Comparison of the Effects of Sulphenyl, Sulphinyl, and Sulphonyl Substituents on Diene Reactivity and Regioselectivity in the Diels–Alder Reaction

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The Diels–Alder reactions of 2-phenylthiobuta-1,3-dienes with PhS, PhSO, and $PhSO_2$ groups in position 3 indicate that both reactivity and regioselectivity follow the order PhS > PhSO > $PhSO_2$.

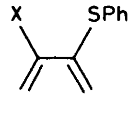
The use of hetero-substituted 1,3-dienes in Diels–Alder reactions for synthesis has been an area of great activity.[1] Hetero-substituents exert a significant influence on the reactivity and regioselectivity of cycloaddition. It is now well established that 2,5-dihydrothiophene *S*,*S*-dioxides are useful precursors of substituted buta-1,3-dienes.[2] We have recently used this approach to synthesize some sulphur-substituted dienes.[3] We have now studied the Diels–Alder reactions of sulphenyl-, sulphinyl-, and sulphonyl-substituted dienes (**1a**—**c**) in order to determine the directing ability of these groups.

The dienes (**1a**—**c**) were prepared by thermal extrusion of sulphur dioxide from the corresponding sulphones (**2a**—**c**). The syntheses of (**2a**) and (**2c**) have been reported;[4] (**2b**) was obtained by selective oxidation of (**2a**) with 1 equiv. of *m*-chloroperbenzoic acid. The dienes (**1b**) and (**1c**) are quite stable at room temperature, but (**1a**) readily decomposes. Thus, it is more convenient to use the sulphone precursor (**2a**) in the Diels–Alder reaction.

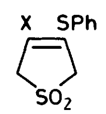
Upon heating (**2a**), (**1b**), or (**1c**) with *N*-phenylmaleimide (1.2 equiv.) in refluxing *p*-xylene for 6 h, the reaction of (**2a**) proceeded to completion but the dienes (**1b**) and (**1c**) were recovered in 17 and 48% yield, respectively. This indicates

Table 1. Diels–Alder reactions of the dienes (**1**) with dienophiles.

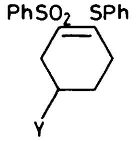
Entry	Reactant	Dienophile	Conditions	Product (Ratio)	Yield (%)
1	(**2a**)	*N*-Phenylmaleimide	135 °C, 2.5 h	(**3a**)	98
2	(**1b**)	*N*-Phenylmaleimide	160 °C, 2 h	(**3b**)	62
3	(**1c**)	*N*-Phenylmaleimide	200 °C, 3 h	(**3c**)	90
4	(**1b**)	$HC{\equiv}CCO_2Me$	170 °C, 6 h	(**4b**) + (**5b**) (60:40)	72
5	(**1c**)	$HC{\equiv}CCO_2Me$	200 °C, 6.5 h	(**4c**) + (**5c**) (70:30)	50
6	(**1c**)	$H_2C{=}CHCOMe$	190 °C, 7 h	(**6**) + (**7**) (75:25)	81
7	(**1c**)	$H_2C{=}CHCO_2Me$	200 °C, 8 h	(**8**) + (**9**) (75:25)	98
8	(**1c**)	$H_2C{=}CHCOMe$	$ZnCl_2$, room temp., 24 h	(**6**)	90
9	(**1c**)	$H_2C{=}CHCO_2Me$	$ZnCl_2$, room temp., 72 h	(**8**)	85

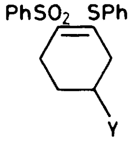


(**1**)



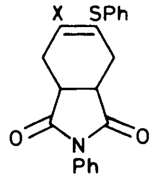
(**2**)



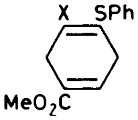


(**6**) Y = MeCO (**7**)

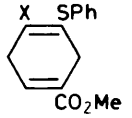
(**8**) Y = $MeCO_2$ (**9**)



(**3**)



(**4**)



(**5**)

a; X = PhS
b; X = PhSO
c; X = $PhSO_2$

that, towards an electron-deficient dienophile, the reactivity of the dienes (**1**) follows the order PhS > PhSO > $PhSO_2$, according to their electron-donating ability.

The results of the Diels–Alder reactions are summarized in Table 1.† When the reactions with *N*-phenylmaleimide were carried out to completion, good yields of product (**3**) were obtained (entries 1—3). The reaction of (**1b**) with methyl propiolate gave the cycloaddition products (**4b**) and (**5b**) in the ratio 60:40 (entry 4). Similar reaction of (**1c**) with methyl propiolate gave products (**4c**) and (**5c**) in the ratio 70:30 (entry 5).‡ These results indicate that the (*para*-) directing ability of the substituents in the dienes (**1**) also follows the order PhS > PhSO > $PhSO_2$. This is in contrast with the prediction made by Hehre[6] for 1-(acylamino)-1,3-dienes[7] bearing sulphenyl, sulphinyl, and sulphonyl substitution at C-4, that the (*ortho*-) directing ability should follow the order $PhSO_2$ > PhS > PhSO.[6] These differences are of theoretical interest.[7]

The reactions of (**1c**) with methyl vinyl ketone (entry 6) and methyl acrylate (entry 7) under thermal conditions gave the cycloadducts (**6**)—(**9**) in good yields. Again, the regioselectivity of the Diels–Alder reaction was influenced by the sulphenyl group more than sulfonyl group (3:1). It is interesting that the regioselectivity was considerably enhanced by using zinc chloride as catalyst to give only one regioisomer (entries 8 and 9).

In summary, the Diels–Alder reactions of the dienes (**1**) indicate that both reactivy and regioselectivity follow the order PhS > PhSO > $PhSO_2$. Lewis acid catalysis can greatly increase regioselectivity. These results should be useful for further synthetic applications.

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† All new compounds were characterized by i.r. and n.m.r. spectroscopy and gave satisfactory elemental analyses.

‡ Treatment of (**4c**) with KOH in $MeOH/CH_2Cl_2$ at room temperature for 4 h gave the known compound methyl *p*-(phenylthiobenzoate.[5]