. Crude product was subjected to column chromatography on silica gel (100 g, eluent benzene). Obtained 3,5-dichloro derivatives *IIa – IIg* were crystallized from appropriate solvents to the constant melting point (Table I).

3,5-Dichloro-2,4,4,6-tetraphenyl-4*H*-thiopyran-1-oxide (*IVa*)

Method A: Reaction of 4*H*-thiopyran *Ia* (1.24 mmol) with Cl_2 (14.9 mmol) was carried out as above but with 5 min stirring. Chromatography of the reaction mixture on a silica gel column (50 g, eluent benzene and then acetone) afforded besides the 3,5-dichloro derivative *IIa* (0.19 g, 32%), m.p. 196 – 198 °C (heptane) also the sulfoxide *IVa* (0.22 g, 36%), m.p. 226 – 228 °C (heptane–benzene). For $C_{29}H_{20}Cl_2OS$ (487.5) calculated: 71.46% C, 4.14% H, 14.55% Cl, 6.58% S; found: 71.51% C, 4.38% H, 14.81% Cl, 6.43% S. IR spectrum: 1 048 ν(SO); 1 576, 1 592, and 1 634 ν(CC,CS). ^{1}H NMR spectrum: 7.38 – 7.48 m, 16 H (Ph); 7.62 m, 2 H; 7.77 m, 2 H (*o*-Ph4,4′). ^{13}C NMR spectrum: 65.16, 1 C, (C-4); 128.33, 2 CH and 128.34, 2 CH (*m*-Ph4,4′); 128.34, 1 CH and 128.40, 1 CH (*p*-Ph4,4′); 128.79, 4 CH (*o*-Ph2,6); 129.45, 2 CH (*p*-Ph2,6); 130.30, 2 CH and 130.53, 2 CH (*o*-Ph4,4′); 133.15, 2 C (*i*-Ph2,6); 137.65, 2 C (C-3,5); 137.83, 1 C and 137.84, 1 C (*i*-Ph4,4′); 141.29, 2 C (C-2,6). EI MS, *m/z* (% rel. int.): 442 (12), 441 (19), 440 (63), 439 (30), 438 (100), 368 (13), 367 (21), 346 (10), 325 (10), 291 (10), 290 (9), 289 (24), 121 (5), 105 (13).

Method B: Aqueous H_2O_2 (30%, 1.43 ml) was added to the solution of 3,5-dichloro derivative *IIa* (1.17 mmol) in the mixture of acetic acid (20 ml) and chloroform (20 ml). The reaction mixture was stirred 20 h at 20 °C. Chloroform (50 ml) was added and the mixture was repeatedly washed with water. Organic layer was separated and the aqueous one extracted with chloroform (50 ml). Combined extracts were washed with aqueous $NaHCO_3$, dried over $MgSO_4$, and the solvent was removed in vaccuo. The residue was chromatographed on a silica gel column (30 g, eluent benzene and then

acetone). Sulfoxide *IVa* (0.42 g, 74%), m.p. 227 – 228 °C (heptane–benzene), identical with the above described compound, was obtained.

3,5-Dichloro-2,6-diphenyl-4,4-di(4-*tert*-butylphenyl)-4*H*-thiopyran (*IVe*)

The same procedure as for chlorination of *Ia* was used for 4*H*-thiopyran *Ie* (1.24 mmol). Chromatography of the reaction mixture gave 3,5-dichloro derivative *IIe* (0.22 g, 30%), m.p. 232 – 234 °C (ethanol) and sulfoxide *IVe* (0.28 g, 37%), m.p. 266 – 268 °C (ethanol). For $C_{37}H_{36}Cl_2OS$ (599.6) calculated: 74.11% C, 6.05% H, 11.82% Cl, 5.35% S; found: 74.38% C, 6.18% H, 12.30% Cl, 5.45% S. IR spectrum: 1 048 ν(SO); 1 581, 1 593 and 1 638 ν(CC,CS). ^{1}H NMR spectrum: 1.36 s, 9 H and 1.37 s, 9 H (Me,Me′); 7.37 – 7.53 m, 16 H and 7.66 m, 2 H (*o*-, *m*-, *p*-Ph and *o*-, *m*-*tert*-BuC_6H_4). ^{13}C NMR spectrum: 31.33, 3 CH_3 and 31.34, 3 CH_3 (Me,Me′); 34.61, 1 C and 34.62, 1 C (CMe_3,CMe_3′); 64.39, 1 C (C-4); 125.04, 2 CH and 125.18, 2 CH (*m*-Ph4,4′); 128.74, 4 CH (*o*-Ph2,6); 129.34, 2 CH (*p*-Ph2,6); 129.92, 2 CH (*o*-Ph4); 130.04, 4 CH (*m*-Ph2,6); 130.12, 2 CH (*o*-Ph4′); 133.32, 2 C (*i*-Ph2,6); 134.80, 1 C and 134.84, 1 C (*i*-Ph4,4′); 136.96, 2 C (C-3,5); 141.82, 2 C (C-2,6); 151.16, 1 C and 151.17, 1 C (*p*-Ph4,4′).

6,7-Benzo-1,3,5-triaryl-4,8,8-trichloro-2-thiabicyclo[3.2.1]octa-3,6-dienes *IIIa* – *IIIf*

Carbon disulfide solution of Cl_2 (5 ml, 14.9 mmol) was added at 0 °C to the solution of appropriate 4*H*-thiopyran *Ia* – *Ie* (1.24 mmol) in the same solvent (10 ml). The reaction mixture was stirred another 30 min at this temperature. The stirring was then continued at 20 °C until all intermediates disappeared (HPLC analysis). After the above described work-up, the crude products were crystallized from a suitable solvent (compounds *IIIa*, *IIIb* and *IIId*) or chromatographed on silica gel column (50 g, benzene–chloroform) and then crystallized (compounds *IIIc* and *IIIe*). The results of all these preparative experiments are summarized in Table I. 4*H*-Thiopyrans *If* and *Ig* afforded under the described conditions multicomponent mixtures (HPLC analysis). With compound *If* only, a successful preparative HPLC (C18 bonded phase, aqueous methanol 20 : 80 v/v) yielded small amount (15 mg from 40 mg of the mixture) of the trichloro derivative *IIIf*, m.p. >350 °C. Mass spectrum is given in Table VI. In another run, the treatment of 3,5-dichloro compound *IIa* (0.5 g) with carbon disulfide solution of Cl_2 (10.6 mmol) for 12 h gave 4,8,8-trichloro derivative *IIIa* (0.32 g, 68%), m.p. 240 – 241 °C (acetone), identical with the earlier prepared compound (Table I).

3,5-Dichloro-2,4,4,6-tetraphenyl-4*H*-thiopyran (*IIa*)

tert-Butyl hypochlorite[15] was dropwise added to a stirred carbon disulfide solution (11.5 ml) of 4*H*-thiopyran *Ia* (0.5 g). The stirring was continued 6.25 h at 20 °C. Upon decomposition with saturated aqueous solution of sodium sulfite was the organic layer separated, washed with water (50 ml), dried over magnesium sulfate, and the solvents were evaporated. The crude product was subjected to a column flash chromatography (silica gel 25 g, heptane–ether 92 : 8). 3,5-Dichloro derivative *IIa*, m.p. 196 – 197 °C (ethanol), identical with the earlier prepared compound (Table I), was obtained in 50% yield (0.29 g).

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REFERENCES

1. Kuthan J., Sebek P., Bohm S.: Adv. Heterocycl. Chem. *59*, 179 (1994).
2. Schwarz M., Sebek P., Kuthan J.: Collect. Czech. Chem. Commun. *57*, 546 (1992).
3. Sebek P.: *Ph.D. Thesis*. Prague Institute of Chemical Technology, Prague 1992.
4. Sebek P., Sedmera P., Husak M., Novotny J., Kuthan J.: Mendeleev Commun. *1992*, 102.
5. Baenziger N. G., Buckles R. E., Maner R. J., Simpson T. D.: J. Am. Chem. Soc. *91*, 5749 (1969).
6. Wilson G. E., Chang M. M. Y.: J. Am. Chem. Soc. *96*, 7533 (1974).
7. Oae S., Numata T., Yoshimura T. in: *The Chemistry of Sulfonium Group* (C. J. M. Stirling, Ed.), Part 2, p. 592. Wiley, New York 1981.
8. Sebek P., Nespurek S., Hrabal R., Adamec M., Kuthan J.: J. Chem. Soc., Perkin Trans. 2 *1992*, 1301.
9. Husak M., Novotny J., Kratochvil B.: Z. Kristallogr. *205*, 350 (1993).
10. Hawkes G. E., Smith R. A., Roberts J. D.: J. Org. Chem. *39*, 1276 (1974).
11. Bowie J. H., Williams D. H., Lawesson S.-O., Madsen J. O., Nolde C., Schroll G.: Tetrahedron *22*, 3515 (1966).
12. Bax A., Freeman R.: J. Magn. Reson. *44*, 542 (1981).
13. Aue W. P., Karhan J., Ernst R. R.: J. Chem. Phys. *64*, 4226 (1976).
14. Bax A., Morris G. A.: J. Magn. Reson. *42*, 501 (1981).
15. Rabjohn N.: Org. Synth., Coll. Vol. *4*, 125 (1967).

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