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GAS CHROMATOGRAPHIC AND GAS CHROMATOGRAPHIC-MASS SPECTROMETRIC CHARACTERISATION OF METHANE THIOLSULPHONATES CARRYING FURTHER FUNCTIONAL GROUPS

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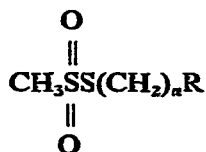
SUMMARY

A further group of methane thiolsulphonates have been characterised by gas chromatography (GC) and GC-mass spectrometry (MS). These compounds contain additional functional groups and have the general structure $\text{CH}_3\text{SO}_2\text{S}(\text{CH}_2)_n\text{R}$ (Type III) and $\text{CH}_3\text{SO}_2\text{SCH}_2\text{CO}(\text{CH}_2)_n\text{R}$ (Type IV). Although in a few cases some decomposition on GC to the respective sulphones was observed, all samples gave characteristic mass spectra and all but one could be characterised by combined GC-MS. Certain aspects of the GC and MS behaviour are briefly discussed.

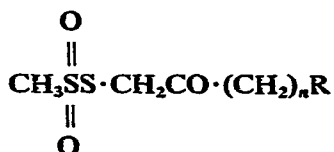
INTRODUCTION

The characterisation¹ and application in enzyme studies² of some thiolsulphonates and bithiolsulphonates have recently been described. These and other studies^{3,4} have shown that these compounds are generally amenable to characterisation by gas chromatography-mass spectrometry (GC-MS) and MS. A further group of thiolsulphonates has been synthesised in our laboratory. These new compounds are thiolsulphonates in which additional functional groups are separated from the methanethiolsulphonate moiety by methylene chains of varying lengths. Their characterisation by GC-MS is described in this report. These new compounds are broadly classified into two further structural types (for types I and II, see ref. 1):

Type III



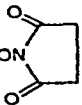
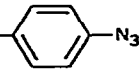
Type IV



Individual structures are shown in Table I. It was found that during both GC and direct probe analyses, compounds 6, 7 and 8 showed a variable (pyrolytic?) loss of sulphur to form the corresponding sulphone. GC and MS data from these sul-

TABLE I

STRUCTURES AND GC RETENTION TIMES (ON OV-1) OF METHANE THIOLSULPHONATES AND SULPHONES

Number	Compound structure	Oven temperature (°C)	Retention time (min)
1A	CH ₃ SO ₂ S(CH ₂) ₃ OH	170	3.8
1B	CH ₃ SO ₂ S(CH ₂) ₃ OTMS*	170	4.1
2A	CH ₃ SO ₂ S(CH ₂) ₅ COOH	220	3.9
2B	CH ₃ SO ₂ S(CH ₂) ₅ COO CH ₃	220	3.5
2C	CH ₃ SO ₂ S(CH ₂) ₅ COO TMS	220	5.0
3	CH ₃ SO ₂ S(CH ₂) ₅ CO·NH·CH(CH ₃)·COOCH ₂ CH ₃	140	4.5
4	CH ₃ SO ₂ S(CH ₂) ₅ COON 	—	—**
5	CH ₃ SO ₂ S(CH ₂) ₃ O·OC-  -N ₃	150	5.0
6A	CH ₃ SO ₂ SCH ₂ CO·(CH ₂) ₂ COOCH ₃	—	—**
6B	CH ₃ SO ₂ SCH ₂ CO(CH ₂) ₂ COOCH ₃	160	5.4
7A	CH ₃ SO ₂ SCH ₂ CO(CH ₂) ₆ COCH ₂ Cl	270	4.2
7B	CH ₃ SO ₂ SCH ₂ CO(CH ₂) ₆ COCH ₂ Cl	270	5.8
8A	CH ₃ SO ₂ S CH ₂ CO(CH ₂) ₁₄ CH ₃	—	—**
8B	CH ₃ SO ₂ SCH ₂ CO(CH ₂) ₁₄ CH ₃	250	3.0
8C	HS·CH ₂ CO(CH ₂) ₁₄ CH ₃	250	5.7
(8D)	[-S-CH ₂ CO(CH ₂) ₁₄ CH ₃] ₂	250	16.5

* TMS = trimethylsilyl.

** Parent compounds did not elute.

phones are included for completeness because of their significance in characterisation. Compound 8 elutes from the GC only as the sulphone. Some aspects of the mass spectra of sulphones have been described.

EXPERIMENTAL

Specific synthetic details and enzyme studies will be reported elsewhere; however, in outline the synthetic routes are similar to that described for bismethanethiol-sulphonates².

For analysis, the compounds were freshly dissolved in acetone or methylene chloride. GC and GC-MS conditions were as described previously¹ using an OV-1 column; the GC column temperatures are listed in Table I. Identities of GC decomposition products were initially obtained by GC-MS and this identification is used in Table I. All the compounds gave satisfactory analyses without the need for reduction to the thiol, but mass spectra for "intact" 4, 6A and 8A were obtained only by direct probe.

RESULTS

Gas chromatography

The retention times of compounds 1 to 5, 6B, 7A, 7B, 8B and 8C are summarised in Table I. Structures of compound 4, and the parent compounds 6A and 8A are also included; these did not elute unchanged from the GC. Structures 6B, 7B, 8B and 8C represent the major identified decomposition products, attributed to pyrolytic loss of sulphur on injection. Approximate proportions of the major peaks were as follows: 6B = 95%; 7A = 35%; 7B = 45%; 8B = 60%; 8C = 20%; 8D (see Discussion) = 10%. Other minor peaks (<10%) were observed; these were not analysed. Compounds 1 to 5 gave clean traces with little evidence of decomposition.

MS and combined GC-MS

Mass spectra were obtained for all compounds listed in Table I. Normalised partial spectra are given in tabular form (Table II) including the molecular ion (where present) and a 10-ion listing from m/z 50, including base peak. The list is biased towards diagnostic peaks at higher mass rather than high abundance, but less unique, ions at lower mass. Molecular ions are absent in some cases but these samples produced diagnostic peaks at high mass, due to loss of simple fragments.

Some features of the individual spectra are outlined below; $M - 79$ and $M - 111$ were observed except where noted.

Compound 1. A, small M^+ , base peak m/z 91 ($M - 79$), small peak at m/z 137, showing an unexpected loss of SH. 1B no M^+ ($M - 15$ present), otherwise predictable fragmentation.

Compound 2. A, no M^+ ; base peak at m/z 64, probably SO_2 , an unusual finding for these compounds. 2B and C, base peaks m/z 129 $[C_6H_9OS]^+$, probably cyclic.

Compound 3. M^+ present. Shows combination of predictable fragments with the base peak the well documented cyclic ion $[C_5H_9S^+]$ at m/z 101 and similar peaks at m/z 129, 131 $[C_6H_{11}OS]^+$ and 231 $[M - (79 + 15)]$.

Compound 4 (probe only). M^+ absent, base peak m/z 101. Prominent peaks from succinimide moiety (m/z 99 and 115) and also m/z 129 from the central portion of the molecule.

Compound 5. M^+ present, but not $M - 79$. Azide characterised by $M - 28$ at m/z 287 and peaks from phenyl azide⁵ at m/z 90, 91, 118, 134. Other peaks at 73 (base, $C_3H_5S^+$) and 153 $[M - OOC PhN_3]$.

Compound 6. A, M^+ absent, base peak m/z 115 formed by cleavage at the ketone, as is m/z 129 in this compound $[CH_2CO(CH_2)_2CO_2CH_3]^+$; 6B, M^+ present, other fragments corresponding to those from 6A with the addition of m/z 149 $[M - COOCH_3]^+$.

Compound 7. The 2,9-diketone structure gave complex spectra, the predominant fragmentations were due to McLafferty rearrangements giving peaks at m/z 191, 168, 136 and 137, together with simple α -cleavage with loss of $\cdot CH_2Cl$ or $CH_3SO_2(S)CH_2\cdot$ to give m/z 189, 233 and 264. The peak at m/z 111 is probably $[(CH_2)_5CHCO]^+$ (see Discussion). Also found were the ion series $[CH_3SO_2(CH_2)_n]^+$ at m/z 93, 107, 121 and 135 in 7B, and a weaker series in 7A ascribed to $[CH_3SO_2S(CH_2)_n]^+$ at m/z 125, 139 and 153. The values of the lower mass ions in this series thus imply that there has been an elision of CO from the chain. Some unusual fragments at high mass (m/z 266–264, 250–248) in 7A await further study.

TABLE II
TEN-JON LISTING OF MASS SPECTRAL PEAKS FROM METHANE THIOSULPHONATES AND SULPHONES

		1A		1B		2A		2B		2C		3		4		5		6A		6B		7A		7B		8A		8B		8C	
m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I	m/z	I		
170	0.69	242	—	226	—	240	—	240	—	298	—	325	1.9	323	—	315	4.9	240	—	208	1.1	314	—	282	5.7	364	0.50	332	1.2	286	7.9
153	0.81	227	56	209	8.0	209	12	283	38	283	38	252	46	244	18	287	11	209	1.6	177	5.8	264	3.3	233	7.3	332	3.3	252	6.5	256	1.1
139	3.6	169	80	161	20	161	23	219	28	219	28	246	28	209	55	224	12	194	3.0	176	2.2	248	3.8	191	22	285	4.8	239	13	239	100
137	1.0	163	43	147	21	129	100	187	6.6	187	6.6	231	9.8	145	3.9	153	26	179	4.3	149	2.2	191	40	189	15	252	96	234	22	137	1.8
125	3.9	147	7.7	129	90	127	33	171	70	209	12	131	16	146	23	146	23	161	6.6	129	3.2	189	37	149	26	239	82	194	19	123	3.5
112	13	137	21	127	18	101	47	169	48	169	48	200	8.9	129	65	137	14	129	11	121	1.8	169	11	137	22	234	39	149	21	111	2.8
106	2.1	135	14	113	33	97	7.2	137	74	137	74	159	16	116	16	134	28	123	5.3	115	100	149	20	125	58	194	30	136	85	109	7.9
91	100	133	25	101	45	95	17	129	100	129	13	115	15	115	15	118	49	115	100	97	11	137	15	121	28	149	20	121	18	95	13
90	44	115	9.1	95	20	87	53	117	24	118	96	101	100	106	28	88	45	88	45	88	45	121	16	111	48	137	75	111	22	85	26
79	30	103	39	87	89	85	35	101	28	101	100	99	25	90	86	83	79	87	79	87	17	111	100	107	58	125	40	97	59	83	14
64	47	73	100	64	100	67	40	75	64	67	70	87	30	73	100	65	14	65	14	79	45	69	71	69	100	57	100	57	100	71	43

Compound 8 (8A probe only). All showed M^+ , although of low intensity. Base peak of m/z 57 in 8A and 8B is a hydrocarbon fragment. The peak at $M - 80$ (m/z 252) in 8B is the only instance of hydrogen transfer, presumably influenced by the long hydrocarbon chain, to the eliminated methanesulphonyl group. This transfer is common in sulphonates⁶. Present also is m/z 111. The spectrum of 8C is dominated by α -cleavage to the keto group to give a base peak at m/z 239 through loss of $HSCH_2$. This is the only important peak at high mass.

DISCUSSION

Gas chromatography

All compounds except 4 produced peaks on the GC. Pyrolytic loss of sulphur (during injection) appears to be preferred to SO_2 loss^{7,8} and also to the loss of $[CH_3SO_2]$ as observed previously¹ in SS'-polymethylenebis (methanethiolsulphonates). Thermal loss of $[CH_3SO_2]$ is observed only in the 8A-8C transition. A later eluting minor peak in the 8 group was tentatively identified by MS as the disulphide, 8D $[-SCH_2CO-(CH_2)_{14}CH_3]_2$ presumably from oxidation and cyclisation of 8C, but was not studied further.

Loss of sulphur from 7 was also observed on direct probe analyses (see below). Thermal loss of sulphur in type IV compounds may be attributable to the keto group in close proximity to the thiolsulphonate group; no sulphur loss was observed in 1-5. Loss of sulphur from 8A was so facile that no unchanged 8A eluted from the GC. The presence of a long hydrocarbon chain may also be influential in these decompositions, e.g. 8A and 8C. The loss of $[CH_3SO_2]$ from polymethylenethiolsulphonates¹ similarly increases with increasing methylene chain length $[CH_2SO_2S \cdot (CH_2)_n \cdot S \cdot SO_2CH_3]$, when $n > 8$. Pyrolytic decomposition and disproportionation of thiolsulphonates, usually resulting in loss of SO_2 , is known from other chemical studies⁹ and has been used in synthetic sequences.

Mass spectrometry

The spectra in general showed major fragments similar to those found previously^{1,3} or formed by predictable or established pathways. Hydrocarbon ions also were prominent in the long-chain compounds.

The tendency of type IV compounds to undergo thermal loss of sulphur on GC was mirrored by their behaviour on the heated direct probe. For example, the decomposition of 7A to 7B with parallel appearance of peaks due to free sulphur (S8)¹⁰ was observed.

An alternative mode of sulphur loss, that occurring as a fragmentation process, is apparently preferred over the loss of SO_2 (except in 2A) observed in sulphonates⁶ and certain thiolsulphonates^{7,11,12}. That this loss is sulphur (and not O_2) is shown by subsequent loss of mass 79 $[CH_3SO_2]$, other fragments and S isotope peaks. Loss of mass 79 and 111 $[CH_3SO_2S]$ was observed from the appropriate compounds. However, a peak appearing at mass 111, in 7 and 8, not normally observed in thiolsulphonates so far examined, has an identity different from $[CH_3SO_2S]$ because the methane sulphonyl group is not normally charge-retaining⁴. The peak at m/z 111 is also present in those compounds where one sulphur has already been eliminated and is associated with those compounds which, in addition, contain a ketone group. A probable identity is $C_6H_{11}CO$.

The presence of a carbonyl group, especially in the longer-chain compounds, also suppresses the high intensity cyclic sulphide ions, but enhances ions formed via McLafferty rearrangements, and simple hydrocarbon ions. In addition to the predicted cyclic sulphur-containing ions at m/z 73, 87, 101 a further group of ions, containing the keto group, was found at m/z 129 $[\text{C}_6\text{H}_9\text{OS}]^+$, 131 $[\text{C}_6\text{H}_{11}\text{OS}]^+$ and a series of $[\text{CH}_3\text{SO}_2(\text{S})(\text{CH}_2)_n]^+$ or $[\text{CH}_3\text{SO}_2\text{SCH}_2(\text{CO})(\text{CH}_2)_n]^+$ were found for structures containing the keto grouping.

Smaller peaks from rearrangements and elisions are fairly numerous. The high propensity of sulphur compounds for rearrangements is well known, and where such a rearrangement ion is intense and diagnostically useful, it has been included in Table II. Complete assignments were not attempted in this study, some were ambiguous at low resolution and would require elucidation using higher resolution or isotopes. Certain similarities were seen with simple ethane and higher alkyl thiolsulphonates^{1,3}; however other previously reported peaks^{3,4,11} from thiolsulphonates were not observed, possibly because of the relatively complex nature of the acylthiol moieties and a predominance of peaks from these. Mass spectra of the sulphones (6B, 7B and 8B) showed general similarities to those of the thiolsulphonates from which they were derived and to published fragmentation behaviour¹³ of sulphones. The major peaks are listed in Table II.

ACKNOWLEDGEMENTS

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