

Reaction of Sulphides with Acyl Nitrates; a Simple and Rapid Method for Preparing Sulphoxides

By ROBERT LOUW,* HANS P. W. VERMEEREN, JOOST J. A. VAN ASTEN, and WILLEM J. ULTÉE

(*Gorlaeus Laboratoria, The University of Leiden, P. O. Box 75, The Netherlands*)

Summary Sulphides react rapidly with acyl nitrates, even at -76°C , to give sulphoxides in high yield with no sulphone formation; either acetyl nitrate, formed from acetic anhydride and concentrated nitric acid, or, for milder conditions, benzoyl nitrate, formed from benzoyl chloride and silver nitrate, give satisfactory results.

A LARGE variety of reagents is available for the conversion of sulphides into sulphoxides,¹ hydrogen peroxide, *m*-chloroperoxybenzoic acid (*m*-CPBA), and sodium (meta) periodate being most frequently employed. None of these oxidants appears to be of general applicability, major drawbacks encountered being: slow (or zero) conversion, further

oxidation to sulphone, or formation of α -substituted sulphides rather than sulphoxides.

We have found that acyl nitrates $\text{RCO}_2\cdot\text{NO}_2$ (I) are excellent reagents for converting various types of sulphides into sulphoxides, very rapidly and with (near) quantitative yield. Excess of (I) did not lead to observable amounts of sulphones. The nitrates (I) are well known as nitrating agent;² oxidative properties have, to our knowledge, not been described earlier.

Generally, acetyl nitrate (I, R = Me), made from HNO_3 (98%)– Ac_2O^2 (1:2–3) at $\leq 0^{\circ}\text{C}$ was used *in situ* [method (A)]. The sulphide was added slowly with stirring at $\leq 0^{\circ}\text{C}$, after *ca.* 10 min NO_x was pumped off, and the

anhydride was then distilled off *in vacuo*. Sulphoxides carrying electron-attracting substituents may be too sensitive to the anhydride, giving Pummerer-type reactions during work-up. In these cases method (B) is advantageous: benzoyl chloride (1 equiv.) was added dropwise to 1:1 equiv. of dry, powdered AgNO₃ in CHCl₃ or CH₂Cl₂ at ca. -15 °C.³ The resulting solution of (I, R = Ph) can be used as such; a stock solution (after removal of AgCl by filtration) was stable for months at -15 °C, however. With reagent (B), oxidation of the sulphides was also complete within minutes at ≤ 0 °C (Table).

TABLE

Conversion of sulphides into sulphoxides by acyl nitrates

Sulphide	Product	Method ^a	Temp. (°C)	Yield (%)
Me ₂ S	Me ₂ SO	(A)	0	100 ^b
		(B)	-76	>95 ^b
Et ₂ S	Et ₂ SO	(A)	0	83 ^b
		(B)	-76	100
PhSMe	Ph·SO·Me ^c	(A)	0	85 ^b
		(B)	0	100
MeS·CH ₂ ·CO ₂ Et	Me·SO·CH ₂ ·CO ₂ Et	(B) ^d	0	>90
PhS[CH ₂] ₂ ·COPh	Ph·SO·[CH ₂] ₂ ·COPh	(A)	-20	>95 ^{b, e}
1,2-Dithiacyclohexane	1,2-Dithiacyclohexane 1-S-oxide	(A)	0	94 ^{b, f}
		(B)	-76	>90

^a (A) = Ac₂O-HNO₃; (B) = PhCO₂NO₂ from PhCOCl and AgNO₃ in CHCl₃ or CH₂Cl₂. ^b Isolated, pure materials; other data refer to yields determined by n.m.r. spectroscopy. ^c Nitrated product not formed. ^d Method (A) fails owing to decomposition during work up. ^e M.p. 77-78 °C, n.m.r. spectra in accord with structure. Oxidations with H₂O₂, *m*-CPBA, or NaIO₄ led to mixtures of sulphide, sulphoxide, and sulphone (requiring tedious work up by column chromatography) and gave modest yields. ^f M.p. and mixed m.p. with authentic samples: 85.2-85.5 °C.⁴

This method is extremely rapid. Thus, the reaction between PhSMe and PhCO₂NO₂ [method (B)] is complete within a few minutes at -76 °C (*k* ca. 4 × 10⁻² l mol⁻¹ s⁻¹).

Me₂S reacts faster by about an order of magnitude. Competitive runs at 0 °C in chloroform lead to the relative rates: PhSMe (1), Me₂S (9), MeOH (2), cyclohexene (1.2), and tetramethylethene (15). Hence, (I) may competitively add to C=C⁵ in unsaturated sulphides, or convert hydroxy-groups into esters. We have found that the nitrate (I) reacts vigorously³ with alcohols giving a quantitative yield of the corresponding ester.

Remarkably, 'oxidations' with (I) are also very much faster than those with peroxy compounds. Conversions with *t*-butyl peroxyesters⁶ or benzoyl peroxide⁷ are slow at 20-80 °C; peroxyacids, typically, take hours at 0 °C,⁸ and even peroxyacyl nitrates, RCO·OO·NO₂ (II), react some two orders of magnitude more slowly.⁹ The nitrate (I) also reacts much more rapidly than do solutions of N₂O₄ in, e.g., CCl₄.¹⁰ On this basis, and judging from relative rates we observed for PhSMe *vs.* Me₂S at 0 °C [*m*-CPBA, 0.78; (II; R = pentyl), 0.70; (I; R = Ph), 0.11; *cf.* N₂O₄ at 10 °C, 0.017^{10b}] N₂O₄ (or NO₂) can be excluded as an intermediate in our systems.

The nitrate (I) may be in equilibrium with some N₂O₅ and anhydride. In the nitration of benzene derivatives with (I), N₂O₅ was suggested to be the active species.¹¹ Judging from the high speed for sulphide conversion even at -76 °C, N₂O₅ is not a likely oxidant in this case, which is corroborated by our observation that, in contrast with nitration,¹¹ addition of (PhCO)₂O [2 equiv.; method (B)] does not lead to lower rates.

The mechanism may well involve nucleophilic attack by sulphur on an oxygen atom of (I). In contrast with oxidations by (II)⁹ or by aqueous HNO₃,¹² we did not observe any C.I.D.N.P. signals. Probably, the first step is a regular S_N2 displacement rather than an electron transfer reaction.¹²

(Received, 8th April 1976; Com. 380.)

¹ See, for instance Tse-Lok Ho and C. M. Wong, *Synthesis*, 1972, 561, and refs. cited therein.

² (a) J. G. Hogget and R. B. Moodie, 'Nitration and Aromatic Chemistry,' Cambridge University Press, 1971; (b) S. Sifriades, *J. Org. Chem.*, 1975, **40**, 3562.

³ F. E. Francis, *J. Chem. Soc.*, 1906, **89**, 1.

⁴ R. M. Carlson and P. M. Helquist, *J. Org. Chem.*, 1968, **33**, 2596.

⁵ F. G. Bordwell and E. W. Garbisch, Jr., *J. Amer. Chem. Soc.*, 1960, **82**, 3588; *J. Org. Chem.*, 1962, **27**, 2322; and 3049; 1963, **28**, 1765.

⁶ W. A. Pryor and W. H. Hendrickson, Jr., *J. Amer. Chem. Soc.*, 1975, **97**, 1581.

⁷ W. A. Pryor and H. T. Bickley, *J. Org. Chem.*, 1972, **37**, 2885.

⁸ S. N. Lewis in 'Oxidation,' Vol. I, ed. R. L. Augustine, Marcel Dekker, New York, 1969, p. 244.

⁹ H. P. W. Vermeeren and R. Louw, unpublished results.

¹⁰ D. Victor and R. D. Whitaker, *J. Inorg. Nuclear. Chem.*, 1973, **35**, 2393; H. G. Hauthal, H. Onderka, and W. Pritzkow, *J. für Prakt. Chem.*, 1969, **311**, 82; C. C. Addison and J. C. Sheldon, *J. Chem. Soc.*, 1956, 2705.

¹¹ V. Gold, E. D. Hughes, and C. K. Ingold, *J. Chem. Soc.*, 1950, 2467.

¹² W. A. Pryor and W. H. Hendrickson, Jr., *J. Amer. Chem. Soc.*, 1975, **97**, 1582.