Nitroacetylene Equivalents. Preparation and Cycloadditions of 2-Phenylsulphinyl-1-nitroalkenes[1]

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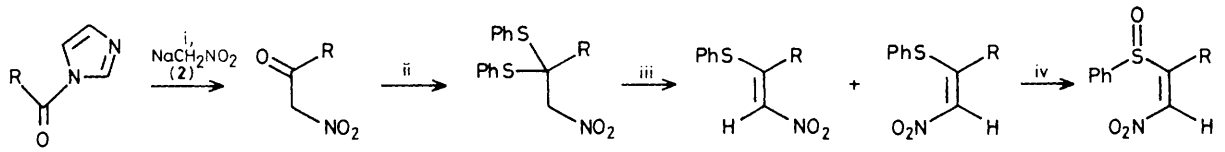
β-Phenylsulphinyl-nitro-alkenes (**7**) are readily prepared from acyl imidazoles and react as nitroacetylene equivalents in Diels–Alder reactions to give good yields of cycloadducts and their further products.

Nitroacetylenes, potentially useful electron-deficient compounds for cycloadditions and Michael additions, are too unstable towards polymerization to be generally useful.[2,3] The only nitroacetylene that has been isolated[2] bears the very bulky t-butyl group on the acetylene which presumably blocks facile polymerization. Viehe reported[2] that this compound undergoes fast cycloaddition with cyclopentadiene implying that the activating effect of the nitro group outweighs the steric hindrance of the t-butyl group. Since nitroacetylenes with simple alkyl groups on the acetylene β-carbon would be predicted to be so unstable towards polymerization as to preclude isolation, we decided to investigate the use of β-phenylsulphinyl-nitro-alkenes as isolable equivalents of nitroacetylenes. Herein we report their easy preparation and reactions with electron-rich dienes.[4]

Of the several possible synthetic routes to β-phenylsulphinyl-nitro-alkenes, we settled on the following as the most general and efficient. The acyl imidazole (**1**; R = Me, Et, or Ph) was treated with the preformed sodium salt of nitromethane (**2**) in tetrahydrofuran (THF) to give good yields (60—80%) of the α-nitroketones (**3**).† Formation of the dithioacetals (**4**) occurred in excellent crude yields (isolated

† These compounds have been prepared before from various activated acyl derivatives by reaction with nitrocarbanions: G. B. Bachman and T. Hokama, *J. Am. Chem. Soc.*, 1959, **81** 4882; D. C. Baker and S. R. Pott, *Synthesis*, 1978, 478; G. F. Field and W. J. Zally, *ibid.*, 1979, 295. **Caution:** After several successful destructions of the excess of the powdery sodium salt of nitromethane by pouring water on it, one such attempt resulted in a violent explosion and this procedure is therefore not recommended. All new compounds exhibited spectroscopic data (500 MHz ^{1}H and 125 MHz ^{13}C n.m.r.; i.r., high resolution mass, and/or elemental analysis) in full accord with their assigned structures.



(1a) R = Me	80%	(3a)	>95%	(4a)	60%	(5a)	1 : 9	(6a)	>95%	(7a) R = Me
(1b) R = Et	70%	(3b)	58%	(4b)	75%	(5b)	3 : 7	(6b)	>95%	(7b) R = Et
(1c) R = Ph	58%	(3c)	45%	(4c)	82%	(5c)	<5 : >95	(6c)	98%	(7c) R = Ph

Scheme 1. *Reagents and conditions:* i, THF, heat; ii, PhSH, $BF_3{\cdot}OEt_2$; iii, $Hg(O_2CCF_3)_2$, Li_2CO_3 (6 equiv.), MeCN, −23 or 25 °C; iv, MCPBA, CH_2Cl_2, 25 °C.

Table 1. Cycloaddition of β-phenylsulphinyl-nitro-alkenes (**7**) with dienes.

Dienophile	Diene	Product
(7a) (7c)	(8)	(9a) R = Me[a] (9c) R = Ph[a]
(7a) (7b)	(10)	(11a) R = Me, 73% (11b) R = Et, 52%
(7a) (7b)	(12)	(13a) R = Me, 32% (13b) R = Et, 30%
(7a) (7b)	(14)	(15a) R = Me, 32% (15b) R = Et, 32%

[a]Quantitative yield.

yields ~60%) by treatment of (**3**) with benzenethiol and boron trifluoride–diethyl ether. Elimination of one of the phenylthio groups β to the nitro group was attempted with mixed success under a variety of acidic and basic conditions (including adsorption on silica gel for several days). We found that the following two methods were generally useful for the clean preparation of (**5**) and (**6**). Oxidation of (**4a**) with 1 equiv. of *m*-chloroperbenzoic acid (MCPBA) in dichloromethane at 0 °C produced a 38 : 62 mixture of (**5a**) and (**6a**) in 60% yield. However a more consistently useful preparation involved treatment of the dithioacetal (**4**) with 1 equiv. of mercury(II) trifluoroacetate and 6 equiv. of lithium carbonate in acetonitrile at 25 °C (**4a**, **4c**) or −23 °C (**4b**)‡ to give in excellent yields a mixture of isomers in which the *Z*-isomer (**6**) predominated over the *E*-isomer (**5**). The isomers could be separated by fractional crystallization or careful column chromatography. Finally the *Z*-isomer (**6**) was oxidized to the desired phenylsulphinyl-alkene (**7**) by simple oxidation with MCPBA in dichloromethane at room temperature in essentially quantitative yield. The stereochemistry of the isomers was determined by a difference nuclear Overhauser enhancement (n.O.e.) experiment on (**7b**). Irradiation of the olefinic proton (with gated decoupling) caused an n.O.e. increase of 10% in the methyl group, thereby indicating their *cis*-arrangement. This is in agreement with similar n.O.e. determinations for analogous compounds.[5] Thus the β-phenylsulphinyl-nitro-alkenes (**7a—c**) are available from (**1a—c**) *via* a four-step synthesis in good overall yield.

The β-phenylsulphinyl-nitro-alkenes (**7**) are quite reactive in cycloaddition reactions. Typical cycloadditions with a variety of dienes are listed in Table 1. Thus both (**7a**) and (**7c**) react with cyclopentadiene (**8**) at room temperature in benzene to give quantitative disappearance of starting material and clean conversion into the expected *endo*-nitro adducts (**9a,c**). The stereochemistry of these adducts was determined by the coupling constant of the proton α to nitro with the adjacent bridgehead proton (*J* 3.5—3.9 Hz) and the lack of any W coupling to the bridge protons. A remarkable substituent effect has been observed in this system. Whereas the methyl derivative (**7a**) reacts completely with (**8**) (C_6H_6, 25 °C, 10 h) to give (**9a**), the corresponding ethyl derivative (**7b**) does not react at all with (**8**) under the same conditions or even after 2 days at 25 °C.§

One of the best uses of a nitroacetylene equivalent would be as the dienophilic component in a cycloaddition approach to substituted nitro-aromatic compounds which could themselves serve as precursors to substituted indoles. We have now demonstrated that the sulphinyl-nitro-alkenes (**7**) can be used in just such an approach. For example, reaction of Danishefsky's diene (**10**) with (**7a,b**) (C_6H_6, 25 °C, 1 day; 65 °C, 1 day; dil. HCl–THF) afforded the 3-alkyl-4-nitrophenols (**11a,b**) in unoptimized yields of 73 and 52%, respectively. In

‡ When this elimination of (**4b**) was carried out at 25 °C rather than −23 °C, the major product was the β,γ-unsaturated nitro compound, $NO_2CH_2C(SPh)=CHMe$, as a mixture of *E*- and Z- isomers, with (**5b**) and (**6b**) being minor products.

§ The reasons for this remarkable substituent effect will be discussed in detail elsewhere.

this case there is no major substituent effect on the reactivity as is the case with (**7a**,**b**) and (**8**). Other 1-alkoxy- or 1-acyloxy-butadienes have also been tested in this process. Reaction of 1-acetoxy-3-methylbutadiene (**12**)[6] with (**7a**,**b**) (C_6H_6, heat, 1 day; aq. base) furnished directly the nitro-*m*-xylene (**13a**) and the ethyl analogue (**13b**) in unoptimized yields of 32 and 30%, respectively. Finally, the methyl trimethylsilyl ketene acetal (**14**)[7] reacted with (**7a**,**b**) to give 3-alkyl-5-methyl-2-nitrophenol (**15a**,**b**) (alkyl = Me or Et) in fair yield. We are now investigating the use of analogues of (**7**) with more functionalized alkyl groups in a cycloaddition route to substituted indoles.

Thus we have developed a new general method for the preparation of β-phenylsulphinyl-nitro-alkenes and demonstrated their use in cycloadditions, epecially for the synthesis of nitro-aromatic compounds.

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