

# Synthesis of Phenyl Arylsulfonyl-alkyl-dithiocarbamates and Their Hydrolytic Reactivity in Hydroxide and Hydroperoxide Media

Fátima Norberto,<sup>[a,b]</sup> M. Eduarda M. Araújo,<sup>\*[a]</sup> Lúcia Santos,<sup>[a]</sup> Marta S. P. Jaime,<sup>[a]</sup> Pedro M. V. Mateus,<sup>[a]</sup> and Pablo Hervés<sup>[c]</sup>

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Eight previously unreported phenyl arylsulfonyl-alkyl-dithiocarbamates were synthesized by treatment of arylsulfonamides with phenyl chlorodithioformate in an adaptation of a general amine acylation method. A kinetic investigation of

their alkaline hydrolysis was performed and the experimental data are discussed.

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## Introduction

Dithiocarbamates are an important class of chemicals, with vast utilization as insecticides, herbicides and fungicides, with a worldwide consumption of between 25000 and 35000 tons a year.<sup>[1]</sup> Their chelating properties allow them to be used as antidotes against nickel and copper poisoning, in analytic determination of heavy metals and in wastewater treatment. They can also affect metal-containing enzymes.<sup>[2]</sup>

In the field of medicine these compounds are used in the treatment of chronic alcoholism and in fungi- and bacteria-related diseases, and they have also received some attention as experimental therapy for AIDS, as potential auxiliaries in oncological chemotherapy and in the prevention of arteriosclerosis.<sup>[3]</sup>

Dithiocarbamates exhibit low chronic and acute toxicity in humans and mammals, although their high reactivity, associated with their chelating properties and their high affinities for HS-containing proteins, is responsible for adverse effects including neurotoxicity, antithyroid properties, eye and skin sensitization etc.<sup>[4]</sup>

Dithiocarbamates can be absorbed by organisms through the respiratory and digestive tracts, skin and mucous membranes and can be found along with their metabolic pro-

ducts in the liver, kidneys and thyroid, although no accumulation takes place, thanks to their rapid metabolism.<sup>[1]</sup>

The impact of the biological activity of dithiocarbamates is determined by their stability in aqueous media, which governs their environmental persistence.

Hydrolysis of secondary monothiocarbamates has already been studied<sup>[5]</sup> but the hydrolytic decomposition of dithiocarbamates has not yet been reported.

Carbamates can undergo alkaline hydrolysis by a B<sub>AC</sub>2 or an E1cB mechanistic pathway depending on their individual structural properties.<sup>[6–9]</sup> We have previously studied the alkaline hydrolysis of aryl methyl-arylsulfonyl-carbamates<sup>[6]</sup> and have proposed a general base-catalysed mechanism for this reaction.

This paper presents eight previously unreported phenyl arylsulfonyl-alkyl-dithiocarbamates **3** and proposes a mechanism for their hydrolytic decomposition in basic media.

## Results and Discussion

### Synthesis

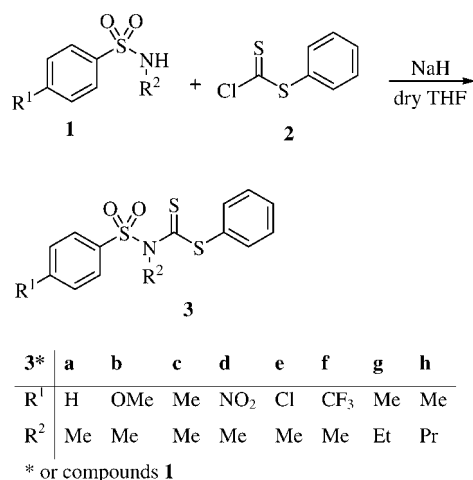
Eight previously unreported phenyl arylsulfonyl-alkyl-dithiocarbamates were obtained by nucleophilic substitution of arylsulfonamides **1a–h** on phenyl chlorodithioformate (**2**) in the presence of sodium hydride as a base (Scheme 1).

The reaction proceeds smoothly at room temperature and the products are easily crystallized from the reaction mixture, in moderate yields (69–14%). Spectral data for the new esters **3** are presented in Table 2 and Table 3.

[a] CQB and Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal  
Fax: +351-217500088  
E-mail: eduaraujo@fc.ul.pt

[b] Departamento de Ciências da Saúde, Universidade Lusófona de Humanidades e Tecnologia, Av. Campo Grande, 376-1749, Lisboa, Portugal

[c] Departamento de Química Física, Facultad de Ciencias, Universidad de Vigo, Apartado 874, Vigo (Pontevedra), España  
E-mail: jhervés@uvigo.es



Scheme 1. Synthesis of phenyl arylsulfonyl-alkyl-dithiocarbamates 3a–h.

### Reactivity

The alkaline hydrolysis of esters 3 to the corresponding sulfonamide 1 and thiophenol proceeds by attack at the thiocarbonyl group rather than at the sulfonyl group. The same has also previously been observed for arylsulfonyl-carbamates.<sup>[6]</sup> The influence of HO<sup>−</sup> concentration on the reaction rates of compounds 3a–f was studied at 25.0 ± 0.1 °C in aqueous sodium hydroxide solutions containing 30% v/v dioxane, with [HO<sup>−</sup>] in the 0.01–0.5 M range, and with ionic strength kept constant at 0.5 M with KCl (Figure 1, Table 1). The slope and the positive intercepts are  $k_{\text{OH}^-}$  and  $k_{\text{w}}$ , respectively, where  $k_{\text{OH}^-}$  is the reactivity constant in the presence of HO<sup>−</sup> and  $k_{\text{w}}$  the reactivity constant in the solvent.

Compounds 3c and 3f were studied in sodium deuterioxide solutions, giving  $k_{\text{DO}^-} = (7.8 \pm 0.3) \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$  and  $(3.75 \pm 0.09) \times 10^{-3} \text{ M}^{-1} \text{ s}^{-1}$ , respectively. The solvent isotope effects ( $k_{\text{HO}^-}/k_{\text{DO}^-}$ ) for these compounds were found to be 0.91 and 0.99 (Table 1), respectively, values consistent with hydroxide ion acting as a nucleophile rather than a general base, as is usually the case in the presence of HO<sup>−</sup> and in the total absence of other nitrogen or oxygen buffers.<sup>[6,10]</sup> A much higher value for the solvent isotope effect ( $\geq 2$ ) would indicate involvement of a water molecule in the rate-determining step.<sup>[10]</sup>

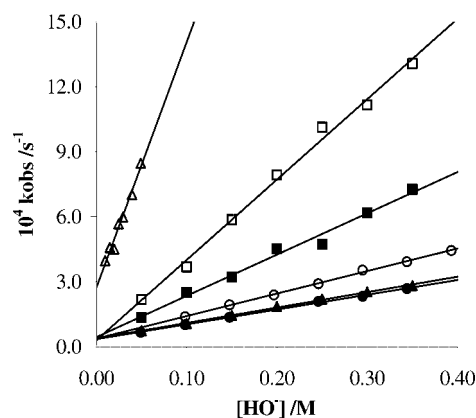


Figure 1.  $k_{\text{obs}}$  vs. [HO<sup>−</sup>] for 3a–f: ○ 3a, ● 3b, ▲ 3c, △ 3d, ■ 3e, □ 3f. [S] =  $1 \cdot 10^{-4}$  M; I = 0.5 M; 30% 1,4-dioxane;  $T = 25.0 \pm 0.1$  °C.

A recently used parameter to distinguish between general base catalysis and nucleophilic catalysis is comparison of the catalytic effect of hydroperoxide vs. hydroxide. It was reported in the literature that hydroperoxide ( $\text{p}K_{\text{a}} = 11.7$ ), although less basic than hydroxide, is much more effective as a nucleophile, due to the so-called  $\alpha$ -effect:<sup>[11]</sup>  $k_{\text{HOO}^-}/k_{\text{HO}^-}$  ratios of ca. 300 in reactions with ester carbonyl groups,<sup>[12]</sup> ca. 200 in reactions with sulfonyl groups of nitrososulfonamides<sup>[13]</sup> and even 3000 in reactions with nitroso groups of alkyl nitrites<sup>[13]</sup> have been reported. The effect of hydroperoxide was evaluated for compounds 3c, 3d and 3f and a linear dependence of  $k_{\text{obs}}$  on [HOO<sup>−</sup>] was observed; the bimolecular rate constants for the compounds 3c, 3d and 3f are presented in Table 1. The catalytic efficiency of HOO<sup>−</sup> for the three compounds studied is evident, ranging from ca. 150 to ca. 500 times higher than the catalytic efficiency of HO<sup>−</sup>. This result agrees well with what is known about the nucleophilic reactivity of HOO<sup>−</sup>.

The influence of the substituent on the arylsulfonyl ring (compounds 3a–f) was evaluated by use of the Hammett correlation for  $k_{\text{HO}^-}$  (Figure 2).

This correlation is quite good with use of  $\sigma^0$ <sup>[14]</sup> values ( $\rho = 1.23 \pm 0.06$ ;  $r^2 = 0.99$ ). The magnitude of  $\rho$  is consistent with a rate-limiting nucleophilic attack of the hydroxide ion on the thiocarbonyl carbon atom. A similar, although lower,  $\rho$  value of 0.8 has been reported for the alkaline hydrolysis of 4-chlorophenyl *N*-methyl-*N*-arylsulfonylcarba-

Table 1. Second-order rate constants for the nucleophilically catalysed hydrolysis of esters 3a–h. [S] =  $1 \cdot 10^{-4}$  M; I = 0.5 M; 30% 1,4-dioxane;  $T = 25.0 \pm 0.1$  °C.

	$k_{\text{HO}^-} [\text{M}^{-1} \text{s}^{-1}]$	$k_{\text{DO}^-} [\text{M}^{-1} \text{s}^{-1}]$	$k_{\text{HO}^-}/k_{\text{DO}^-}$	$k_{\text{HOO}^-} [\text{M}^{-1} \text{s}^{-1}]$	$k_{\text{HOO}^-}/k_{\text{HO}^-}$
3a	$(1.04 \pm 0.02) \times 10^{-3}$	—	—	—	—
3b	$(6.8 \pm 0.2) \times 10^{-4}$	—	—	—	—
3c	$(7.1 \pm 0.1) \times 10^{-4}$ $(3.0 \pm 0.2) \times 10^{-4}$ [a]	$(7.8 \pm 0.3) \times 10^{-4}$	0.91	$0.38 \pm 0.02$	535
3d	$(1.13 \pm 0.08) \times 10^{-2}$	—	—	$1.69 \pm 0.09$	150
3e	$(1.9 \pm 0.1) \times 10^{-3}$	—	—	—	—
3f	$(3.7 \pm 0.1) \times 10^{-3}$	$(3.75 \pm 0.09) \times 10^{-3}$	0.99	$0.95 \pm 0.02$	257
3g	$(1.5 \pm 0.2) \times 10^{-4}$ [a]	$(1.3 \pm 0.1) \times 10^{-4}$ [a]	1.15	$0.18 \pm 0.02$ [a]	1200
3h	$(0.98 \pm 0.06) \times 10^{-4}$ [a]	—	—	—	—

[a] 40% 1,4-dioxane.

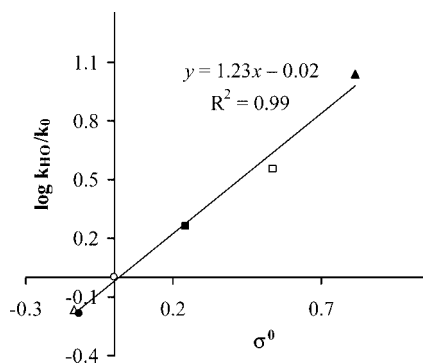
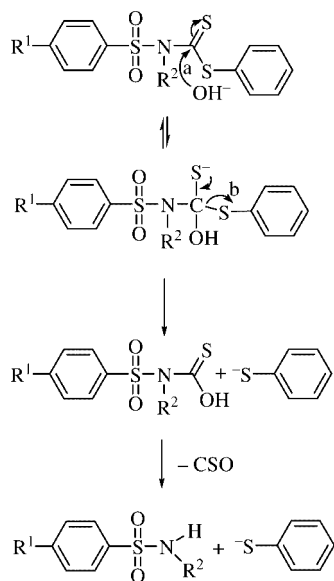


Figure 2. Hammett correlation for the hydrolysis of dithiocarbamates **3a–f**: ○ **3a**, ● **3b**, △ **3c**, ▲ **3d**, ■ **3e**, □ **3f**.

mate esters.<sup>[6]</sup> These results indicate that the electron density in the arylsulfonyl moiety in dithiocarbamates **3** increases as the transition state is approached, as is also found in the case of aryl *N*-alkyl-*N*-arylsulfonylcarbamates. The data are consistent with a transition from the substrate, in which the nitrogen lone pair is delocalized into a planar dithiocarbamate group, into a tetrahedral intermediate, in which no analogous delocalization is possible, with stabilization being afforded only by the arylsulfonyl group. The solvent isotope effect and the catalytic efficiency of hydroperoxide vs. hydroxide found for the hydrolysis of esters **3** both indicate a mechanism that involves a rate-determining bimolecular catalysed pathway through the direct attack of the nucleophile on the thiocarbonyl group (Scheme 2, path a), followed by decomposition of the intermediate formed, probably by loss of thiophenolate anion (Scheme 2, path b).



Scheme 2. Pathways for the nucleophilically catalysed hydrolysis of dithiocarbamates **3**.

Compounds **3** behave differently from the previously studied aryl *N*-methyl-*N*-arylsulfonylcarbamates, which un-

dergo a general base-catalysed process.<sup>[6]</sup> Moreover the dithio derivatives **3** are much less reactive ( $10^{-2}$  effectiveness) than the corresponding arylsulfonylcarbamates,<sup>[6]</sup> probably due to the higher electron density on the carbon-sulfur double bond, caused in turn by the lower electronegativity of the sulfur atom.

The effect of increasing alkyl chain length ( $R^2$ ) at the nitrogen atom of dithiocarbamates **3** on the basic hydrolysis was also evaluated. The hydrolysis of compounds **3c**, **3g** and **3h** in aqueous hydroxide media was studied with  $[HO^-]$  in the 0.01–0.5 M range by use of sodium hydroxide solutions with 40% v/v dioxane (an increase in the organic solvent percentage was needed due to the lower solubilities of these substrates in water). The values obtained for  $k_{obs}$  (Figure 3) show good straight lines and a non-zero intercept. Furthermore, the  $k_{OH^-}$  value for **3c** obtained in this way is lower than that observed at 30% dioxane, due to the decrease in polarity of the solvent, which produces additional stabilization of reactants and consequently a higher energetic barrier. As before, the intercepts represent the reactivity constant in the solvent. We have observed that  $k_{HO^-}$  decreases along the series **3c**, **3g** and **3h** (Table 1).

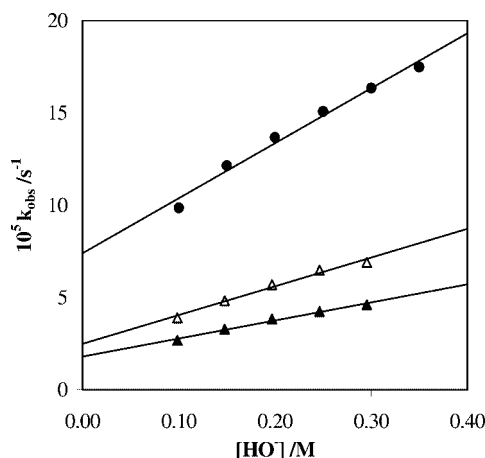
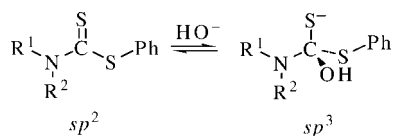


Figure 3.  $k_{obs}$  vs.  $[HO^-]$  for dithiocarbamates **3c**, **3g**, **3h**: ● **3c**, △ **3g**, ▲ **3h**.  $[S] = 1 \cdot 10^{-4}$  M;  $I = 0.5$  M; 40% 1,4-dioxane;  $T = 25.0 \pm 0.1$  °C.

Hydrolysis of compound **3g** was also performed in sodium deuteroxide solutions and in hydrogen/hydroperoxide buffers (Table 1). The ratios  $k_{HO^-}/k_{DO^-} = 1.15$  and  $k_{HOO^-}/k_{HO^-} = 1200$ , indicating that there is no change in the hydrolysis mechanism with increasing alkyl chain length at the nitrogen atom. The decrease in the rate constant with increasing alkyl chain length in the substituents is consistent with the proposed  $B_{AC2}$  mechanism involving nucleophilic catalysis. For the rate-determining step of the proposed mechanism we may also consider that, as the bulkiness of the alkyl substituent increases, so does the steric tension caused by the carbon of the thiocarbonyl group changing from an  $sp^2$  into a  $sp^3$  character (Scheme 3). Thus,  $k_{HO^-}$  decreases, which is in agreement with what has been described previously for the hydrolysis of esters and amides in basic media.<sup>[15,16]</sup>

Scheme 3. Rate-determining step of B<sub>AC</sub>2 with nucleophilic catalysis mechanism.

## Conclusions

In conclusion, phenyl arylsulfonyl-alkyl-dithiocarbamates **3** give thiophenol and the corresponding sulfonamides when hydrolysed in basic media. The kinetic parameters, solvent isotope effect in hydroxide media and hydroperoxide effectiveness support a B<sub>AC</sub>2 mechanism involving

Table 2. Physicochemical properties and corresponding yields of compounds **3a–h**.

	R <sup>1</sup>	R <sup>2</sup>	Yield [%]	M.p. [°C]	IR		HRMS [ <i>M</i> + <i>H</i> ] <sup>+</sup>	
					<i>ν</i> (C=S) [cm <sup>−1</sup> ]	<i>ν</i> (S=O) [cm <sup>−1</sup> ]	Calcd.	Exp.
<b>3a</b>	H	CH <sub>3</sub>	40	107.4–109.4	1089	1362, 1170	324.0187	324.0184
<b>3b</b>	OCH <sub>3</sub>	CH <sub>3</sub>	40	86.5–87.6	1086	1368, 1158	354.0292	354.0305
<b>3c</b>	CH <sub>3</sub>	CH <sub>3</sub>	25	85.0–87.0	1053	1314, 1176	338.0343	338.0356
<b>3d</b>	NO <sub>2</sub>	CH <sub>3</sub>	69	126.7–127.4	1089	1368, 1170	369.0037	369.0034
<b>3e</b>	Cl	CH <sub>3</sub>	14	109.0–110.0	1053	1359, 1173	357.9797	357.9795
<b>3f</b>	CF <sub>3</sub>	CH <sub>3</sub>	26	81.0–83.0	1068	1326, 1179	392.0061	392.0070
<b>3g</b>	CH <sub>3</sub>	C <sub>2</sub> H <sub>5</sub>	22	83.7–84.7	1092	1386, 1182	352.0500	352.0512
<b>3h</b>	CH <sub>3</sub>	C <sub>3</sub> H <sub>7</sub>	24	86.8–87.7	1092	1383, 1182	366.0656	366.0667

Table 3. <sup>1</sup>H NMR and <sup>13</sup>C NMR chemical shifts observed for **3a–h**.

	δ <sub>H</sub> (CDCl <sub>3</sub> ) [ppm] (400 MHz)	δ <sub>C</sub> (CDCl <sub>3</sub> ) [ppm] (100 MHz)
<b>3a</b>	3.87 (s, 3 H, N- <i>Me</i> ), 7.27 (d, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.49 (m, 3 H, H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , <i>Ar-S</i> ), 7.73 (m, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.80 (d, 1 H, H <sub>4</sub> , <i>Ar-SO</i> <sub>2</sub> ), 8.08 (d, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	41.41 (N- <i>Me</i> ), 129.01 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 130.21 (C-4, <i>Ar-S</i> ), 130.37 (C-2,6, <i>Ar-S</i> ), 131.30 (C-3,5, <i>Ar-S</i> ), 132.17 (C-1, <i>Ar-S</i> ), 135.19 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 137.11 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 139.14 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 203.09 (C=S)
<b>3b</b> <sup>[a]</sup>	3.82 (s, 3 H, N- <i>Me</i> ), 3.93 (s, 3 H, O- <i>Me</i> ), 7.18 (d, <i>J</i> = 8.3 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.28 (d, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.45 (m, 3 H, H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , <i>Ar-S</i> ), 8.03 (d, 2 H, <i>J</i> = 8.9 Hz, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	41.49 (N- <i>Me</i> ), 56.38 (O- <i>Me</i> ), 115.35 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 130.18 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 130.34 (C-4, <i>Ar-S</i> ), 131.24 (C-3,5, <i>Ar-S</i> ), 131.62 (C-2,6, <i>Ar-S</i> ), 132.47 (C-1, <i>Ar-S</i> ), 137.20 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 165.24 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 202.96 (C=S)
<b>3c</b>	2.46 (s, 3 H, <i>Me-Ar-SO</i> <sub>2</sub> ), 3.83 (s, 3 H, N- <i>Me</i> ), 7.38 (m, 5 H, H <sub>2</sub> , H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.39 (d, <i>J</i> = 9 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.89 (d, <i>J</i> = 9 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	21.75 ( <i>Me-Ar-SO</i> <sub>2</sub> ), 40.95 (N- <i>Me</i> ), 128.38 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 129.44 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 129.72 (C-4, <i>Ar-S</i> ), 130.42 (C-2,6, <i>Ar-S</i> ), 131.43 (C-1, <i>Ar-S</i> ), 135.06 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 136.37 (C-3,5, <i>Ar-S</i> ), 145.30 (C-4, <i>Ar-SO</i> <sub>2</sub> )
<b>3d</b> <sup>[a]</sup>	3.96 (s, 3 H, N- <i>Me</i> ), 7.31 (d, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.48 (m, 3 H, H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , <i>Ar-S</i> ), 8.33 (d, <i>J</i> = 4.4 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> ), 8.49 (d, <i>J</i> = 4.4 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> )	40.55 (N- <i>Me</i> ), 125.25 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 130.51 (C-3,5, <i>Ar-S</i> ), 130.55 (C-2,6, <i>Ar-S</i> ), 131.01 (C-1, <i>Ar-S</i> ), 131.59 (C-4, <i>Ar-S</i> ), 137.18 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 144.52 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 151.57 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 202.41 (C=S)
<b>3e</b>	3.86 (s, 3 H, N- <i>Me</i> ), 7.38 (m, 5 H, H <sub>2</sub> , H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.53 (d, <i>J</i> = 8.8 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.94 (d, <i>J</i> = 8.8 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	40.50 (N- <i>Me</i> ), 129.36 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 129.57 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 129.84 (C-4, <i>Ar-S</i> ), 130.62 (C-2,6, <i>Ar-S</i> ), 130.85 (C-1, <i>Ar-S</i> ), 136.60 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 136.36 (C-3,5, <i>Ar-S</i> ), 140.75 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 201.96 (C=S)
<b>3f</b>	3.90 (s, 3 H, N- <i>Me</i> ), 7.37 (m, 5 H, H <sub>2</sub> , H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , H <sub>6</sub> , <i>Ar-S</i> ), 7.82 (d, <i>J</i> = 8.4 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 8.11 (d, <i>J</i> = 8.0 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	40.27 (N- <i>Me</i> ), 126.17 (C-2,6, <i>Ar-SO</i> <sub>2</sub> ), 128.90 (C-3,5, <i>Ar-SO</i> <sub>2</sub> ), 129.63 (C-4, <i>Ar-S</i> ), 130.63 (C-2,6, <i>Ar-S</i> ), 130.51 (C-1, <i>Ar-S</i> ), 135.29 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 136.33 (C-3,5, <i>Ar-S</i> ), 141.88 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 201.92 (C=S)
<b>3g</b>	1.53 (t, <i>J</i> = 6.8 Hz, 3 H, N-CH <sub>2</sub> CH <sub>3</sub> ), 2.45 (s, 3 H, CH <sub>3</sub> - <i>Ar-SO</i> <sub>2</sub> ), 4.55 (q, <i>J</i> = 6.8 Hz, 2 H, N-CH <sub>2</sub> CH <sub>3</sub> ), 7.34 (d, <i>J</i> = 8.4 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.37 (m, 5 H, H <sub>2</sub> , H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , H <sub>6</sub> , <i>Ph-S</i> ), 7.90 (d, <i>J</i> = 8.0 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	14.73 (N-CH <sub>2</sub> CH <sub>3</sub> ), 21.72 (CH <sub>3</sub> - <i>Ar</i> ), 49.05 (N-CH <sub>2</sub> CH <sub>3</sub> ), 128.53 (C-2, C-6, <i>Ar-SO</i> <sub>2</sub> ), 129.40 (C-3, C-5, <i>Ar-SO</i> <sub>2</sub> ), 129.56 (C-4, <i>Ph-S</i> ), 130.42 (C-2, C-6, <i>Ph-S</i> ), 131.08 (C-1, <i>Ph-S</i> ), 135.73 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 136.52 (C-3, C-5, <i>Ph-S</i> ), 145.05 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 201.14 (C=S)
<b>3h</b>	1.01 (t, <i>J</i> = 7.2 Hz, 3 H, N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 2.45 (s, 3 H, CH <sub>3</sub> - <i>Ar-SO</i> <sub>2</sub> ), 1.99 (m, 2 H, N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 4.40 (t, <i>J</i> = 8.0 Hz, 2 H, N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 7.33 (d, <i>J</i> = 8.0 Hz, 2 H, H <sub>3</sub> , H <sub>5</sub> , <i>Ar-SO</i> <sub>2</sub> ), 7.36 (m, 5 H, H <sub>2</sub> , H <sub>3</sub> , H <sub>4</sub> , H <sub>5</sub> , H <sub>6</sub> , <i>Ph-S</i> ), 7.88 (d, <i>J</i> = 8.4 Hz, 2 H, H <sub>2</sub> , H <sub>6</sub> , <i>Ar-SO</i> <sub>2</sub> )	11.06 (N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 21.72 (CH <sub>3</sub> - <i>Ar</i> ), 22.72 (N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 55.02 (N-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ), 128.55 (C-2, C-6, <i>Ar-SO</i> <sub>2</sub> ), 129.40 (C-3, C-5, <i>Ar-SO</i> <sub>2</sub> ), 129.51 (C-4, <i>Ph-S</i> ), 130.40 (C-2, C-6, <i>Ph-S</i> ), 131.08 (C-1, <i>Ph-S</i> ), 135.73 (C-1, <i>Ar-SO</i> <sub>2</sub> ), 136.47 (C-3, C-5, <i>Ph-S</i> ), 144.97 (C-4, <i>Ar-SO</i> <sub>2</sub> ), 201.37 (C=S)

[a] Spectra obtained in (CD<sub>3</sub>)<sub>2</sub>CO.



a nucleophilic catalysis pathway. The presence of alkyl substituents of different length on the dithiocarbamate nitrogen did not affect the bimolecular mechanism ( $B_{AC2}$ ). Although the dithiocarbamate esters studied are similar to their oxygen analogues (*O*-phenyl *N*-methyl-*N*-arylsulfonyl-carbamates), they display different mechanistic behaviour in the form of a nucleophilic  $B_{AC2}$  pathway rather than a general base-promoted reaction.

## Experimental Section

**General Remarks:** Melting points are uncorrected. IR spectra were obtained with a Hitachi 270–50 spectrophotometer.  $^1\text{H}$  NMR spectra were recorded with 400 MHz Bruker AR 400 or Bruker Advance DP 400 instruments, in  $(\text{CD}_3)_2\text{CO}$  or  $\text{CDCl}_3$  with TMS as internal standard.  $J$  values are given in Hz.  $^{13}\text{C}$  NMR spectra were recorded with a 100 MHz Bruker Advance machine. MS and HRMS were recorded in a VG Autospec M mass spectrometer. UV spectra and kinetic studies were performed on a HP-845 instrument, with UV/Visible chemstation software. All solvents and reagents were obtained from Merck or Aldrich and were used without further purification.

**General Procedure for the Preparation of Phenyl Arylsulfonyl-alkyl-dithiocarbamates 3:** The synthesis of arylsulfonamides **1** was accomplished by the Schotten–Baumann reaction.<sup>[17]</sup> The synthesis of **3a** is described as an example of the general procedure: phenyl benzenesulfonyl-methyl-dithiocarbamate **3a** was prepared by stirring a solution of *N*-methyl-sulfonamide **1a** (1.49 g, 9 mmol) in anhydrous THF (20 mL) and sodium hydride (0.264 g, 9 mmol) for 30 min at room temperature, and then adding dithiochloroformate **2** (1.3 mL, 9 mmol) dropwise. The mixture was stirred for a further 24 hours. Evaporation to dryness and recrystallization with ethanol/water afforded the corresponding dithiocarbamate **3a** (1.12 g, 40%). Spectral data for the new dithiocarbamate esters are presented in Table 2 and Table 3.

**Kinetic Method:** The hydrolysis kinetics of esters **3a–f** were studied at  $25.0 \pm 0.1^\circ\text{C}$  in dioxane/water 30% (v/v) (40% in the case of **3g**, **3h**, and again **3c**) and the ionic strength was kept constant at 0.5 M with KCl. The decrease in absorbance at 305 nm, corresponding to the decomposition of substrate, was monitored continuously. Reactions were in all cases carried out under pseudo-first order conditions, the substrate concentration being much lower than the concentrations (ca.  $1 \cdot 10^{-4}$  M) of other reagents. Hydroperoxide-catalysed hydrolysis was accomplished by in situ addition of the appropriate volume of hydrogen peroxide and sodium hydroxide to obtain the desired pH = 12. The absorbance/time data for all kinetic experiments were fitted by first-order integrated equations, and the values of the pseudo first-order rate constants ( $k_{\text{obs}}$ ) were reproducible to within 5%.

**Isolation and Identification of Reaction Products:** Hydrolysis of dithiocarbamate **3a** was accomplished in sodium hydroxide solution (0.5 M) on a semimicro scale. After the reaction had ended the resulting products were analysed by TLC on silica gel plates with several eluents. The compounds were identified by their corresponding  $R_f$  values, by comparison with the standards, the parent sulfonamide and the decomposition product thiophenol.

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