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DIARYLDIACYLOXYSPIROSULFURANES—II

SYNTHESES FROM SULFOXIDES AND HYDROLYSIS

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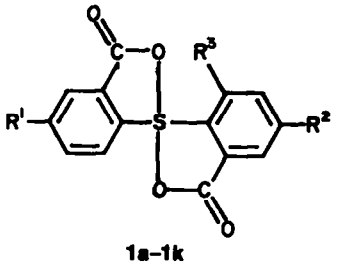
Abstract—The preparations of spirocyclic sulfuranes from bis(2-carboxyaryl) sulfoxides with dehydrating agents were investigated. Depending on the manner of dehydration, spirosulfurane formation follows different courses established by using ^{18}O-labelled 2,2'-sulfinyldibenzoic acid. Sulfoxides with 2-carboxybenzyl group failing to form spirosulfuranes undergo the Pummerer reaction yielding lactones. In aqueous dioxan spirosulfuranes hydrolyse generally into sulfoxides. A spirosulfurane having two nitro groups on the same aromatic ring hydrolyses with S–C_{ar} bond cleavage.

In Part I we reported the syntheses of diaryldiacyloxyspirosulfuranes from sulfides with halogenating agents, and discussed briefly the spectroscopic properties (UV and IR) of the spirosulfurane products.[1] Herein we describe their syntheses achieved by dehydration of sulfoxides (Scheme 1), and suggest mechanisms for these reactions on the basis of ^{18}O-tracer experiments. Moreover, results obtained on the dehydration of sulfoxides allowing either sulfurane formation or Pummerer reaction and on the hydrolyses of diaryldiacyloxyspirosulfuranes are summarized.

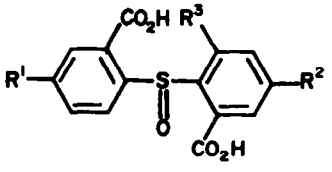
RESULTS AND DISCUSSION

Spirosulfuranes from Bis(2-carboxyaryl) Sulfoxides. Reinvestigating the formation of the spirosulfurane **1a** (1,1'-spirobi[3H-2,1-benzoxathiol]-3,3'-dione) from 2,2'-sulfinyldibenzoic acid (**2a**) in dried acetic acid solvent,[2] we have found that, owing to the presence of acetic anhydride, the conversion of **2a** becomes unambiguous, and the product **1a** is formed in a good yield. Subsequently, the formation of **1a** from **2a** by treatment with acetic anhydride, acetyl chloride, N,N'-dicyclohexylcarbodiimide (DCC) or by thermic dehydration process has been studied.

The experimental data collected in Table 1 indicate that both acetic anhydride and acetyl chloride are excellent reactants for the preparation of spirocyclic sulfuranes from the corresponding sulfoxides. The use of DCC as dehydrating agent is particularly advantageous, if the difference in the solubility of spirosulfurane and

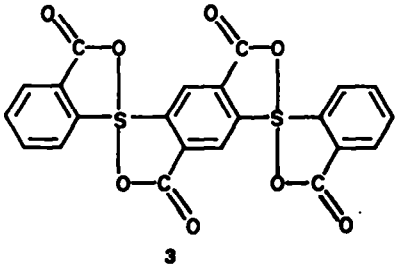


1a–1k



2a–2k

	a	b	c	d	e	f	g	h	i	j	k
R^1	H	NO_2	Cl	NHAc	OMe	NO_2	Cl	NHAc	OMe	H	H
R^2	H	H	H	H	H	NO_2	Cl	NHAc	OMe	Cl	NO_2
R^3	H	H	H	H	H	H	H	H	H	Cl	NO_2



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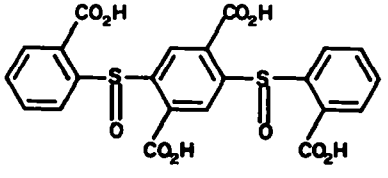

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Scheme 1.

Table 1. Methods for the preparation of the spirosulfurane 1a from the sulfoxide 2a with dehydrating agents

Method	Reactant/Solvent	Reaction Temp (°C)	Reaction Time (min)	Yield (%)	$^{18}O^{b}$ (%)
A	Ac_2O/AcOH	118	30	93	34
B	Ac_2O/pyridine	40	5	74	69
C	Ac_2O/dioxan	101	30	63	—
D	AcCl/pyridine	20	5	90	—
E	AcCl/dioxan	40	[a]	59	—
F	AcCl/DMF–Et_3N	−50	[a]	76	68
G	DCC/dioxan	101	[a]	54	61
H	heating/"Diphyl"	240–260	30	88	<5

[a] See Experimental. [b] ^{18}O-contents of products prepared from the sulfoxide 2a-^{18}O were calculated from the $(M+H)^+$ peaks observed in their CI (isobutane) mass spectra (accuracy ±2%).

Table 2. Preparations of the spirosulfuranes 1b–1j and 3 from the sulfoxides 2b–2j and 4

Precursor (a)	Method (b)	Reaction Temp (°C)	Time (min)	Spirosulfurane[a] Product (c)	Yield (%)
2b	A	118	30	1b	54
	B	40	5		73
2c	A	118	30	1c	68
	B	20	5		38
2d	A	118	30	1d	74
	B	40	5		78
2e	A	118	10	1e	69
	B	20	5		76
2f	A	118	5	1f	79
	B	40	30		73
2g	A	118	30	1g	79
	B	20	10		81
2h	A	118	5	1h	78
	B	20	5		91
2i	A	118	5	1i	79
	B	40	5		83
2j	A	118	5	1j	55
	B	20	80		69
4	A	118	30	3	88
	B	80	5		78

[a] See Scheme 1; [b] Ac_2O in AcOH (A); Ac_2O in pyridine (B); [c] All spirosulfuranes produced were identical (m.p., analysis and IR) with those prepared by other methods previously.[1]

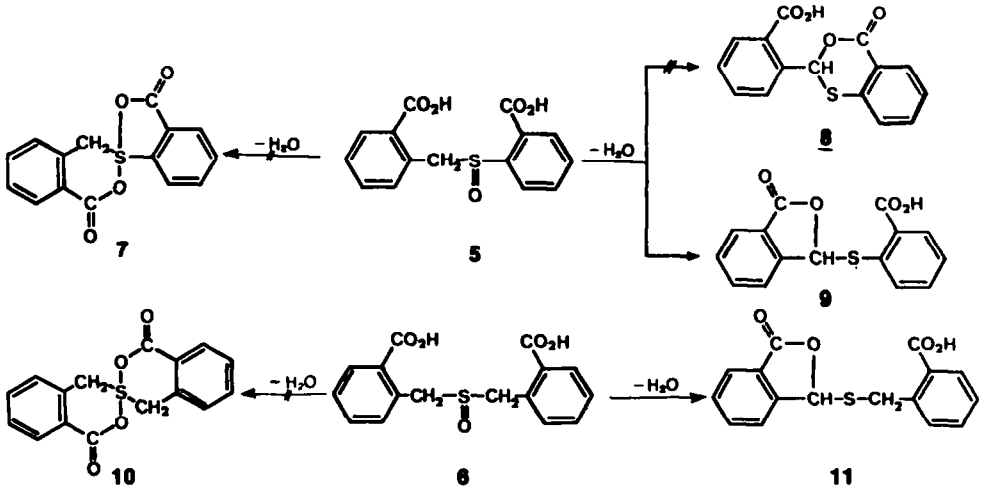
N,N'-dicyclohexylurea (DCU) is high enough to separate these products (Experimental, Method G). The thermic dehydration of the sulfoxide 2a dissolved in boiling "Diphyl" proved to be a better method than the heating of the solid substrate *in vacuo* (see Ref. 2).

Applying Method A (acetic anhydride in acetic acid) or B (acetic anhydride in pyridine), the compounds 2b–2j, derivatives of the sulfoxide 2a with different electron-withdrawing or -donating substituents, as well as the bis-sulfoxide 4 can be dehydrated in high yields to the spirosulfuranes 1b–1j and 3 (Table 2). Since 3,5-dinitro-2,2'-sulfinyldibenzoic acid (2k) could not be prepared either by the oxidation of the corresponding sulfide or by the hydrolysis of the spirosulfurane 1k (see later in Scheme 3, its preparation in Ref. 1), the reaction 2k → 1k was not investigated.

Pummerer reaction of dicarboxy substituted sulfoxides. As it has been demonstrated, the sulfoxide dicarboxylic acids 2a–2j and 4 having no α-CH_2 group can be dehydrated into spirosulfuranes. On the other hand, sulfoxides with α-CH_2 and neighbouring CO_2H groups are known to undergo Pummerer reaction, when they are heated[3] or treated with acetic anhydride,[4–6] yielding lactones with 5- or 6-membered rings.

Using acetic acid or pyridine as solvent we investigated the reaction of acetic anhydride with α-(2-carboxyphenylsulfinyl)-*o*-toluic acid (5) and α,α'-sulfinyldi-*o*-toluic acid (6). In other experiments the compounds 5 and 6 were heated in an inert solvent of high b.p. The constitution of these sulfoxide dicarboxylic acids formally permits both Pummerer reaction yielding lactones and the formation of spirosulfuranes. Spectroscopic data given in the Experimental show that the lactones 9 and 11 with 5-membered ring are formed, while the formation of the spirosulfuranes 7 and 10 or that of the isomeric lactone 8 with 6-membered ring does not take place (Scheme 2, Table 3).

Hydrolysis of spirosulfuranes. In boiling aqueous acetone or dioxan, the spirosulfuranes 1a–1j and 3 hydrolyse solely to the sulfoxides 2a–2j and 4, respectively (see Scheme 1, and Ref. 2). The hydrolysis of the spirosulfurane 1k having two electron-withdrawing nitro groups at one of the benzene rings gives, however,



Scheme 2.

Table 3. Preparations of the lactones 9 and 11 from the sulfoxides 5 and 6

Precursor (a)	Method (b)	Reaction Temp (°C)	Time (min)	Lactone Product (a)	Yield (%)
5	A	118	10	9	87
	B	115	60		70
	H	240–260	30		91
6	A	118	10	11	51
	B	115	60		69
	H	240–260	30		90

[a] See Scheme 2 and text. [b] Ac_2O in AcOH (A); Ac_2O in pyridine (B); heating in "Diphyl" (H).

3,5-dinitrosalicylic acid (12), 2,2'-dithiodibenzoic acid (14) and 2-sulfobenzoic acid (15) products through S-C_{ar} bond cleavage. In the formation of the compounds 14 and 15 presumably the sulfenic acid intermediate 13 is involved[7] (Scheme 3).

The products of the above hydrolyses can be checked by tlc. They can also be isolated from the mixture directly or in the form of their derivatives (e.g. the compound 15).

Mechanism. Reaction pathways for the hydrolysis of the spirosulfurane 1a to the sulfoxide 2a, as well as for the dehydrations of the latter compound to the parent spirosulfurane 1a were studied by means of ^{18}O-tracer experiments. When the spirosulfurane 1a was hydrolysed with ^{18}O-enriched (82.9 atom %) water, only the ν(S=O) band was markedly shifted (from 989 to 953 cm^{-1} in KBr pellet) in the IR spectrum of the resulting ^{18}O-labelled 2,2'-sulfinyldibenzoic acid (2a-^{18}O), and the sulfinyl group of the product 2a-^{18}O was found to contain the same amount of ^{18}O-label as the ^{18}O-enriched water (Experimental). These observations reveal that the nucleophilic attack of water occurs exclusively at the S atom of the spirosulfurane 2a.

The sulfoxide 2a-^{18}O was dehydrated to spirosulfurane by applying the Methods A, B, F, G and H. The ^{18}O-contents of the spirosulfurane products were determined by mass spectra (Table 1). These data indicate ^{18}O-retentions in different rate, except in the case of thermic dehydration (Method H) yielding an unlabelled product. The ^{18}O-distributions between the C=O and O–S–O groups were determined by IR spectroscopic method (Experimental). The spirosulfurane products prepared by the Methods B, F and G were found to be labelled only in the O–S–O moiety. When the dehydration was carried out by the Method A, about 17% ^{18}O was retained both in the C=O and O–S–O groups of the product, independently of the time of reaction (0.5–3 hr). The ^{18}O-content of the spirosulfurane prepared by the Method F did not change when this product was boiled in AcOH–Ac_2O solvent, but a ^{18}O-distribution of about 50 and 18% was observed in the O–S–O and C=O groups, respectively.

The above results suggest two mechanisms (pathways a and b in Scheme 4) for the dehydration of bis(2-carboxyaryl) sulfoxides of type 2a.

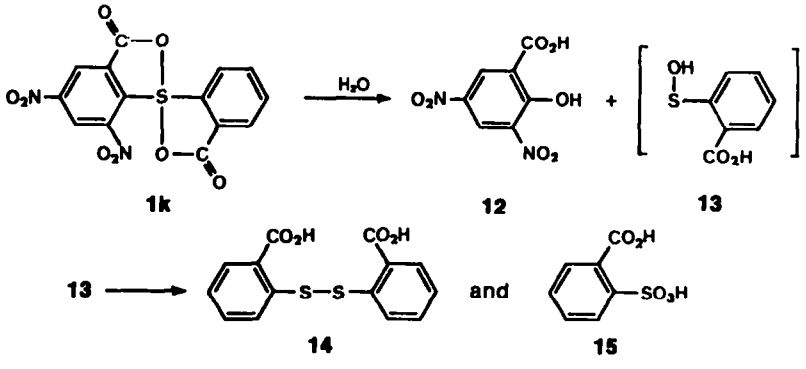
Dehydration starting with O-acetylation of the *ortho* carboxyl group, followed by the nucleophilic attack of the sulfinyl-oxygen on the mixed anhydride moiety, results in the formation of ^{18}O-labelled spirosulfurane (path b in Scheme 4; major pathway for Methods B and F; see Refs. 5, 12).

No ^{18}O-retention in the spirosulfurane product is to be expected when the sulfinyl group is acetylated and subsequently attacked by the nucleophilic *ortho* carboxyl group (path a in Scheme 4; see Pummerer reaction of sulfoxides in Refs. 8–11). On the basis of data given for the rate of ^{18}O-retentions in Table 1 it may be assumed that pathways a and b are concurrent when dehydration is carried out in AcOH with Ac_2O (Method A). Since AcOH as protic solvent favours to the equilibrium 18-$^{18}O \rightleftharpoons$ 18-(C=^{18}O), the ^{18}O-incorporation into the carbonyl group of the spirosulfurane may be explained by an intramolecular ^{18}O-exchange (path c in Scheme 4).

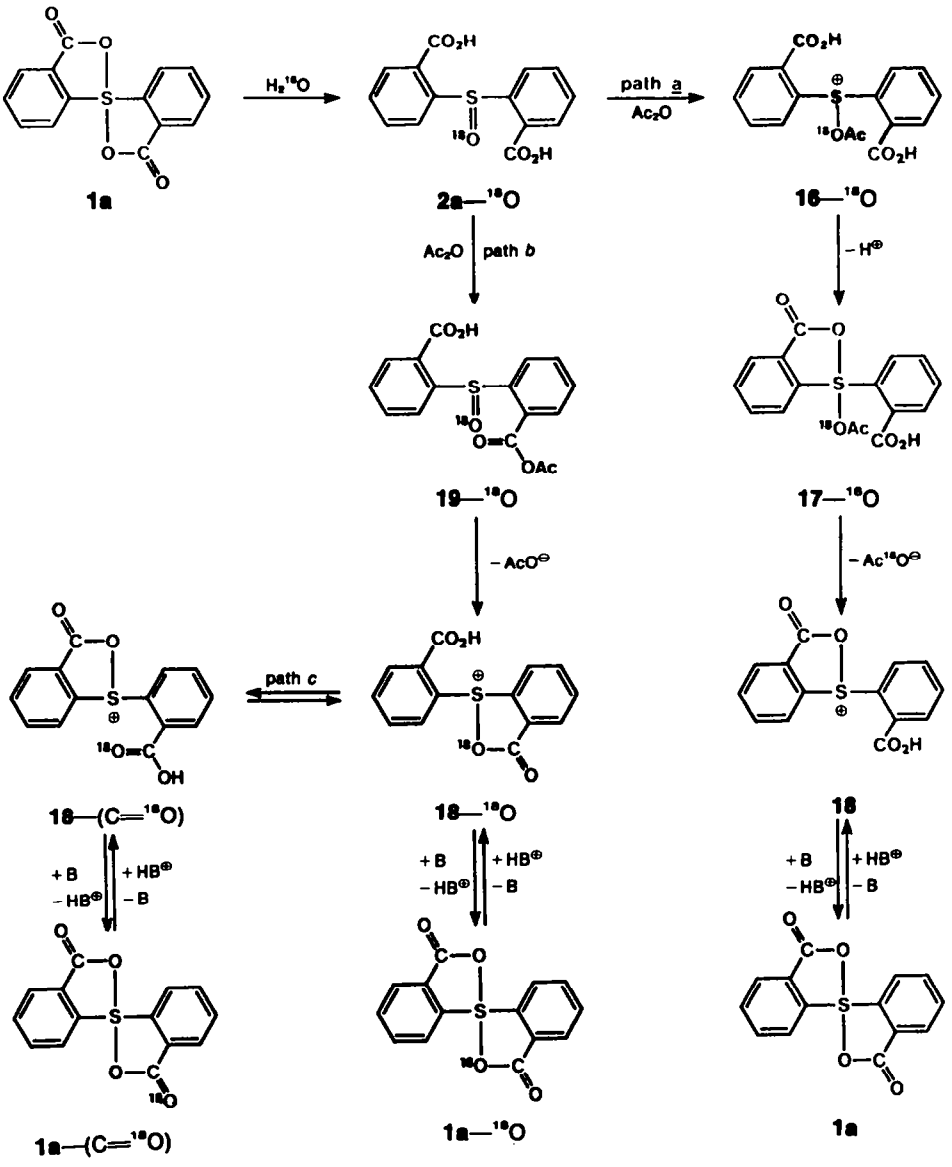
Dehydration with DCC (Method G) leading to the ^{18}O-labelled spirosulfurane appears to involve the activation of the *ortho* carboxyl group (see 20-^{18}O) and 19-^{18}O in Schemes 5 and 4, respectively; (see Refs. 6, 13).

Thermic dehydration (Method H) of the sulfoxide 2a-^{18}O to unlabelled spirosulfurane 1a presumably starts with the activation of the sulfinyl group by proton-transfer, followed by the departure of $H_2{}^{18}O$ (see 21-^{18}O and 17-^{18}O in Schemes 5 and 4, respectively; cf. the intramolecular H– bond between SO and o-CO_2H groups indicated by IR spectra).

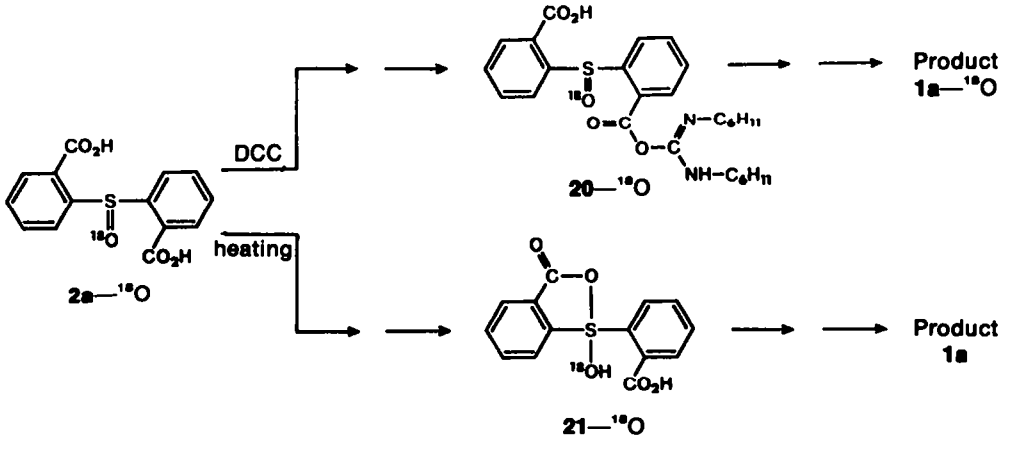
As to the mechanism of Pummerer reaction of the sulfoxides 5 and 6, it may be assumed that the initial steps leading to acetyloxysulfonium and/or cyclic acyloxysulfonium ion intermediates are analogous to those demonstrated on spirosulfurane formations (see path a and b in Scheme 4). The subsequent steps yielding the lactones 9 and 10 may involve an α-proton removal giving rise to the formation of ylide-ylene and ion-pair intermediates (see Ref. 11). Further work on the details of this mechanism are now underway in our laboratory and will be published elsewhere.



Scheme 3.



Scheme 4.



Scheme 5.

EXPERIMENTAL

Experimental conditions for the preparations of spirosulfuranes and lactones (solvent, reaction temp., reaction time, yield) as well as their characteristic data (m.p., analyses, UV, IR) are quoted only in case if they are not given in the main text (Tables 1–3). The compounds produced by different methods were identical.

Solvents were purified and dried by usual methods; pyridine by distillation over P_2O_5. Unless otherwise stated, evaporation was carried out under reduced pressure. Products obtained from mixtures or by crystallization were, after filtration and washing with cold solvent and ether, dried *in vacuo* over KOH pellets or P_2O_5, depending on the solvent used.

M.ps were determined with a "Boetius" m.p. apparatus. Microanalyses were carried out in the microanalytical laboratory of this Institute by Dr. H. Medzihradszky-Schweiger and Mrs. S. Kutassy. UV and IR spectra were recorded by Mrs. Zs. Petres and Miss K. Fehér with a Specord UV-VIS (Zeiss, Jena) and with a Specord IR 75 or an UR 10 (Zeiss, Jena) spectrometer, respectively.

Preparations for spirosulfuranes from bis (2-carboxyaryl) sulfoxides (see also Tables 1 and 2)

The spirosulfuranes were isolated from the mixtures after they had been allowed to cool to room temp.

Method A. To the hot, nearly saturated solns of **2a–2j** (10 mmol) in dry AcOH was added Ac_2O (5 ml for 100 ml of AcOH) and the mixtures were boiled. When **4** was dehydrated by this method, a mixture of AcOH (200 ml) and Ac_2O (5 ml) was used, and **3** was isolated from the heterogenous mixture.

Method B. To the solns of **2a–2j** and **4** (2 mmol) in dry pyridine (10 ml) was added Ac_2O (1 ml) at the temp. given in Tables 1 and 2.

Method C. The mixture of **2a** (0.72 g, 2.5 mmol) and Ac_2O (2.5 ml) in dry dioxan (50 ml) was heated under reflux.

Method D. To the soln of **2a** (1.45 g, 5 mmol) in dry pyridine (25 ml) was added AcCl (0.78 g, 10 mmol) and shaken at room temp.

Method E. 0.72 g (2.5 mmol) of **2a** was dissolved in boiling dioxan (60 ml), and then AcCl (2.2 ml, 30 mmol) was added to the soln at 40°. After standing overnight at room temp., the crystals of **1a** were isolated.

Method F. To the soln of **2a** (0.10 g, 0.34 mmol) in DMF (8 ml) in the presence of Et_3N (0.11 g, 1.12 mmol) AcCl (0.031 g, 0.4 mmol) dissolved in CH_2Cl_2 (0.2 ml) at −50° was added dropwise under stirring. The cooling bath was removed, the mixture was allowed to stand at room temp. for 10 min and then cooled again to −30°. At this temp. 2 ml of water was added to the mixture under stirring and the crystals of **1a** were immediately filtered off. After washing with cold water (2 × 1 ml) they were dried *in vacuo* over P_2O_5.

Method G. (a) A soln of DCC (0.082 g, 0.4 mmol) in dry dioxan (2 ml), was added to **2a** (0.1 g, 0.34 mmol) in boiling dry dioxan (20 ml) and the mixture was allowed to stand at room temp. for 24 hr. The crystals of DCU were filtered off (0.056 g) and the filtrate was evaporated. The crystalline residue was shaken with abs. EtOH (20 ml), filtered off, washed with EtOH (2 × 4 ml) and dried. (b) To the soln of 1.0 g (3 mmol) of **2b** in dry dioxan (50 ml) was added 1.03 g (5 mmol) of DCC dissolved in dry dioxan (5 ml). The crystals of DCU formed within 1 min were filtered off (0.62 g). The **1b** was precipitated from the filtrate by addition of petroleum ether (0.8 g, 84%).

Method H. Into 100 ml of "Diphyl" solvent (dried with P_2O_5) was added 2.0 g (6.9 mmol) of **2a** in a flask fitted for distillation, and then 80–85 ml of the solvent was distilled off at atmospheric pressure (*ca.* 0.5 hr). After cooling the residue was diluted with petroleum ether to precipitate the crystals of **1a**.

Preparations for lactones **9** *and* **11** *from sulfoxides* **5** *and* **6** *by Pummerer reaction* (see also Table 3)

Method A. The procedure was similar to that described above for the preparation of spirosulfuranes from bis(2-carboxyaryl) sulfoxides by Ac_2O in AcOH solvent (see Method A there and Table 3). From **5** (3.0 g, 10 mmol), *3-(2-carboxyphenylthio)-phthalide* (**9**) (2.5 g, 87%) was obtained, m.p. 239–40° (lit.[14] m.p. 237°); λ_{max} (dioxan) 220 sh (log ε 4.49) 248 sh (3.96), 276 (3.48), 283 (3.49), 305 nm (3.45); ν_{max}(KBr) 3200–2400 br (OH), 1778 vs (lactone C=O), 1684 vs (carboxyl C=O), and 1285 s, 1045 s, 960 s (lactone C–O–C) cm^{-1}. Using **6** (3.2 g, 10 mmol) as starting material, *3-(2-carboxybenzylthio)-phthalide* (**11**) (1.5 g, 55%) was obtained, m.p. 156–7°. After recrystallization from benzene–petroleum ether (5:1) m.p. 157.5–8°; λ_{max}(dioxan) 226 sh (log ε 4.29), 277 (3.47), 283 nm (3.48); ν_{max} (KBr) 3200–2400 br (OH), 1762 vs (lactone C=O), 1675 vs (carboxyl C=O), and 1285 s, 1272 s, 1059 s, 949 s (lactone C–O–C) cm^{-1} (Found: C, 64.1; H, 4.1; S, 10.7. $C_8H_{12}O_4$ requires: C, 64.0; H, 4.0; S, 10.7%).

Method B. To the solns of 10 mmol of **5** or **6** in dry pyridine (20 ml) was added Ac_2O (4 ml) and the mixtures were refluxed, then evaporated. To isolate the *lactone* (**9**), the residue was triturated with cold water (100 ml), acidified to pH 3 with 20% HCl aq, and the crystals were filtered off, washed with cold water and recrystallised from EtOH. After evaporation, the *lactone* (**11**) was obtained from the residue of the evaporation by crystallization from benzene–petroleum ether (5:1).

Method H. The procedure was similar to that described above for dehydration of **2a** into **1a** by heating in "Diphyl" solvent (see Method H there and Table 3).

Hydrolysis of spirosulfuranes

General procedure. 0.1 mmol of **1a–1k** and **3** in 2 ml of dioxan–water (9:1 v/v) were heated at 80–85° until the mixtures became homogeneous (0.5–10 hr). The products of the hydrolyses were checked by tlc using Silica gel G (Type 60, Merck) and the following solvent systems: benzene–dioxan–acetic acid (9:2.5:4 v/v); benzene–dioxan–acetic acid (9:3:2 v/v); benzene–methanol–acetic acid (9:1.5:8 v/v); butanol–acetone–methanol (4:2:1 v/v). Spots were located by exposing the dried (at 120–30°) plates to iodine vapour or by spraying them with a 0.1% soln of methyl red indicator (pH 7). The products formed from **1a–1j** and **3** were identified as **2a–2j** and **4** by comparison with authentic samples. From the hydrolysate of **1k** only **12** and **14** could be authentically identified in this way.

Starting from larger quantities of **1a–1j** and **3**, after removing the solvent, **2a–2j** and **4** can be obtained in quantitative yields, by this procedure.

Hydrolysis of the spirosulfurane **1k** *with the identification of the products*

The **1k** (3.64 g, 10 mmol)[1] was heated in dioxan–water (1:1 v/v; 100 ml) at 100° for 3 hr. After evaporation of the solvent 50 ml of water was added to the residue, heated at 100° for an additional 0.5 hr then cooled. The crystalline product was filtered off and dried yielding *2,2'-dithiodibenzoic acid* (**14**) (0.96 g) identified by tlc, IR and m.p. 295–6° (lit.[15] m.p. 289°). $KHCO_3$ (2 g) was added to the filtrate and the yellow ppt formed was filtered off and dried (2.25 g). The *potassium 3,5-dinitrosalicylate* (**12a**) was identified by its IR spectrum (see lit.[16]). *3,5-Dinitrosalicylic acid* (**12**) was prepared from the potassium salt **12a** using Dowex 50W-X2 resin (H^+ form), m.p. 170–2° (lit.[17] m.p. 173°). To isolate *2-sulfobenzoic acid* (**15**), the filtrate of the potassium salt **12a** was passed through a column filled with Dowex 50W-X2 resin (H^+ form) and the acidic fraction was evaporated to 4 ml of volume (some gummy was separated and discarded). From this soln *bis(S-benzylthiuronium) 2-sulfobenzoate* (**15a**) was separated by the usual method[18] (0.7 g; m.p. 170–80°; after several recrystallizations from water, m.p. 205–6°, lit.[19] m.p. 205.5–206.5°) and found identical to that prepared from 2-sulfobenzoic acid[20] and S-benzylthiuronium chloride.

Preparations of sulfoxides (see also Table 4)

General procedure for preparations of the sulfoxides **2a–2j** *and* **4**. To a mixture of the corresponding sulfide[1] (10 mmol), MeOH (30 ml) and water (2 ml) were added chloramine-T ($TsNClNa \cdot 2H_2O$; 2.9 g, 11 mmol; 5.8 g, 22 mmol of it for **4**) and AcOH (1 ml). After stirring at room temp. for 8 hr, the solvent was removed and the residue dissolved in a soln of $KHCO_3$ (3 g) in water (30 ml) by heating to 100°, then cooled. The major part of $TsNH_2$ separated was filtered off and the filtrate was extracted with EtOAc (3 × 30 ml), then acidified with 10% HCl aq to

Table 4. Preparations of the sulfoxides 2a–2j and 4–6; UV and IR data for sulfoxides

Sulfoxide[a]	Yield (%)	M.p.[d] (°C)	Formula	Analyses[e] C(%)	H(%)	S(%)	UV spectra[h] λ_{max}/nm (log ϵ)	Characteristic IR bands[i] cm^{-1} ν(OH)	ν(C=O)	ν(S=O)
2a	62	310–5[c]					225sh (4.27)	3600–2200br	1727s	974s
							281 (3.41)		1703vs	
2b	60	231–3[f]	$C_{14}H_9NO_7S \cdot C_2H_5OH$	50.3	4.2	8.4	264 (4.01)	3500–2200br	1709sh	962s
				50.4	4.0	8.4	333sh[j] (3.22)		1693s	
2c	66	251–6	$C_{14}H_9ClO_5S$	51.9	3.0	9.7	231 (4.23)	3500–2200br	1697s	1000s
				51.8	2.8	9.9	285 (3.43)			
2d	46	180–200 (>360)	$C_{16}H_{13}NO_6S \cdot \frac{1}{2}H_2O$	53.5	4.5	8.8	*j*	3600–2300br	1688s	988s
				53.9	4.0	9.0				
2e	61	195–200	$C_{15}H_{12}O_6S$	56.0	4.2	10.0	240sh (4.17)	3500–2200br	1691s	952s
				56.2	3.8	10.0	293 (3.58)			
2f	94[b]	270–5	$C_{14}H_8N_2O_9S$	44.0	2.3	8.6	256 (4.20)	3550–2200br	1695s	1061s
				44.2	2.1	8.4	333sh[j] (3.13)			1030m
2g	72	295–300	$C_{14}H_8Cl_2O_5S$	46.6	2.6	9.2	235 (4.29)	3500–2200br	1707s	983s
				46.8	2.3	8.9	248sh (4.19)		1680s	
							294(3.54)			
2h	93[b]	>300	$C_{18}H_{16}N_2O_7S \cdot H_2O$	51.0	4.5	7.9	228 (4.47)	3600–2200br	1710s	989s
				51.2	4.3	7.6	272[k] (4.25)			
2i	57	244–7	$C_{16}H_{14}O_7S \cdot \frac{1}{2}H_2O$	53.4	4.5	8.9	237sh (4.16)	3550–2200br	1695s	940s
				53.5	4.2	8.9	253sh (4.10)			
							297 (3.64)			
2j	86	208–13	$C_{14}H_8Cl_2O_5S$	46.5	2.4	8.9	234sh (4.35)	3600–2200br	1728s	990s
				46.8	2.3	8.9	287sh (3.55)		1700s	
4	95[b]	308–12[b]	$C_{22}H_{14}O_{10}S_2$	52.3	3.2	12.5	*j*	3600–2150br	1710s	1028s
				52.6	2.8	12.8			1670s	
5	95[c]	240–2	$C_{15}H_{12}O_5S \cdot \frac{1}{2}H_2O$	57.6	4.4	10.4	227 (4.15)	3300–2100br	1690sh	999s
				57.5	4.2	10.2	287 (3.50)		1682vs	
6	70[c]	202	$C_{16}H_{14}O_5S$	60.4	4.4	10.1	231sh (4.21)	3400–2200br	1720sh	988s
				60.3	4.4	10.1	285 (3.54)		1710vs	

[a] See Scheme 1 and 2. [b] For the crude product suitable for the preparation of spirosulfurane. [c] For the crude product suitable for the preparation of lactone. [d] M.p.'s are not characteristic of the sulfoxides because under heating the formation of spirosulfuranes or lactones was observed (*cf* m.p.'s for the spirosulfuranes and lactones[1]). [e] Lit.[21] m.p. 312°C. [f] Crystallized from EtOH. [g] Upper row "Found"; lower row "Required". [h] Solvent dioxan. Upper row "primary band", lower row "secondary band". [i] $n \rightarrow \pi^*$ band of NO_2 group. [j] The sulfoxides 2d and 4 are practically insoluble in dioxan and in common solvents. [k] Secondary band with vibrational structure. [l] In KBr pellets.

precipitate the sulfoxide. The crude product was filtered off, washed with water, dried and recrystallized from EtOH diluted with an equal volume of hot water. The sulfoxides 2b and 2e were dried over P_2O_5 at 78° *in vacuo*. When preparing the sulfoxides 2h and 4 by this procedure, the product was isolated directly from the heterogenous mixture by filtration, the crystals were washed with cold MeOH and water, then dried.

α-(2-Carboxyphenylsulfinyl)-o-toluic acid (5). To a soln of NaOEt (75 mmol; from 1.73 g of Na and 25 ml of abs. EtOH) were added methyl thiosalicylate[22] (12.6 g, 75 mmol) and subsequently phthalide[23] (10.0 g, 75 mmol). After refluxing the mixture under N_2 for 8 hr, KOH (10 g) dissolved in water (3 ml) and in EtOH (40 ml) was added, then refluxed for an additional 2 hr and cooled. The salt formed was filtered off, washed with EtOH and dissolved in water (150 ml). On acidification with 20% HCl aq a solid product formed which was filtered off, washed with water and dried yielding crude *α-(2-carboxyphenylthio)-o-toluic acid* (22) (20 g). After recrystallization from AcOH (twice) the pure sulfide 22 was obtained (7.8 g, 36%), m.p. 262° (Found: C, 61.2; H, 4.3; S, 10.6. $C_{15}H_{12}O_4S \cdot 1/4CH_3CO_2H$ requires: C, 61.4; H, 4.3; S, 10.6%). Applying a procedure reported in lit.[24] 2.9 g (10 mmol) of 22 was oxidized with H_2O_2 to give a crude product (2.9 g, 95%). For analysis a sample (1 g) was recrystallized from EtOH (20 ml) diluted with hot water (15 ml) to obtain the pure 5 (0.7 g).

α,α'-Sulfinyldi-o-toluic acid (6). This compound was prepared from *α,α'*-thiodi-*o*-toluic acid[25] (3.0 g, 10 mmol) by the method given in lit.[26] with the modification that the mixture diluted with water was evaporated to half of its volume and cooled. The crude product was filtered off, washed with water, and dried (2.2 g, 70%), m.p. 194–6°, then recrystallized from EtOH (30 ml) diluted with hot water (45 ml) to give the pure product (1.6 g, 50%).

Sulfinyl ^{18}O-labelled 2,2'-sulfinyldibenzoic acid (2a-^{18}O). A mixture of 1a (0.41 g, 1.5 mmol), ^{18}O-enriched water (82.9 atom %; 0.3 ml, 15 mmol), and dry dioxan (2.7 ml) was heated at 100° in a sealed tube with occasional shaking (3 hr) and it was allowed to stand at room temp. (12 hr). The crystals of the resulting sulfinyl ^{18}O-labelled sulfoxide were filtered off, washed with ether, dried (0.43 g, 98.7%) and used without further purification. The ^{18}O-content of this product was determined indirectly by calculating the ^{16}O-content from the intensity of the $\nu(S=^{16}O)$ band at 1028 cm^{-1} in the IR spectra (dimethylformamide soln, c = 50 mg/ml, cell length: 0.04 mm, accuracy: ±3%).

Experiments with sulfinyl ^{18}O-labelled sulfoxide 2a. In ^{18}O-tracer experiments for the dehydration of the ^{18}O-enriched 2a (0.2 mmol of it was used for each experiment), the procedures were similar to those outlined above for the preparation of 1a (Table 1 and Methods A, B, F, G and H in the Experimental). The ^{18}O-distribution in the C=O and O–S–O groups of the products were calculated from the intensities of the ν(C=O): 1719, $\nu(C=^{18}O)$: 1680, ν(O–S–O): 819 and $\nu(^{18}O–S–O)$: 812 cm^{-1} bands in $CHBr_3$ soln (c = 1–4 mg/ml, cell length: 1 mm), with the assumption that the absorptivity for both the ^{18}O-labelled and the unlabelled groups is equal.

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