An Inverted Relationship between Stability and Rate of Formation of Meisenheimer-type Adducts from Dinitrothiophen and Trinitrobenzene Derivatives

By G. Doddi, G. Illuminati,* and F. Stegel

(*Department of Chemistry and Centro C. N. R. sui Meccanismi di Reazione, University of Rome,* 00185 *Roma, Italy*)

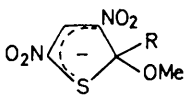
Summary A σ-adduct (II) is formed by the action of the methoxide ion on 2,4-dinitrothiophen; the equilibrium and rate constants for this process have been determined at 25° in methanol and the striking differences between the dinitrothiophen and the trinitrobenzene systems are discussed.

In continuation of our studies on the 2,4-dinitrothiophen system,[1] we have been interested in obtaining quantitative results about the formation of adducts resulting from the attack of the nucleophile on a H-bearing position of the five-membered ring heterocycle. N.m.r. evidence for the formation of such an adduct from 3-methoxy-2-nitrothiophen has been reported.[2]

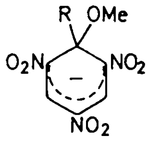
The reaction of 2-methoxy-3,5-dinitrothiophen (MDNTH) with methoxide ion leads to the formation of (I).[1] During the early stages of this reaction, very fast formation and disappearance of a small amount of a species other than (I) was observed, whose structure could not be determined. Therefore we investigated the reaction of 2,4-dinitrothiophen (DNTH), which is known[3] to give a deep-red colour in alcoholic potassium hydroxide.

DNTH reacts with methanolic sodium methoxide to give an adduct (λ_{max} 272 and 529 nm in MeOH). The n.m.r.

spectrum of the adduct in MeOH displays two doublets of the same intensity ($J \simeq 0{\cdot}5$ Hz.), at τ 1·96 (sp^2C–H) and 3·50 (sp^3C–H). The adduct was shown to be (II) by the n.m.r. spectrum of the addition product of methoxide ion to 5-deuterio-2,4-dinitrothiophen.



(I); R=OMe
(II); R=H



(III); R=OMe
(IV); R=H

The rate constants and the equilibrium constants for the formation of adducts (I) and (II) are reported in the Table, together with related data for the similarly substituted trinitrobenzene derivatives (III) and (IV).

In the 2,4-dinitrothiophen system the adduct possessing geminal methoxy-groups (I) is much more stable than the one resulting from the attack of the nucleophile on the 'unsubstituted' system (II). This is in agreement with previously noted effects[4] with the 1,3,5-trinitrobenzene system [adducts (III) and (IV)]. In fact there is a remarkable quantitative similarity of the influence of the methoxy-group on the stability of the adducts, the $K_{\mathrm{I}}/K_{\mathrm{II}}$ and $K_{\mathrm{III}}/K_{\mathrm{IV}}$ values being about 5×10^2, and 7×10^2, respectively. Although this close similarity may be partly fortuitous due to the structural differences between the substrates involved (see below), it suggests that the presence of geminal-alkoxy groups is also a major factor in the dinitrothiophen system.

The K data in the Table also confirm our previous observations[1] that the adducts deriving from the dinitrothiophen system are more stable than those coming from the similarly substituted trinitrobenzene system.

In the trinitrobenzene system the rate constant increases markedly on going from the methoxy-derivative (attack on the position occupied by the methoxy-group) to the parent substrate, while a slight decrease is found in the dinitrothiophen system. Furthermore, as the data in the Table show, the rate constants for the formation of the adducts do not correlate in any simple way with their stability. Clearly, in the observed cases the configurations of the transition states do not uniformly resemble those of the adducts, probably because the reactivities of the different substrates may involve significant relative shifts along the reaction co-ordinate.

There has been some speculation in the attempt to interpret the energetics of adduct formation in terms of structural effects. The origins of the higher energy requirement for the transition state leading to (III) [relatively to that leading to (IV)] have been attributed to the fact that 2,4,6-trinitroanisole, as compared to 1,3,5-trinitrobenzene, can be stabilized by significant direct conjugation of the methoxy-group with the nitro-groups (in spite of some steric inhibition of resonance), and that such a conjugation is lost when the methoxide ion attacks position 1. Since in MDNTH steric inhibition of resonance should be far less important because of the five-membered ring structure[5] and of the presence of only one nitro-group flanking the site of reaction, loss of conjugation upon the formation of the adduct would lead to a $k_{\mathrm{I}}/k_{\mathrm{II}}$ value even lower than $k_{\mathrm{III}}/k_{\mathrm{IV}}$, which is opposite to what is found.

TABLE. *Specific rates and equilibrium constants relative to the formation of Meisenheimer-type adducts, in methanol, at* 25°.

	(I)[a]	(II)[a]	(III)[b]	(IV)[c]
k(M^{-1} s^{-1})	$3{\cdot}6 \times 10$	$1{\cdot}5 \times 10$	$1{\cdot}73 \times 10$	$7{\cdot}05 \times 10^3$
K(M^{-1})	$\sim 4 \times 10^5$	8×10^2	$1{\cdot}7 \times 10^4$	$2{\cdot}31 \times 10$

[a] This work, except K_{I} value (ref. 1). Total salt concentration was kept at 0·2 M by addition of $NaClO_4$. [b] J. H. Fendler, E. J. Fendler, and C. E. Griffin, *J. Org. Chem.*, 1969, **34**, 689; [c] C. F. Bernasconi, *J. Amer. Chem. Soc.*, 1970, **92**, 4682.

(*Received*, 3*rd August* 1972; *Com.* 1363.)

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[4] C. F. Bernasconi, *J. Amer. Chem. Soc.*, 1971, **93**, 6975, and references therein.

[5] D. Spinelli, G. Guanti, and C. Dall'Erba, *J. Heterocyclic Chem.*, 1968, **5**, 323.