Mass Spectral Behaviour of Some *m*-Dimethoxybenzene and *sym*-Trimethoxybenzene Sulphur Derivatives

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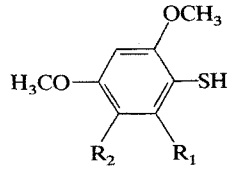
The mass spectra of fifteen *m*-dimethoxybenzene and *sym*-trimethoxybenzene sulphur derivatives (including thiols, sulphides, disulphides and trisulphides) have been investigated. Main fragmentation pathways have been proposed for each class of sulphur compound. Primary skeletal rearrangements of the molecular ions occurring in (poly)sulphur-bridged derivatives can provide a sensitive diagnostic tool both in structure elucidation and in the problem of locating methoxy substituents.

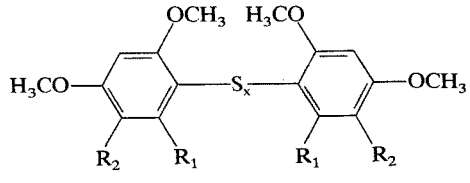
INTRODUCTION

Sulphur compounds are of great potential interest in mass spectrometry because they have been shown often to undergo skeletal rearrangements upon electron impact.[1]

Recently, we have used mass spectrometry for structure elucidation of a set of (poly)sulphur-bridged macrocyclic ring systems, containing *m*-dimethoxybenzene units.[2a–2d] As relatively little is known about the mechanisms of fragmentation of sulphur-bridged aromatic compounds bearing methoxy groups *in the ortho* positions,[3] we have undertaken a study of the behaviour upon electron impact of a variety of *m*-dimethoxybenzene and *sym*-trimethoxybenzene sulphur derivatives, including thiols **1–4**, sulphides **5–8**, disulphides **9–12** and trisulphides **13–15**, and the results of this investigation are discussed here.



	R_1	R_2
1	H	H
2	H	Cl
3	OCH_3	H
4	OCH_3	Cl



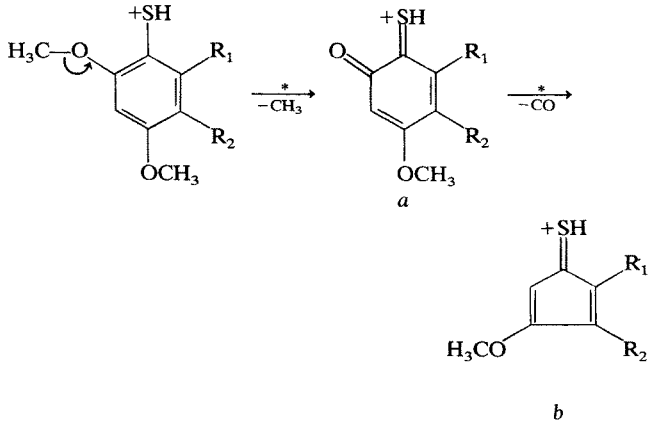
	x	R_1	R_2
5	1	H	H
6	1	H	Cl
7	1	OCH_3	H
8	1	OCH_3	Cl
9	2	H	H
10	2	H	Cl
11	2	OCH_3	H
12	2	OCH_3	Cl
13	3	H	Cl
14	3	OCH_3	H
15	3	OCH_3	Cl

RESULTS AND DISCUSSION

The general rationale for the electron impact induced mass spectral fragmentation of compounds **1–15** is shown in Schemes 1–5. The low resolution mass spectral data are presented in Tables 1–3. For purposes of discussion it is convenient to deal separately with each class of compound.

Thiols

The molecular ion of compounds **1–4** forms the base peak (Table 1), and the main fragmentation process arises from the breakdown of the molecular ion by loss of a methyl radical to generate the stable quinoid structure *a* (Scheme 1). Subsequent loss of carbon



Scheme 1

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Table 1.[a] Significant ions in the mass spectra (70 eV) of 2,4-dimethoxythiophenol derivatives 1–4

Compound	R_1	R_2	Ion assignments[b] $[M]^+$	a	$[M-Cl]^+$	b	a − Cl	b − CH_3
1	H	H	170	155*		127*		112
			(100)	(39)		(22)		(4)
2	H	Cl	204	189*	169*	161*	154	146
			(100)	(50)	(16)	(39)	(2)	(9)
3	OCH_3	H	200	185*		157*		142
			(100)	(18)		(13)		(4)
4	OCH_3	Cl	234	219*	199*	191	184	176
			(100)	(22)	(12)	(12)	(17)	(12)

[a] Relative intensity in parentheses; an asterisk indicates that the corresponding metastable ion is observed.
[b] Ion assignments as shown in Scheme 1.

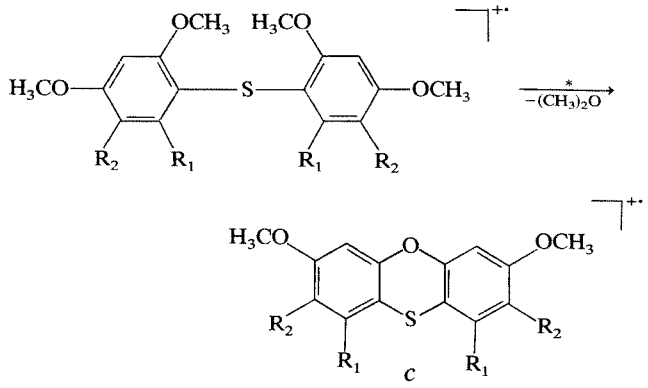
monoxide from ion *a* gives rise to the thiacyclopentadienyl ion *b*. In most cases the presence of the appropriate metastable peaks is observed for both processes. Processes involving the breakdown of C_{Ar}—O or C_{Ar}—S bonds are much less important.

The behaviour of thiols **1–4** upon electron impact resembles that of 2- and 4-methoxythioanisole, whose ability to form stable quinoid structures on fission of the CH_3—O bond has been demonstrated.[4]

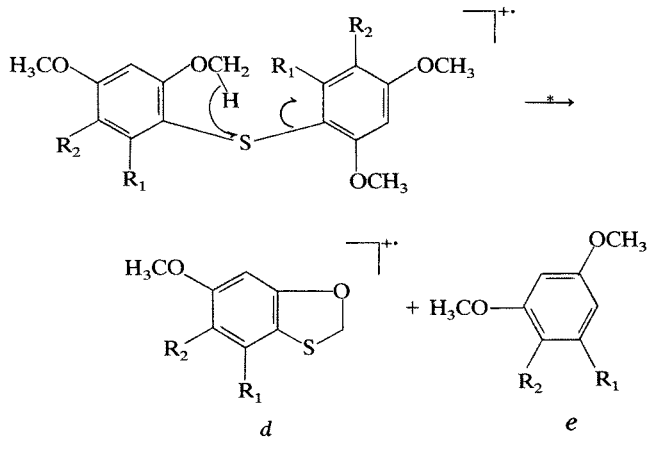
Sulphides

This class of compounds is characterized by high stability under electron impact, as shown by very strong molecular ion intensities, and by peaks attributable to doubly charged molecular ions (Table 2).

Two competing fragmentation routes are observed. The first (Scheme 2) involves the direct ejection of dimethyl ether, as a neutral molecule, from the molecular ion, which may be associated with the formation of a very stable phenoxathiin ion *c*.[5] Appropriate metastable peaks support this transition in most cases. Ion *c* suffers the subsequent loss of a methyl radical and of carbon monoxide. It is interesting to note that the intensity of ion *c* is higher in the tetra-*ortho* substituted sulphides **7** and **8** than in the di-*ortho* substituted sulphides **5** and **6**, reflecting a more favourable conformation of the former with respect to dimethyl ether ejection. An analogous skeletal rearrangement to produce dibenzodioxin has been observed previously for the closely related di(2-methoxyphenyl) ether.[6]



Scheme 2



Scheme 3

Table 2.[a] Significant ions in the mass spectra (70 eV) of di(2,4-dimethoxyphenyl) sulphide derivatives 5–8

Compound	R_1	R_2	Ion assignments[b] $[M]^+$	$[M-CH_3]^+$	c	$[M-CH_3-Cl]^+$	c − CH_3	c − CH_3CO	d	d − CH_3	e
5	H	H	306	291*	260*		245	217	168*	153	138
			(100)	(8)	(11)		(3)	(2)	(6)	(6)	(1)
6	H	Cl	374	359*	328	324	313	285	202	187	172
			(100)	(13)	(8)	(19)	(1)	(1)	(7)	(8)	(2)
7	OCH_3	H	366	351*	320*		305*	277	198*	183	168
			(100)	(2)	(16)		(2)	(2)	(19)	(7)	(13)
8	OCH_3	Cl	434	419*	388*	384	373	345	232*	217	202
			(100)	(3)	(16)	(5)	(2)	(2)	(19)	(9)	(4)

[a] Relative intensities in parentheses; an asterisk indicates that the corresponding metastable ion is observed.
[b] Ion assignments as shown in Schemes 2 and 3.

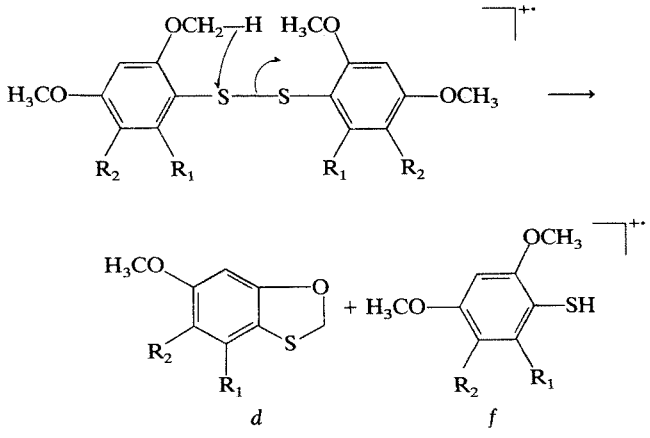
A second equally important decomposition process of compounds **5–8** arises from direct elimination of the *m*-dimethoxybenzene derivative *e* from the molecular ion, as a neutral molecule, to generate the fragment ion *d* (Scheme 3). This last process is verified by the presence of appropriate metastable peaks in most cases (Table 2). This decomposition probably proceeds via a 7-membered cyclic transition state, by a methoxy hydrogen transfer to the bridgehead carbon atom of the remote benzene ring. Similar *ortho* rearrangements have been proposed for the production of water from *o*-methoxybenzoic acid,[7] and of ammonia from *o*-ethoxybenzamide.[8]

Disulphides

Disulphides **9–12** display intense molecular ions, which in the case of compound **12** forms the base peak (Table 3). A common feature of these compounds is the occurrence of prominent skeletal rearrangements upon electron impact, as shown by the presence in their mass spectra of pronounced $[M-S]^{+\cdot}$ ions. Appropriate metastable peaks substantiate this process in some cases. Subsequent loss of dimethyl ether from the $[M-S]^{+\cdot}$ ion affords the characteristic phenoxathiin ion *c*. Interestingly, the $[M-S]^{+\cdot}/c$ intensity ratio in each disulphide is almost coincident with that observed in the corresponding sulphides (Table 1). In contrast with diphenyl disulphide and di(2-methoxyphenyl) disulphide,[3] compounds **9–12** do not suffer S_2 extrusion from the molecular ion.

In addition to the skeletal rearrangements of the molecular ions, two important decomposition pathways are observed. The first process arises from a methoxy induced *ortho* rearrangement of the molecular ion, leading to the formation of ions *d* and *f* (Scheme 4). The intensity of ion *f* is much greater than the intensity of the 'alternative' ion *d*. Ion *f* then generates fragment ions *a* and *b*, by fission of the CH_3—O bond and subsequent loss of carbon monoxide.

The second competing process involves fission of the S—S bond to produce the intense ion g (Scheme 5). Subsequent decomposition paths of ion g are plain, if one considers the possibility of *O*-methyl group migration to sulphur. A closely related methyl migration has been demonstrated in the electron impact induced fragmentation of 2-methoxythioanisole.[4] Therefore, ion g can lose (a) a methyl radical to give the quinoid structure *h*; (b) carbon monoxide (metastable peak) to generate the thiomethoxycyclopentadienyl ion *i*, or alternatively carbon monosulphide to produce the methoxycyclopentadienyl ion *j*; remarkably, ion *i* is more intense than ion *j*, due to the greater capacity of sulphur than oxygen to accommodate a positive charge;[9] (c) a thioformaldehyde molecule via a 4-membered transition state to afford ion *k*, which subsequently expels carbon monoxide to give ion *l*.



Scheme 4

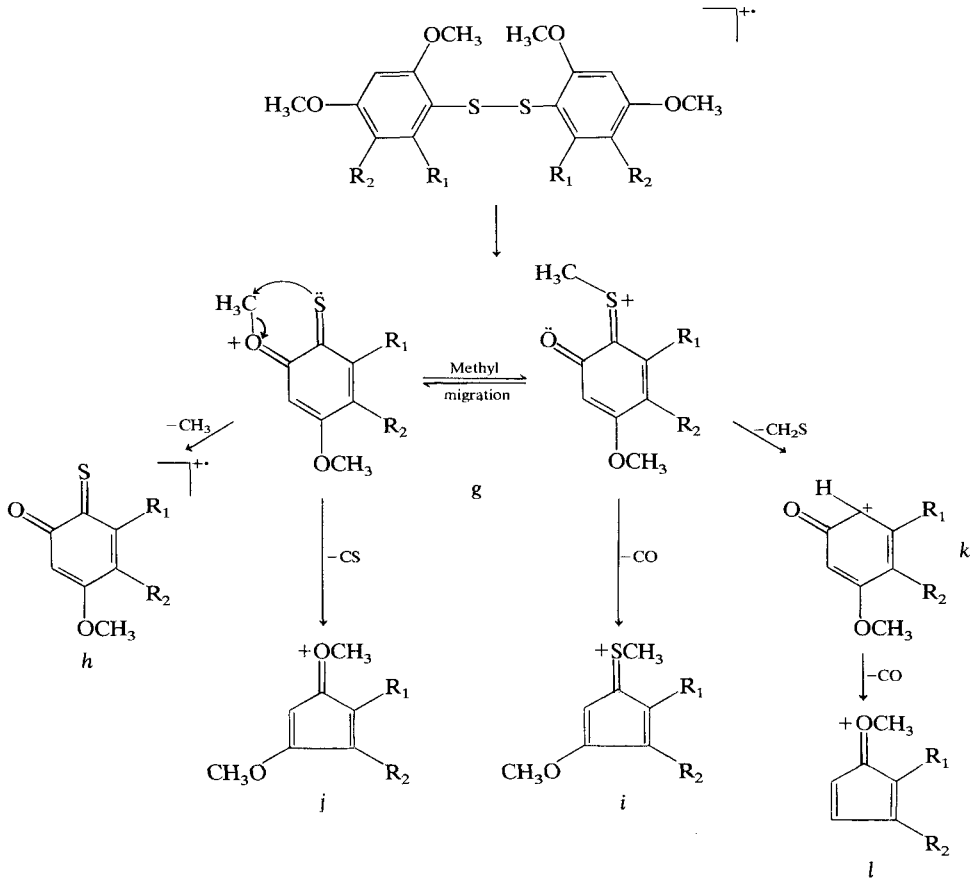
Trisulphides

Most of the trisulphides investigated give molecular ions which are easily recognized. Only in compound **14** is a very weak peak observed (Table 3). The similarities to the spectra of the corresponding disulphides are very striking; however, the spectra of the last two series are different in two important ways. First, the spectra of trisulphides **13–15** contain fairly abundant (9–42%) $[M-S_2]^{+\cdot}$ ions, substantiated in each

Table 3.[a] Significant ions in the mass spectra (70 eV) of di(2,4-dimethoxyphenyl) disulphide and trisulphide derivatives 9–15

							Ion assignments[b]												
Compound	x	R_1	R_2	$[M]^+$	$[M-S]^+$	$[M-S_2]^+$	*c*	*f*	*g*	*d*	*a*	*h*	*i*	*g*–Cl	*b*	*j*	*k*	*a*–Cl	*l*
9	2	H	H	338	306		260	170	169	168	155	154	141*		127*	125	123		95
				(84)	(5)		(1)	(100)	(83)	(14)	(39)	(25)	(26)		(22)	(11)	(23)		(19)
10	2	H	Cl	406	374		328	204	203*	202	189	188	175	168*	161	159	157	154	129
				(76)	(7)		(<1)	(74)	(100)	(11)	(29)	(2)	(9)	(84)	(20)	(6)	(27)	(2)	(18)
11	2	OCH_3	H	398	366*		320*	200	199	198	185*	184	171		157*	155	153		125
				(30)	(48)		(8)	(100)	(44)	(13)	(20)	(11)	(11)		(17)	(5)	(6)		(13)
12	2	OCH_3	Cl	466	434		388	234	233*	232	219*	218	205	198*	191	189	187	184	159
				(100)	(13)		(2)	(57)	(50)	(8)	(13)	(20)	(6)	(32)	(6)	(2)	(3)	(7)	(7)
13	3	H	Cl	438	406	374*	328	204	203	202	189*	188	175	168*	161	159	157	154	129
				(17)	(41)	(29)	(<1)	(100)	(69)	(21)	(46)	(2)	(8)	(61)	(34)	(12)	(20)	(2)	(18)
14	3	OCH_3	H	430	398	366*	320*	200	199	198	185*	184	171*		157*	155	153*		125*
				(1)	(28)	(11)	(2)	(100)	(64)	(11)	(21)	(14)	(15)		(18)	(7)	(7)		(16)
15	3	OCH_3	Cl	498	466	434*	388	234	233	232	219*	218	205	198*	191	189	187	184	159
				(5)	(22)	(42)	(6)	(100)	(50)	(18)	(23)	(22)	(6)	(35)	(11)	(4)	(4)	(16)	(10)

[a] Relative intensities in parentheses; an asterisk indicates that the corresponding metastable ion is observed.
[b] Ion assignments as shown in Schemes 1–5.



Scheme 5

case by the presence of the appropriate metastable peaks, which are not evident in the spectra of the corresponding disulphides. Second, in the low mass range a peak at m/z 64 (S_2) (absent in disulphides) is detected, which is significantly intense (20–23%) in the case of compounds **13** and **15** bearing chlorine atoms.

CONCLUSIONS

In conclusion, our results show that the stability of sulphur-bridged derivatives **5–15** upon electron impact decreases on increasing the length of the bridging chain. Our data also show that the electron impact induced fragmentation of these compounds is influenced by a prominent *ortho* effect[10] of methoxy groups. Furthermore, the observed skeletal rearrangements of the molecular ions with attendant loss of sulphur and or dimethyl ether can provide a sensitive diagnostic tool both in structure elucidation and in the problem of locating methoxy substituents in the diphenyl (poly)sulphide nucleus.

EXPERIMENTAL

Melting points are uncorrected. We have described compounds **2**,[2d] **3**,[11] **4**,[11] **5**,[2b] **6**,[2d] **10**,[2d] **12**[11] and **14**[11] previously. Compounds **1** and **9** were prepared by literature procedures.[12] Proton NMR spectra were recorded on a Varian EM-360 instrument in deuterochloroform solutions. Chemical shifts are in ppm (δ) from internal TMS. Low resolution mass spectra were obtained by direct insertion into the ion source of an LKB-9000S instrument under the following conditions: ionization energy, 70 eV; source temperature, 230–270 °C; trap, 60 μA.

Di(2,4,6-trimethoxyphenyl) sulphide (7)

Thionyl chloride (1.19 g, 0.01 mol) in $CHCl_3$ (10 cm^3) was added dropwise at 0 °C to a stirred mixture of *sym*-trimethoxybenzene (16.8 g, 0.1 mol) and iron powder (*c.* 50 mg) in $CHCl_3$ (50 cm^3). The mixture was stirred under N_2 until the evolution of hydrogen chloride subsided, then concentrated under reduced pressure and chromatographed on silica gel using diethyl ether–light petroleum (1:1 v/v) as an eluent. The first fraction gave unchanged trimethoxybenzene. Further elution afforded the sulphide **7** in a 20% yield as colourless crystals, m.p. 126–127.5 °C (from methanol); δ 3.79 (12H, s, OCH_3), 3.83 (6H, s, OCH_3), 6.16 (4H, s, aromatic-H). (Found: C, 58.84; H, 6.01; S, 8.92. $C_{18}H_{22}O_6S$ requires: C, 59.00; H, 6.05; S, 8.75%).

Di(3-chloro-2,4,6-trimethoxyphenyl) sulphide (8)

This compound, m.p. 148.5–150 °C (from methanol), was prepared similarly to **7** in a 28% yield starting from 2,4,6-trimethoxychlorobenzene[13] (8.08 g, 0.04 mol) and thionyl chloride (0.95 g, 0.008 mol); δ 3.77 (6H, s, OCH_3), 3.87 (6H, s, OCH_3), 3.90 (6H, s, OCH_3), 6.37 (2H, s, aromatic H). (Found: C, 49.75; H, 4.68; Cl, 16.43; S, 7.23. $C_{18}H_{20}Cl_2O_6S$ requires: C, 49.66; H, 4.63; Cl, 16.29; S, 7.37%).

Di(2,4,6-trimethoxyphenyl) disulphide (11)

2,4,6-Trimethoxythiophenol **3** (0.5 g, 2.5 mmol), dissolved in dimethylsulphoxide (5 cm^3), was stirred for 24 h at room temperature. On pouring the mixture into brine, the disulphide **11** precipitated in almost quantitative yield. It was collected by filtration, washed with water, and recrystallized from acetic acid, m.p. 160–162 °C; δ 3.72 (12H, s, OCH_3), 3.86 (6H, s, OCH_3), 6.12 (4H, s, aromatic-H). (Found: C, 54.11; H, 5.63; S, 15.88. $C_{18}H_{22}O_6S_2$ requires: C, 54.25; H, 5.56; S, 16.09%).

Di(5-chloro-2,4-dimethoxyphenyl) trisulphide (13)

A solution of sulphur dichloride (2.5 mmol) in anhydrous diethyl ether (10 cm^3) was added with stirring at 0 °C to a solution of thiol **2** (1.02 g, 5 mmol) in diethyl ether (100 cm^3). The mixture was flushed with N_2 and stirred until the evolution of hydrogen chloride subsided. On removal of most of the solvent, crude crystals of **13** were obtained (52% yield), which were recrystallized twice from alcohol, m.p. 128–130 °C; δ 3.99 (12H, s, OCH_3), 6.50 (2H, s, aromatic-H), 7.53 (2H, s, aromatic-H). (Found: C. 43.81; H, 3.72; Cl, 16.31; S, 21.75. $C_{16}H_{16}Cl_2O_4S_3$ requires: C, 43.73; H, 3.67; Cl, 16.14; S, 21.89%).

Di(3-chloro-2,4,6-trimethoxyphenyl) trisulphide (15)

Treatment of thiol **4** with SCl_2 in diethyl ether under conditions identical to those used for **13**, afforded trisulphide **15** in a 45% yield, m.p. 167–169 °C (from acetic acid); δ 3.96 (18H, s, OCH_3), 6.31 (2H, s, aromatic-H). (Found: C. 43.16; H, 3.98; Cl, 14.40; S, 19.12. $C_{18}H_{20}Cl_2O_6S_3$ requires: C, 43.29; H, 4.04; Cl, 14.20; S, 19.26%).

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