Pergamon

Tetrahedron Letters, Vol. 35, No. 44, pp. 8275-8278, 1994
Elsevier Science Ltd
Printed in Great Britain
0040-4039/94 \$7.00+0.00

0040-4039(94)01775-1

ALKENYLSULFENYLCHLORIDES : SYNTHESIS AND Ad_E REACTIONS OF 2-ALKOXY-2-OXO-3-R-4-CHLOROTHIO-1,2-OXAPHOSPHOL-3-ENES

Igor V. Alabugin, Valery K. Brel*, Anatoly N. Chekhlov and Nikolai S. Zefirov*
Institute of Physiologically Active Compounds of Russian Academy of Science,
Chernogolovka, Moscow Region 142432, Russia

and **Peter J. Stang**
Department of Chemistry, University of Utah, Salt Lake City, Utah 84112, *USA*.

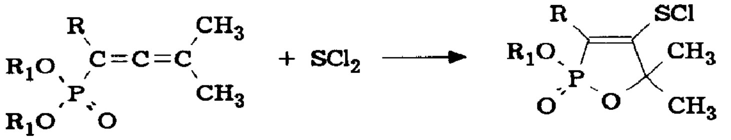
Abstract : Synthesis of titled representatives of alkenylsulfenylchlorides by the reaction of SCl_2 with allenes 1 and 2 is described and their Ad_E reactions with some model olefins are discussed.

The chemistry of unsaturated sulfenylchlorides is largely unexplored because there are a very limited number of synthetic approaches to these compounds[1]. The most common one is the Ad_E reaction of SCl_2 with acetylenes[1a,b]. The obvious alternative route to unsaturated sulfenylchlorides, namely Ad_E reaction of SCl_2 with allenes is still unexplored[2]. Secondly, there are many types of phosphorus containing sulfenylchlorides[3]. They are widely used for the introduction of a phoshorus containing moiety into a number of organic substrates to obtain compounds possessing a wide spectrum of biological activity. However, reports concerning unsaturated sulfenylchlorides having a phosphorus group are rather scarce[3b].

We wish to report here the first synthesis of phosphorus containing alkenylsulfenyl chlorides **3** and **4** based on the above mentioned approach, namely the Ad_E reaction of SCl_2 [4] with allenic phosphonates **1** and **2** [5] as well as some Ad_E reactions of these sulfenylchlorides. It should be emphasized, that the reactions of unsaturated sulfenylchlorides with olefins have received very limited exploration[1a].

The reaction of allenes **1** and **2** [6] with SCl_2 in aprotic nonpolar solvents proceeded smoothly[7] and afforded 5,5-dimethyl-2-alkoxy-2-oxo-4-chlorothio-1,2-oxaphosphol-3-enes, **3** and **4**, in excellent yields.

Compound **3** is quite stable and could be stored in a refrigerator for several weeks[8]. The sulfenylchloride **4** is less stable; nevertheless, it is possible to use freshly prepared **4** without isolation for further transformations.



1 R=H $R_1=CH_3$

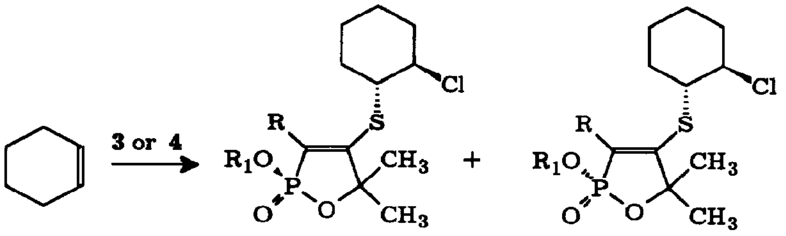
2 $R=CH_2OCH_3$ $R_1=C_2H_5$

3 R=H $R_1=CH_3$

4 $R=CH_2OCH_3$ $R_1=C_2H_5$

Both sulfenylchlorides **3** and **4** react with olefins[9] in accordance with an Ad_E reaction scheme [10]. The reaction of **3** and cyclohexene resulted in a mixture of two diastereomeric oxaphospholes **5a** and **5b** (2 : 1 ratio by NMR

^1H and ^{31}P) with a total yield of 95%. Crystallization from pentane gave colourless crystals (35%) which proved to be the major isomer **5a** with 10-15% admixture of minor one **5b**. Stereochemical assignments for **5a** and **5b** were made by double resonance ^1H NMR. The $J_{1,2}$ between HCS and HCCl were about 7Hz for the major isomer **5a** and 5.6 Hz for **5b**. These values indicate, first, the trans-addition and, secondly, an appreciable content of diaxial conformer in the conformational equilibria[11]. Final proof of the diastereomeric configuration was made by an X-ray study of **5a**, which unambiguously confirmed the trans-stereochemistry of the Ad_E process and established that relative configuration of **5a** is (2S, 1'R, 2'R) and, hence, the configuration of **5b** is (2R, 1'R, 2'R)[12].

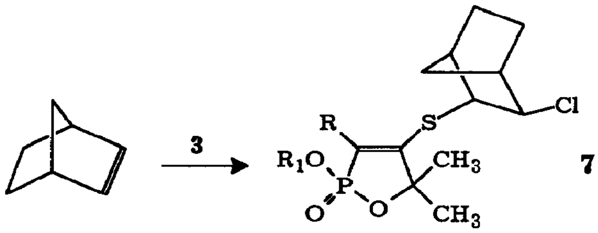


5a R=H; R_1=Me **5b** R=H; R_1=Me

6a R=CH_2OMe; R_1=Et **6b** R=CH_2OMe; R_1=Et

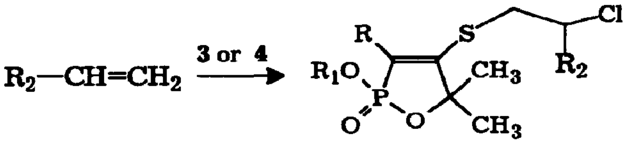
Sulfenylchloride **4** reacts analogously with cyclohexene to give the adducts **6a** and **6b** respectively, which demonstrate the generality of this Ad_E reaction.

The reaction of **3** with norbornene proceeded analogously (for an addition of sulfenylchlorides to this olefin see[13]) to give two diastereomeric products of trans-exo-1,2-addition (major isomer **7a** along with a minor isomer **7b**) in a ratio of 8 : 1.



7 R=H; R_1=Me

The reactions of **3** with styrene and 1-hexene proceeded to give Markovnikov products **8** and **9** exclusively. Sulfenylchloride **4** reacts analogously with styrene to give the adduct **10** (48%).



8 R=H; R_1=Me; R_2=Ph
9 R=H; R_1=Me; R_2=C_4H_9
10 R=CH_2OMe; R_1=Et; R_2=Ph

In conclusion, (i) the reaction of SCl_2 and 1,2-alkadienephosphonates represents a novel pathway to unsaturated sulfenylchlorides, (ii) their reactions with nucleophilic olefins demonstrates their ability to undergo an Ad_E-addition process.

Acknowledgment. This work was sponsored in part by the Russian Foundation for Fundamental Studies, grant 93-03-4566.

References and notes.

1. (a) Barton, T. J.; Zika, R. G. *J. Org. Chem.*, **1970**, *35*, 1729. (b) Ried, W.; Ochs, W. *Chem. Ber.*, **1974**, *107*, 1334. (c) Weil, E.; Smith, K.; Geering, E. *Ger. Pat.* 1,169,439, *C. A.*, **1964**, *61*, 4220. (d) Bekker, R. A.; Popkova, V. Ya. *Izv. Acad. Nauk SSSR., ser. Khim.*, **1984**, 660. (e) Jasis,V. J.; Kellog, M. S.; Volkmann, R. A. *Tetrahedron Lett.*, **1991**, *32*, 3771.
2. (a) At the same time several Ad_E-reactions of RSCl with allenes were described. (b) Jacobs, T. L.; Johnson, R. N. *J. Am. Chem. Soc.*, **1960**, *82*, 6397. (c) Mueller, W. H.; Butler, P. E. *J. Org. Chem.*, **1968**, *33*, 1533. (d) Yzawa, K. *J. Am. Chem. Soc.*, **1973**, *95*, 4090. (e) Angelov, Ch. M.; Vachkov, K. V.; Petrova, J.; Lebedev, V. B. *Zh. Obshch. Khim.*, **1982**, *52*, 538. (f) Khusainova, N. G.; Naumova, L. V.; Berdnikov, E. N.; Kutyrev, G. A.; Pudovik, A. N. *Phosp. and Sulfur*, **1982**, *13*, 2, 147.
3. (a) Recent review : Gololobov, Yu. G.; Gusar', N. I. *Sulfenylchlorides.* - Moscow: Nauka, **1989**, pp. 56-97. (b) There is an example of the sulfenylchloride containing simultaneously nitrogen-carbon double bond and phosphorus : Shicke, H. G.; Stoelzer, C. *Belg. Pat.* 657 241, *C. A.*, **1966**, *65*, 654.
4. For syntheses of alkylsulfenylchlorides *via* reactions of allyl- and vinylphosphonates with SCl_2, see: Ivin, S. Z.; Promonenkov, V. K. *Chemistry of Organic Compounds of Phoshorus.* - Leningrad: Nauka, **1967**, p. 139.
5. (a) 1,2-Alkadienephosphonates **1** and **2** were synthesized according to [5b] and [5c] respectively. (b) Ignat'ev, V. M.; Ionin, B. I.; Petrov, A. A. *Zh. Obshch. Khim.*, **1967**, *37*, 1898. (c) Brel, V. K.; Ionin, B. I.; Petrov, A. A. *Zh. Obshch. Khim.*, **1982**, *52*, 818.
6. (a) It was known that **2** containing methoxymethyl group which can act as an internal nucleophile reacts with different electrophiles through a different pathways giving either oxaphospholenes[6b] or phosphorylated dihydrofuranes[6c]. This was an additional reason to study how the reaction with SCl_2 would proceed . (b) Prudnikova, O. G.; Brel, V. K.; Ionin, B. I. *Zh. Obsh. Khim.*, **1986**, *56*, 764. (c) Zefirov, N. S.; Koz'min, A. S.; Kasumov, T.; Potekhin, K. A.; Sorokin, V. D.; Brel, V. K.; Abramkin, E. V.; Struchkov, Ya. T.; Zhdankin, V. V.; Stang, P. J. *J. Org. Chem.*, **1992**, *57*, 2433.
7. ***Typical procedure*** : to a stirred solution of 1.3-1.5 eq of SCl_2 in CCl_4 at 5-10° C a solution of **1** (**2**) was slowly added and the mixture was stirred at this temperature for a 15 minutes and at r.t. for a half an hour. Then the excess of SCl_2 and solvent were removed *in vacuo* affording **3** (**4**) as a viscous yellow liquid, which was directly used for further reactions. Spectral data: for **3**: ^1H NMR (200 MHz, $CDCl_3$,TMS, δ): 5.95 (1H , d, J_{HP} = 26 Hz, HC=C), 3.8 (3H, t, J_{HP} = 14Hz, OMe), 1.6 (6H, d, J_{HP} = 10Hz, Me); IR (CCl_4, ν, cm^{-1}) :1557 (C=C), 1272 (P=O); for **4**: NMR ^1H : 4.4 (2H, d, J_{HP} = 14Hz, CH_2OMe), 4.3-4.0 (2H, m, OCH_2Me), 3.5 (3H, s, OMe), 1.6 (6H, d, J_{HP} = 8Hz, Me), 1.4 (3H, t, J = 7Hz, $MeCH_2O$); NMR ^{31}P: 31.6.
8. It is known that the sulfenylchlorides containing electronegative groups are more stable. For two remarkable examples of the similar influence of perhalogeno- substituents on the stabilty of an unsaturated sulfenyl chlorides, see 1[c,d].
9. **Typical procedure for the reactions with olefins** : to a solution of 1 eq of **2a** in CH_2Cl_2 at 10-15° C a solution of 1.5 eq of an olefin was added dropwise. The reaction reached completion in 20 minutes at r.t. Solvent and the excess olefin were removed *in vacuo*. The residue was either crystallized (**5** from

pentane, **7** from benzene) or purified by silica-gel column chromatography (**6**, **8**, **9** and **10**; eluent - graduent of hexane/ethyl acetate from 3:1 to 1:1, Silpearl). All new compounds have satisfactory elemental analyses and molecular ion peaks. NMR ^{1}H and ^{31}P spectra were obtained in $CDCl_3$ at 200 and 81 MHz, chemical shifts (δ) are referenced to TMS and 85% H_3PO_4 (ext.) respectively.

5a : m.p.112-113° C, NMR ^{1}H 5.6 (1H, d, J_{HP} = 26Hz, HC=C), 4.1(1H, ddd,J_1=J_2=7Hz, J_3=3.8Hz, HCS), 2.5-2.2 and 1.9-1.6 (2H+6H, m, H of cyclohex. ring), 1.6 (6H, d, J_{HP} = 8Hz, Me); NMR ^{31}P: 35.14. IR : 1555 (C=C), 1264 (P=O). **5b** : NMR ^{1}H spectra of **5b** differs from **5a** only with HCCl (d = 4.2, ddd, J_1=J_2=5.6Hz, J_3=3.5Hz) and HCS (d = 3.85, ddd, J_1=J_2=5.6Hz, J_3=3.5Hz) ; NMR ^{31}P : 35.27.

6a,b : NMR ^{1}H : 4.3 (2H, d, J_{HP} = 14Hz, CH_2OMe), 4.3-4.0 (2H, m, OCH_2Me), 3.9 (1H, m, HCCl), 3.55 (1H, m, HCS), 3.5(3H, s, OMe), 2.4-2.1 and 1.9-1.6 (2H+6H, m, H of cyclohex. ring), 1.6 (6H, d, J_{HP} = 8Hz, Me), 1.4 (3H, t, J = 7Hz, $MeCH_2O$); NMR ^{31}P : 33.15 and 33.4. IR : 1596 (C=C), 1264 (P=O). **7a** : m.p. 167° C. NMR ^{1}H : 5.8 (1H, d, J_{HP} = 26Hz, HC=C), 4.1 (1H, td, $JH_{1'}H_{2'}$= 4.1Hz, $JH_{2'}H_{3'}$=4Hz, J=1.5Hz, HCCl), 3.7 (3H, d, J_{HP} = 12Hz, OMe), 3.0 (1H, dd, $JH_{2'}H_{3'}$= 4Hz, $JH_{3'}H_{7'anti}$=3Hz, HCS), 2.6 (1H, br.t, $JH_{1'}H_{2'}$= 4.1Hz, $JH_{1'}H_{6'exo}$=4Hz, H_1), 2.4 (1H, br.d., $JH_{4'}H_{5'exo}$=4Hz, H_4) and 2.1-1.5(6H, m, H of norborn. ring), 1.6 (6H, d, J_{HP} = 8Hz, Me); NMR ^{31}P: 36.1. IR : 1556 (C=C), 1265 (P=O). **7b** : All sygnals coincide with **7b** ones except for HCS (d=3.2). NMR ^{31}P: 36.8. **8** : NMR^{1}H : 7.5-7.2 (5H,m,Ph), 5.7 (1H, d, J_{HP} = 26Hz, HC=C), 5.1 (1H, t, J_{HH} = 7Hz, HCCl), 3.7 (3H, d, J_{HP} = 12Hz, OMe), 3.5 (1H, d, J_{HH} = 7Hz, H_2CS), 1.4 (6H, d, J_{HP} = 8Hz, Me); NMR ^{31}P : 35.4. IR : 1557 (C=C), 1272 (P=O). **9** : NMR ^{1}H : 5.8 (1H, d, J_{HP} = 26Hz, HC=C), 4.1,3.8 (1H, m, HCCl), 3.8 (3H, d, J_{HP} = 12Hz, OMe), 3.7 (1H, dd, J_1 = 12Hz, J_2 = 7Hz, HCS), 3.3 (1H, dd, J_1 = 12Hz, J_2 = 7Hz, HCS), 2.1-1.3 (4H, m, H of hex. skeleton), 1.6 (6H, d, J_{HP} = 8Hz, Me), 1.0 (3H, t, J = 7Hz, Me); NMR ^{31}P : 35.26. IR : 1556 (C=C), 1275 (P=O). **10** : 7.5-7.2 (5H,m,Ph), 5.7 (1H, d, J_{HP} = 26Hz, HC=C), 4.9 (1H, t, J_{HH} = 7Hz, HCCl), 4.2 (2H, d, CH_2OMe, J_{HP}=14Hz), 4.3-4.0 (2H, m, OCH_2Me), 3.6 (2H, d, J_{HH} = 7Hz, H_2CS), 1.45 (3H, s, Me), 1.4 (3H, s, Me); NMR ^{31}P : 35.4. IR : 1596 (C=C), 1265 (P=O).

10. Smith,W. A.; Zefirov, N. S.; Bodrikov, I. V.; Krimer, M. Z. *Acc. Chem. Res.*, **1979**, *12*, 282.
11. (a) Zefirov, N. S. *Zh. Org. Khim.*, **1970**, *6*, 761; (b) Tolstikov , G. A.; Novitskaya, N. N.; Kantyukova, R. G.; Spirikhin, L. V.; Zefirov, N. S.; Palyulin, V.A. *Tetrahedron*, **1978**, *34*, 2655.
12. The crystal sructure of **5a** is rombic: a=9.452(3), b=24.696(4), c=6.62(2) A, V=1555 (1) A^3 , Z= 4, space group $Pna2_1$. The final R=0.064 for 1050 observed reflections was measured on a CAD-4 diffractometer (CuK_α-radiation). The conformation of cyclohexene ring is chair with atoms of S and Cl occupying an equatorial positions. The other detailes of molecular and crystalline structure of **5a** will be publishe separately.
13. (a) Mueller, W. H.; Butler, P. E. *J. Amer. Chem. Soc.*, **1968**, *90*, 2075. (b) Zefirov, N. S.; Sadovaya, N. K.; Novgorodtseva, L. A.; Achmetov, R. Sh.; Baranov, S. V.; Bodrikov, I. V. *Tetrahedron* , **1979**, *35*, 2759.

(*Received in UK* 17 *June* 1994; *revised* 6 *September* 1994; *accepted* 9 *September* 1994)