HETEROCYCLES, Vol. 57, No. 10, 2002, pp. 1777 - 1780, Received, 24th June, 2002

BIFUNCTIONALIZED ALLENES. PART V. 3-SULFINYL-2,5-DIHYDRO-1,2λ^5-OXAPHOSPHOL-2-ONES AND 3-PHOSPHORYL-1, 2λ^4-OXATHIOL-2(5*H*)-ONES FROM 1-SULFINYL-SUBSTITUTED PHOSPHORYLATED ALLENES

Valerij Ch. Christov* and Boris Prodanov

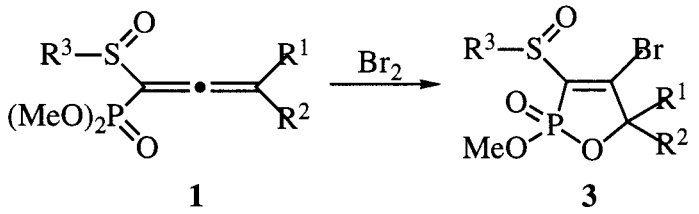
Department of Chemistry, University of Shoumen, BG-9700 Shoumen, Bulgaria
E-Mail: vchristo@shu-bg.net

Abstract - 3-Sulfinyl-2,5-dihydro-1,2λ^5-oxaphosphol-2-ones (**3**) and 3-phosphoryl-1,2λ^4-oxathiol-2(5*H*)-ones (**4**) were synthesized in good yields *via* electrophile-induced cyclization reactions of 1-sulfinyl-substituted phosphorylated allenes (**1**) and (**2**). Bromination of dimethyl 1-sulfinyl-1,2-alkadiene-1-phosphonates (**1**) led to formation of 4-bromo-3-sulfinyl-2,5-dihydro-1,2λ^5-oxaphosphol-2-ones (**3**), while the reaction with methyl 1-diphenylphosphoryl-1,2-alkadiene-1-sulfinates (**2**) afforded 4-bromo-3-diphenylphosphoryl-1,2λ^4-oxathiol-2(5*H*)-ones (**4**).

In the past three decades, synthesis and use of allene derivatives have been expanded in preparative organic chemistry.[1] Reactions of electrophilic addition to allenes[2] present the possibility of formation of different monoaddition products.[2f] An impressive number of heterocyclic systems has been prepared from allenic starting materials. The electrophile-induced cyclization of a variety of monofunctionalized allenes such as alcohols,[3] carboxylic acids and their esters,[4] sulfoxides,[5a] sulfinates,[5b] sulfones,[5b,5c,5d] phosphonates,[5b,6] phosphinates[5b,6] and phosphine oxides,[6] to heterocyclic systems has received considerable attention due to its synthetic utility and remarkable stereoselectivity.[3a,3f,4b,4f,5c,5d,6c] Allenesulfinates and allenyl sulfoxides underwent electrophilic attack on the central atom and ring closure correspondingly to 1,2λ^4-oxathiol-2(5*H*)-ones (γ-sultines)[5b] and 5*H*-1,2-oxathiol-2-ium salts[5a] when treated with electrophiles. On the other hand, the reactions of phosphorylated allenes with electrophilic reagents have been intensively investigated in the past 25 years. It has been shown[6] that depending on the structure of the starting allenic compound as well as the type of the electrophilic reagent, the reactions proceed with cyclization of the allenic system bearing phosphoryl group (O=P-C=C=C) to give heterocyclic compounds in most cases. In a continuation to our previous reports on the synthesis[7a,7b] and electrophile-induced cyclization reactions[7c,7d] of bifunctionalized allenes, we have investigated the bromine-induced heterocyclization of 1-sulfinyl-1,2-alkadienyl-phosphonates and phosphine oxides. It must be noted that conceptually there exist two distinct modes of cyclization of the 1-sulfinyl-substituted phosphorylated allenes if the bromine atom forms a new bond with the central carbon of the allenic system, which seems likely.[5,6] It is evident that these pathways are closely connected with the intramolecular participation of the sulfinyl and/or the phosphoryl groups as internal nucleophile(s) in the final step of the heterocyclization.

In order to establish the preferred pathway, we treated the dimethyl 1-alkyl(aryl)sulfinyl-1,2-alkadiene-1-phosphonates (**1**) with bromine in dichloromethane at -20 °C and found that the reaction took place with

electrophile-induced cyclization by neighboring participation of phosphonate group only as an internal nucleophile to give in good yields (64-73%) the 3-alkyl(aryl)sulfinyl-4-bromo-2-methoxy-2,5-dihydro-1,2λ^5-oxaphosphol-2-ones (**3**)[8] as shown in **Scheme 1**:

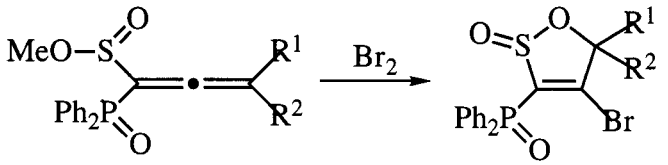


1 **3**

1, 3	R^1	R^2	R^3
a	Me	Me	Me
b	Me	Me	CCl_3
c	- $(CH_2)_5$ -		Me
d	- $(CH_2)_5$ -		Ph

Scheme 1

In contrast, the bromination reaction of the methyl 1-diphenylphosphoryl-1,2-alkadiene-1-sulfinates (**2**) in the same conditions afforded the 4-bromo-3-diphenylphosphoryl-1,2λ^4-oxathiol-2(5*H*)-ones (**4**)[9] in 68 and 73% yields, i. e. the electrophile-induced cyclization proceeded by neighboring participation of sulfinate group as an internal nucleophile, according to the following sequence outlined in **Scheme 2**:

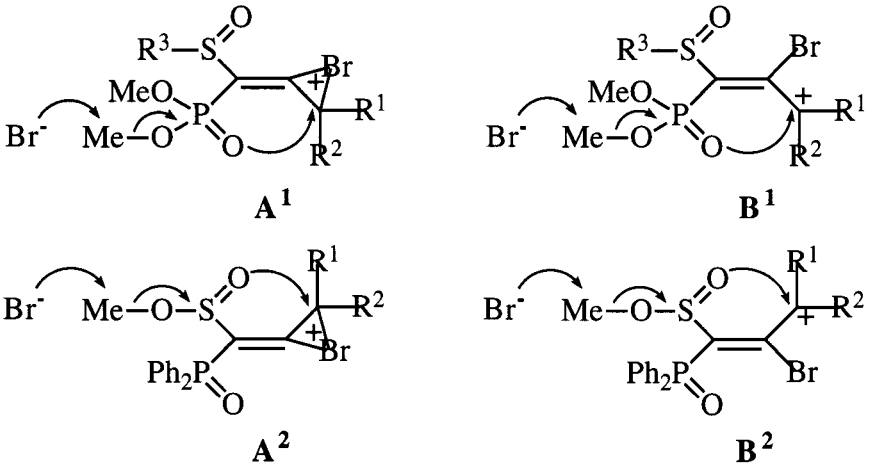


2 **4**

2, 4	R^1	R^2
a	Me	Me
b	- $(CH_2)_5$ -	

Scheme 2

The resulting heterocyclic compounds (**3**) and (**4**) were isolated by column chromatography as light yellow oils or white crystals and exhibited correct IR, ^{1}H and ^{13}C NMR spectral data[8,9] which are in good agreement with spectroscopic properties reported for similar structures.[5,6] The data from elemental analysis confirm the structure of compounds prepared. In addition to the above, we observe second-order kinetics, first-order in electrophile and first-order in substrate, which establishes the composition of the rate determining transition state as containing one equivalent of each reactant as has been reported by Garratt and coworkers[3f] in the cyclization reaction of allenic alcohols with PhSeCl. These data are indicative of a reaction hypersurface containing the cyclic bromonium ions (**A^1**) or (**A^2**) or the open carbenium ions (**B^1**) or (**B^2**), formed either competitively with onium ions formation or by the partial opening of the initially formed onium ions intermediates,[10] which collapse to the products (**3**) and (**4**) after attack of internal nucleophile (phosphonate or sulfinate groups). These are presumed to arise from attack on the allenic C^2-C^3 double bond *anti* to the functional group which assisted in the heterocyclization by neighboring group participation as an internal nucleophile. On the other hand, a possible explanation of the occurred two types cyclization consists in the following. These reaction pathways are probably favorable from energetic point of view. If the sulfoxide group (Scheme 1) and phosphine oxide group (Scheme 2) take place as internal nucleophiles in the cyclization, the prepared cyclic compounds should be sulfonium[5a] and phosphonium salts,[11] since in these cases the stabilization by the elimination of an alkyl bromide and formation of stable products with sulfinyl and phosphoryl groups is impossible. The above mentioned explanation should be corroborated or refuted from the results on study of the bromination reactions of other functionalized



phosphorylated allenes and specially their stereochemistry. Further work in this area is being focused on exploiting and extending the synthetic utility of the bifunctionalized allenes for the preparation of different heterocyclic systems using the electrophile-induced cyclization methodology.

In summary, our results indicate that the 1-sulfinyl-substututed phosphorylated allenes (**1**) and (**2**) are efficient synthons for the synthesis of the 3-sulfinyl-2,5-dihydro-1,2λ^5-oxaphosphol-2-ones (**3**) and the 3-phosphoryl-1,2λ^4-oxathiol-2(5*H*)-ones (**4**) *via* electrophile-induced intramolecular ring closure. Whereas the intramolecular cyclizations are also possible for other monofunctionalized allenes,[3-6] the nature of the electrophile-induced cyclization opens new synthetic routes for several classes of heterocyclic compounds from the bifunctionalized allenes[7a,7b] as precursors. Studies in this area are currently in progress and the results of them will be reported in the near future.

ACKNOWLEDGEMENT

We are grateful for financial support of this work by a Grant-in-Aid for Scientific Research (Project No. 11/2001 and No. 016/2002) from the Research Fund of the University of Shoumen. Special thanks to Miss Radost Nikolova for the technical help in the chromatographical separations.

REFERENCES AND NOTES

1. For reviews on the allenes, see: (a) 'The Chemistry of Ketenes, Allenes and Related Compounds,' ed. by S. Patai, John Wiley & Sons, New York, 1980; (b) 'The Chemistry of the Allenes,' ed. by S. R. Landor, Academic Press, London, 1982; (c) D. J. Pasto, *Tetrahedron*, 1984, **40**, 2805; (d) H. F. Schuster and G. M. Coppola, 'Allenes in Organic Synthesis,' John Wiley & Sons, New York, 1988; (e) R. Zimmer, *Synthesis*, 1993, 165.
2. For reviews on the electrophilic addition to allenes, see: (a) M. C. Caserio in 'Selective Organic Transformations,' ed. by B. S. Thyagarajan, John Wiley & Sons, New York, 1970, p. 239; (b) G. H. Schmid and D. G. Garratt in 'The Chemistry of Double Bonded Functional Groups,' ed. by S. Patai, Wiley-Interscience, New York, 1977, p. 725; (c) P. B. D. de la Mare and R. Bolton, 'Electrophilic Addition to Unsaturated Systems,' Elsevior, Amsterdam, 1982, pp. 317; (d) T. L. Jacobs in 'The Chemistry of the Allenes,' ed. by S. R. Landor, Academic press, New York, 1982, Vol. 2, p. 417; (e) W. Smadja, *Chem. Rev.*, 1983, **83**, 263.
3. For electrophile-induced heterocyclizations of monofunctionalized allenes, see: (a) T. L. Jacobs, R. Macomber, and D. Zucker, *J. Am. Chem. Soc.*, 1967, **89**, 7001; (b) F. Toda, T. Komoda, and K. Akagi, *Bull. Chem. Soc. Jpn.*, 1968, **41**, 1493; (c) S. Hoft and L. Brandsma, *Rec. Trav. Chim. Pays-Bas*, 1969, **88**, 845; (d) R. Gelin, S. Gelin, and M. Albrand, *Bull. Soc. Chim. Fr.*, 1972, 720; (e) L. I. Olsson and A. Claesson, *Synthesis*, 1979, 743; (f) P. L. Beaulieu, V. M. Morisset, and D. G. Garratt, *Tetrahedron Lett.*, 1980, **21**, 129.
4. For electrophile-induced heterocyclizations of allenecarboxylic acids and esters, see: (a) E. P. Kohler and W. J. Whicher, *J. Am. Chem. Soc.*, 1940, **62**, 1489; (b) G. Aksnes and P. Froeyen, *Acta Chim. Scand.*, 1968, **22**, 2347; (c) K. Shingu, S. Hagishita, and M. Nakagawa, *Tetrahedron Lett.*,

1967, 4371; (d) G. Kresze, W. Runge, and E. Ruch, *Liebigs Ann. Chem.*, 1972, 112; (e) S. Musierowicz, A. E. Wroblewski, and H. Krawczyk, *Tetrahedron Lett.*, 1975, 1437; (f) G. Kresze, W. L. Kloimstein, and W. Runge, *Liebigs Ann. Chem.*, 1976, 979; (g) S. Musierowicz and A. E. Wroblewski, *Tetrahedron*, 1978, **34**, 461; (h) G. B. Gill and M. S. H. Idris, *Tetrahedron Lett.*, 1985, **26**, 4811; (i) J. A. Marshal and E. M. Wallace, *J. Org. Chem.*, 1995, **60**, 796.

5. For electrophile-induced heterocyclizations of sulfur containing allenes, see: (a) L. Horner and V. Binder, *Liebigs Ann. Chem.*, 1972, 33; (b) S. Braverman and D. Reisman, *Tetrahedron Lett.*, 1977, 1753; (c) S. Braverman and D. Reisman, *J. Am. Chem. Soc.*, 1977, **99**, 605; (d) S. Braverman and Y. Duar, *J. Am. Chem. Soc.*, 1983, **105**, 1061.
6. For reviews on the electrophile-induced heterocyclizations of phosphorylated allenes, see: (a) Ch. M. Angelov, *Phosphorus and Sulfur*, 1983, **15**, 177; (b) N. G. Khusainova and A. N. Pudovik, *Usp. Khim.*, 1987, **56**, 975; (c) I. V. Alabugin and V. K. Brel, *Russ. Chem. Rev.*, 1997, **66**, 205.
7. Previous reports on bifunctionalized allenes, see: (a) Part. I. V. Ch. Christov and B. Prodanov, *Phosphorus, Sulfur, Silicon*, 2000, **166**, 265; (b) Part. II. V. Ch. Christov, B. Prodanov and R. Nikolova, *Phosphorus, Sulfur, Silicon*, 2000, **166**, 275; (c) Part. III. V. Ch. Christov and B. Prodanov, *Phosphorus, Sulfur, Silicon*, 2002, **177**, 243; (d) Part. IV. V. Ch. Christov and B. Prodanov, *Heterocyclic Commun.*, 2002, in press.
8. (a) *4-Bromo-2-methoxy-5,5-dimethyl-3-methylsulfinyl-2,5-dihydro-1,2λ^5-oxaphosphol-2-one* (**3a**): yield: 67 %, oil, *Anal.* Calcd for $C_7H_{12}O_4BrPS$: Br 26.36, P 10.218, S 10.578. Found: Br 26.53, P 9.98, S 10.63. IR: 987, 1062, 1263, 1586. ^{1}H NMR: 1.61 and 1.7 (ss, 6H, 2Me), 3.03 (s, 3H, Me-S), 3.79 (d, *J* 11.2, 3H, MeO). ^{13}C NMR: 26.9 *J* 8.3, 28.8 *J* 8.3, 41.67 *J* 8.6, 51.45 *J* 14.2, 79.16 *J* 14.9, 130.14 *J* 102.5, 152.75 *J* 33.1; (b) *4-Bromo-2-methoxy-5,5-dimethyl-3-trichloromethyl-sulfinyl-2,5-dihydro-1,2λ^5-oxaphosphol-2-one* (**3b**): yield: 64 %, oil, *Anal.* Calcd for $C_7H_9O_4BrCl_3PS$: Br 19.659, P 7.62, S 7.888. Found: Br 19.75, P 7.58, S 7.79. IR: 981, 1070, 1266, 1582. ^{1}H NMR: 1.61 and 1.69 (ss, 6H, 2Me), 3.81 (d, *J* 11.4, 3H, MeO). ^{13}C NMR: 27.3 *J* 8.1, 29.1 *J* 8.1, 50.85 *J* 14.6, 86.27 *J* 14.9, 115.74 *J* 8.4, 132.87 *J* 98.75, 153.43 *J* 33.3; (c) *4-Bromo-2-methoxy-3-methylsulfinyl-1-oxa-2λ^5-phosphaspiro[4,5]dec-3-en-2-one* (**3c**): yield: 68 %, oil, *Anal.* Calcd for $C_{10}H_{16}O_4BrPS$: Br 23.285, P 9.025, S 9.34. Found: Br 23.41, P 8.89, S 9.38. IR: 991, 1064, 1269, 1587. ^{1}H NMR: 1.39-1.57 and 2.21-2.43 (mm, 10H), 3.01 (s, 3H, Me-S), 3.81 (d, *J* 11.3, 3H). ^{13}C NMR: 19.82 *J* 4.9, 23.15, 33.64 *J* 8.1, 41.71 *J* 8.3, 52.4 *J* 14.3, 77.59 *J* 14.6, 132.36 *J* 104.87, 153.12 *J* 33.5; (d) *4-Bromo-2-methoxy-3-phenylsulfinyl-1-oxa-2λ^5-phosphaspiro[4,5]dec-3-en-2-one* (**3d**): yield: 70 %, mp 92-93 °C, *Anal.* Calcd for $C_{15}H_{18}O_4BrPS$: Br 19.719, P 7.64, S 7.91. Found: Br 19.85, P 7.80, S 7.82. IR: 1000, 1068, 1272, 1590. ^{1}H NMR: 1.4-1.6 and 2.37-2.42 (mm, 10H), 3.84 (d, *J* 11.6, 3H) 7.61-8.26 (m, 5H, Ph). ^{13}C NMR: 21.15 *J* 4.9, 22.48, 35.17 *J* 7.8, 51.3 *J* 14.6, 80.55 *J* 14.5, 125.43 *J* 5.0, 129.78, 134.22, 134.8 *J* 101.18, 150.05 *J* 8.3, 155.18 *J* 34.0.
9. *(a) 4-Bromo-3-diphenylphosphoryl-5,5-dimethyl-1,2λ^4-oxathiol-2(5H)-one* (**4a**): yield: 68 %, mp 102-103 °C, *Anal.* Calcd for $C_{17}H_{16}O_3BrPS$: Br 19.43, P 7.53, S 7.796. Found: Br 19.49, P 7.49, S 7.68. IR: 1127, 1194, 1602. ^{1}H NMR: 1.73 and 1.81 (ss, 6H, 2Me), 7.58-8.19 (m, 10H, 2Ph). ^{13}C NMR: 27.12 *J* 4.9, 28.87 *J* 4.9, 89.05 *J* 7.8, 129.65 *J* 134.12, 129.15-134.85, 154.42 *J* 41.74; (b) *4-Bromo-3-diphenylphosphoryl-1-oxa-2λ^4-thiaspiro[4,5]dec-3-en-2-one* (**4b**): yield: 73 %, mp 89-90 °C, *Anal.* Calcd for $C_{20}H_{20}O_3BrPS$: Br 17.706, P 6.86, S 7.10. Found: Br 17.83, P 6.97, S 7.07. IR: 1130, 1192, 1598. ^{1}H NMR: 1.29-1.91 and 2.60-2.67 (mm, 10H), 7.53-8.15 (m, 10H). ^{13}C NMR: 23.18, 25.9, 30.35 *J* 5.0, 87.11 *J* 8.0, 130.42 *J* 132.8, 130.43-133.15, 153.24 *J* 42.05.
10. (a) D. J. Pasto and K. D. Sugi, *J. Org. Chem.*, 1991, **56**, 4157; (b) C. Chiappe, A. De Rubertis, H. Detert, D, Lenoir, C. S. Wannere, and P. von R. Schleyer, *Chem. Eur. J.*, 2002, **8**, 967.
11. For synthesis of cyclic phosphonium salts by electrophile-induced heterocyclizations of allenyl phosphine oxides, see: (a) Ch. M. Angelov, Ch. Zh. Christov, and B. I. Ionin, *Zh. Obshch. Khim.*, 1982, **52**, 264 (*Chem. Abstr.*, 1982, **96**, 181360t); (b) N. G. Khusainova, L. V. Naumova, E. A. Berdnikov, and A. N. Pudovik, *Zh. Obshch. Khim.*, 1982, **52**, 1040 (*Chem. Abstr.*, 1982, **97**, 1110109c); (c) Ch. M. Angelov and D. D. Enchev, *Phosphorus and Sulfur*, 1988, **37**, 125; (d) D. D. Enchev, Ch. M. Angelov, E. Krawchik, A. Skowronska, and J. Michalski, *Phosphorus, Sulfur, Silicon*, 1991, **57**, 249.