

The Reaction of Phenyliodonium *Bis*(phenylsulfonyl)methylide with Alkyl Iodides

Efstathios P. Gogonas, Ioannis Nyxas,¹ Lazaros P. Hadjiarapoglou*

Section of Organic Chemistry and Biochemistry, Department of Chemistry, University of Ioannina, 45110 Ioannina, Greece
Fax +30(265)1098799; E-mail: lxatziar@cc.uoi.gr

Received 25 July 2004

Abstract: The reactions of a β -disulfonyl iodonium ylide with alkyl iodides provided functionalized iodides via the intermediacy of unstable alkylidonium ylides.

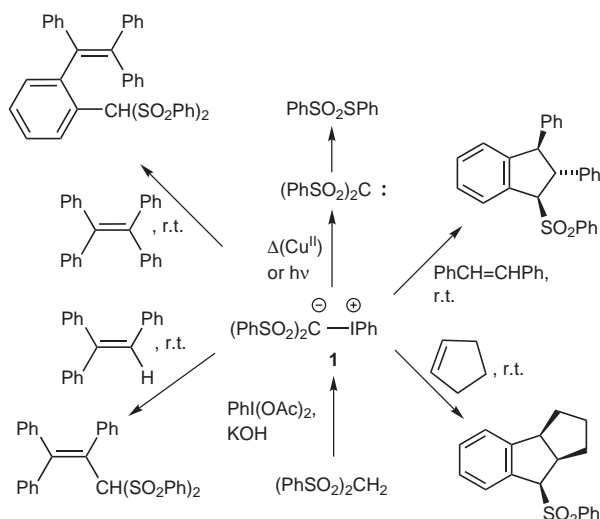
Key words: ylide, iodide, C-I insertion, alkylidonium ylide

The chemical behavior of an iodonium ylide² resembles the related diazo compound.³ This reactivity could be explained by the assumption of a carbene (or carbenoid) operational mechanism,⁴ although this has been questioned quite often.⁵ Phenyliodonium *bis*(phenylsulfonyl)methylide (**1**)⁶ is more reactive than the analogous *bis*(phenylsulfonyl)diazomethane,⁷ which displays thermal and photochemical persistence. Under Cu(II)-catalyzed thermal or photochemical activation, the ylide **1** decomposes⁶ into *bis*(phenylsulfonyl)methylene, evidenced by the isolation^{6,8} of phenyl benzenethiosulfonate. The intermediate carbene (or carbenoid) had been trapped with heteroatom nucleophiles,⁹ thiobenzophenones¹⁰ as well as alkenes.⁶

However, a completely different reaction mode was observed at room temperature, with or without catalytic amounts of Rh₂(OAc)₄. Iodonium ylide **1** affords with acyclic 1,2-disubstituted alkenes (*cis* or *trans*), the *trans,trans*-1,2,3-trisubstituted indanes¹¹ (Scheme 1), whereas, with cyclic alkenes the *cis,cis*-1,2,3-trisubstituted indanes were isolated instead.¹² But this cycloaddition depends heavily on the substitution pattern of the alkene. Introduction of another substituent into the alkene, such as in triphenylethylene and tetraphenylethylene, results in an alkenyl or aryl C-H insertion reaction.¹³ This perplexing reactivity was explained by postulating an initial electrophilic addition of the ylide onto the olefinic double bond and subsequent formation of either the [3+2] cycloadduct or the insertion product.

As a new contribution to this chemistry, we wish to address in this paper the reaction of iodonium ylide **1** with alkyl iodides, a unique reaction among iodonium ylides, which are normally unreactive towards alkyl halides.

Phenyliodonium *bis*(phenylsulfonyl)methylide (**1**) was prepared from the corresponding β -disulfone by treatment with (diacetoxy)iodobenzene and KOH at $-10\text{ }^{\circ}\text{C}$



Scheme 1

(Scheme 1). This ylide is practically insoluble in common organic solvents (except DMSO), thus, the reaction of ylide **1** with alkyl iodides **2** was conducted under heterogeneous conditions.

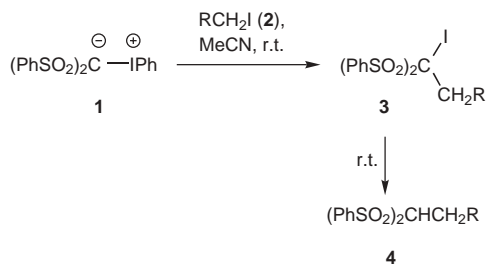
The reaction of iodonium ylide **1** with iodides **2** in acetonitrile at room temperature with exclusion of light afforded the 1,1-*bis*(phenylsulfonyl)-1-iodo-1-alkyl-methanes¹⁴ **3** and the 1,1-*bis*(phenylsulfonyl)-1-alkylmethanes **4**; the latter derives from the decomposition of iodides **3** (Scheme 2). This reaction proceeds well when a primary alkyl iodide was employed (Table 1). In contrast, when 2-iodobutane was employed, only the ylide decomposition product, namely the β -disulfone, was isolated quantitatively.

Table 1 Reaction of Iodonium Ylide **1** with Alkyl Iodides **2**

Entry	Iodide	Substituent R	Product	Yield (%) ^b
1	2a	H	3a	56
2	2b	CH ₃	3b	46
3	2c	CH ₃ CH ₂ CH ₂	3c	24

^a All reactions were carried out by stirring, with exclusion of light, a suspension of iodonium ylide **1** (2.0 mmol) and alkyl iodide (2 mL) in MeCN (10 mL) for 24 h.

^b Yield of isolated product after silica gel chromatography.



Scheme 2

The preferred mechanism to account for this unusual reaction involved the intermediacy of the unstable¹⁵ alkyl-iodonium ylide **5** (Figure 1), which could undergo an intramolecular Stevens rearrangement forming iodides **3**. But the exact initial steps for the generation of **5** are not known. The reaction may be initiated by a SET mechanism. However, an ionic mechanism, involving attack of methyl iodide to the hypervalent iodine of **1**, is also possible. An alternative mechanism involving the alkyl iodide capture¹⁶ of a carbene generated from **1** is not feasible. If this were so, then phenyl benzenethiosulfonate and CO_2 , the typical by-products of the generation of *bis*(phenylsulfonyl)methylene,^{6,8} should have been detected.

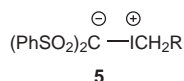
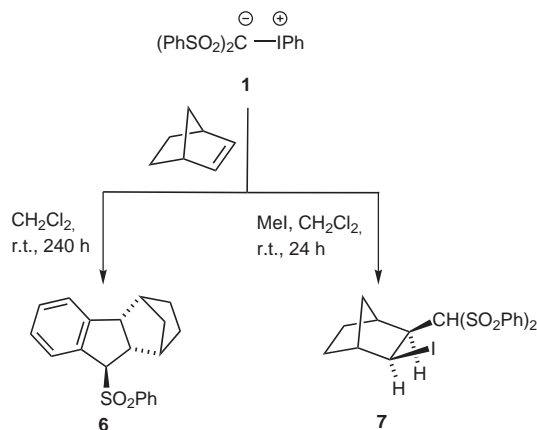


Figure 1

Despite the exact mechanistic details, we thought that the generation of an alkyl-iodonium ylide could be synthetically useful. The room temperature reaction of iodonium ylide **1** with 1,2-disubstituted alkenes, with or without catalytic amounts of $\text{Rh}_2(\text{OAc})_4$, results^{11,12} in the formation of cyclopentane derivatives. Furthermore, norbornene had been used as model¹⁷ to study this cycloaddition under various conditions. To our surprise, when a suspension of ylide **1**, norbornene, and methyl iodide in CH_2Cl_2 was stirred at room temperature for 24 hours, *exo*-iodide **7** and ethane derivative **4a** were isolated in 46% and 34% yield, respectively (Scheme 3); the expected cycloadduct **6** was not even detected in the crude reaction mixture.

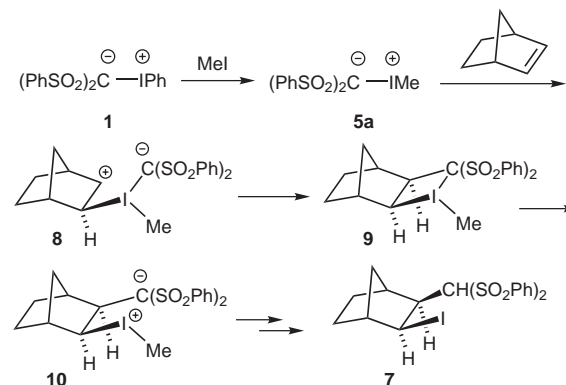
The structure of **7** was established by ^1H NMR and ^{13}C NMR spectral analyses. The $J = 7.1$ Hz coupling constant between H-2 ($\delta = 4.62$ ppm) and H-3 ($\delta = 2.34$ ppm) shows the *cis*-configuration of the substituents. The *exo*-conformation of the C-2, C-3 substituents results from the absence (COSY) of a coupling between H-2 and H-3 with the adjacent bridgehead protons.¹⁸

In accord with our previous proposal^{11–13} and the current results, we offer the mechanism in Scheme 4 to rationalize the formation of the adduct **7**. The reaction is presumably initiated by the fast reaction of iodonium ylide **1** with



Scheme 3

methyl iodide to afford the unstable alkyl-iodonium ylide **5a**. The iodonium functionality of the ylide **5a** attacks the norbornene electrophilically to generate the dipolar species **8**. The *exo*-configuration of **8** is expected and well-documented for cycloadditions with norbornene.^{17,19} Ring closure leads to the four-membered cyclic trivalent iodine compound **9**. The formation of four-membered compound **9** could explain the observed *cis*-configuration of the 2,3-bulky substituents in **7**. The subsequent ring-opening could yield the dipolar intermediate **10** which eventually yields adduct **7**.



Scheme 4

In summary, the work described herein offers a convenient and efficient method for the direct synthesis of functionalized iodides through the unusual reaction of β -disulfonyl iodonium ylides with alkyl iodides via the intermediacy of alkyl-iodonium ylides. Alkyl-iodonium ylides may prove to be of unusual synthetic utility; accordingly this area is being further investigated.

Acknowledgment

We thank Prof. Dr. W. Adam (University of Würzburg) for his generous support. E.P.G. thanks the Greek Ministry of Education for an Hraklitos fellowship.

References

- (1) Undergraduate Research Participant, Spring 2004.
- (2) Koser, G. F. *The Chemistry of Functional Groups, Supplement D*; Wiley: New York, **1983**, Chap. 18.
- (3) (a) Doyle, M. P. *Chem. Rev.* **1986**, 86, 919. (b) Padwa, A.; Hornbuckle, S. F. *Chem. Rev.* **1991**, 91, 263. (c) Padwa, A.; Krumpke, K. E. *Tetrahedron* **1992**, 48, 5385. (d) Adams, J.; Spero, D. *Tetrahedron* **1991**, 47, 1765. (e) Ye, T.; Mc Kervy, A. *Chem. Rev.* **1994**, 94, 1091. (f) Padwa, A.; Weingarten, M. D. *Chem. Rev.* **1996**, 96, 223.
- (4) (a) Müller, P.; Fernandez, D. *Helv. Chim. Acta* **1995**, 78, 947. (b) Müller, P.; Baud, C.; Naegeli, I. *J. Phys. Org. Chem.* **1998**, 11, 597. (c) Müller, P.; Bolea, C. *Synlett* **2000**, 826. (d) Camacho, M. B.; Clark, A. E.; Liebrecht, T. A.; DeLuka, J. P. *J. Am. Chem. Soc.* **2000**, 112, 5210. (e) Müller, P.; Bolea, C. *Molecules* **2001**, 6, 258. (f) Müller, P.; Bolea, C. *Helv. Chim. Acta* **2001**, 84, 1093. (g) Georgakopoulou, G.; Kalogiros, C.; Hadjirapoglou, L. P. *Synlett* **2001**, 1843. (h) Müller, P.; Bolea, C. *Helv. Chim. Acta* **2002**, 85, 483. (i) Batsila, C.; Kostakis, G.; Hadjirapoglou, L. P. *Tetrahedron Lett.* **2002**, 43, 5997.
- (5) (a) Moriarty, R. M.; Prakash, O.; Vaid, R. K.; Zhao, L. *J. Am. Chem. Soc.* **1989**, 111, 6443. (b) Moriarty, R. M.; Kim, J.; Guo, L. *Tetrahedron Lett.* **1993**, 34, 4129. (c) Spyroudis, S.; Tarantili, P. *J. Org. Chem.* **1993**, 58, 4885. (d) Moriarty, R. M.; May, E. J.; Prakash, O. *Tetrahedron Lett.* **1997**, 38, 4333. (e) Moriarty, R. M.; May, E. J.; Guo, L.; Prakash, O. *Tetrahedron Lett.* **1998**, 39, 765. (f) Alexiou, I.; Gogonas, E. P.; Hadjirapoglou, L. P. *Synlett* **1999**, 1925. (g) Gogonas, E. P.; Hadjirapoglou, L. P. *Tetrahedron Lett.* **2000**, 41, 9299.
- (6) (a) Hadjirapoglou, L.; Spyroudis, S.; Varvoglis, A. *J. Am. Chem. Soc.* **1985**, 107, 7178. (b) Hadjirapoglou, L. P. *Ph.D. Dissertation*; Aristotelian University of Thessaloniki: Greece, **1987**. (c) Hadjirapoglou, L.; Varvoglis, A.; Alcock, N. W.; Pike, G. A. *J. Chem. Soc., Perkin Trans. 1* **1988**, 2839.
- (7) (a) Dieckmann, J. *J. Org. Chem.* **1965**, 30, 2272. (b) Klages, F.; Bott, K. *Chem. Ber.* **1964**, 97, 735.
- (8) Sander, W.; Strehl, A.; Winkler, M. *Eur. J. Org. Chem.* **2001**, 3771.
- (9) Hadjirapoglou, L.; Varvoglis, A. *Synthesis* **1988**, 913.
- (10) Hadjirapoglou, L.; Varvoglis, A. *J. Chem. Soc., Perkin Trans. 1* **1989**, 379.
- (11) Adam, W.; Bosio, S.; Gogonas, E. P.; Hadjirapoglou, L. P. *Synthesis* **2002**, 2084.
- (12) Adam, W.; Gogonas, E. P.; Hadjirapoglou, L. P. *J. Org. Chem.* **2003**, 68, 9155.
- (13) Adam, W.; Gogonas, E. P.; Hadjirapoglou, L. P. *Eur. J. Org. Chem.* **2003**, 1064.
- (14) **Representative Experimental Procedure.**
Synthesis of 3a: A suspension of iodonium ylide **1** (1.0 g, 2.0 mmol) and MeI (2.0 mL) in MeCN (10.0 mL) was stirred (exclusion of light) at 25 °C for 24 h. The solvent was evaporated (30 °C at 10 Torr) and the residue was chromatographed on flash silica gel (CH₂Cl₂ as eluent) to yield 0.49 g (56%) of iodide **3a** as white crystals, mp 158–160 °C (lit²⁰ 164–165 °C). ¹H NMR (250 MHz, CDCl₃): δ = 2.52 (s, 3 H), 7.57–7.63 (m, 4 H), 7.71–7.77 (m, 2 H), 8.11–8.15 (m, 4 H). ¹³C NMR (62.5 MHz, CDCl₃): δ = 27.1, 73.9, 128.6, 132.3, 134.3, 135.1.
Synthesis of 7: A suspension of iodonium ylide **1** (1.00 g, 2.0 mmol), norbornene (1.00 g, 10.0 mmol), and MeI (2.0 mL) in dry CH₂Cl₂ (10.0 mL) was stirred (exclusion of light) at 25 °C for 24 h. The solvent was evaporated (30 °C at 10 Torr) and the residue was chromatographed on flash silica gel (CH₂Cl₂ as eluent) to yield 0.43 g (46%) of *exo*-iodide **7** as white crystals, mp 149–151 °C. IR (KBr): 2960, 2900, 2860, 1440, 1330, 1180, 1150, 1125, 1075, 790, 780, 750 cm⁻¹. ¹H NMR (400 MHz, CDCl₃): δ = 1.23 (d, *J* = 10.6 Hz, 2 H), 1.31–1.37 (m, 1 H), 1.51–1.65 (m, 2 H), 1.84 (d, *J* = 10.6 Hz, 1 H), 2.34 (t, *J* = 7.1 Hz, 1 H), 2.80 (d, *J* = 3.4 Hz, 1 H), 3.13 (br s, 1 H), 4.62 (dd, *J* = 1.9, 7.1 Hz, 1 H), 5.42 (d, *J* = 7.1 Hz, 1 H), 7.44–7.48 (m, 4 H), 7.61 (t, *J* = 7.5 Hz, 2 H), 7.96 (t, *J* = 7.5 Hz, 4 H). ¹³C NMR (100 MHz, CDCl₃): δ = 32.3 (t), 36.8 (t), 40.3 (d), 44.5 (d), 48.7 (d), 49.7 (d), 93.4 (d), 128.8 (d), 129.0 (d), 129.1 (d), 129.4 (d), 134.1 (d), 134.2 (d), 138.8 (s), 140.3 (s). Anal. Calcd for C₂₀H₂₁IO₄S₂ (516.4): C, 46.52; H, 4.10; S, 12.42. Found: C, 46.52; H, 4.07; S, 12.39.
- (15) Olah, G. A.; Doggweiler, H.; Felberg, J. D. *J. Am. Chem. Soc.* **1985**, 107, 4975.
- (16) (a) Moriarty, R. M.; Bailey, B. R. III; Prakash, O.; Prakash, I. *J. Am. Chem. Soc.* **1985**, 107, 1375. (b) Yang, R.-Y.; Dai, L.-X.; Chem, C. G. *J. Chem. Soc., Chem. Commun.* **1992**, 1487. (c) Sheppard, W. A.; Webster, Q. W. *J. Am. Chem. Soc.* **1973**, 95, 2695.
- (17) Adam, W.; Gogonas, E. P.; Hadjirapoglou, L. P. *Synlett* **2003**, 1165.
- (18) Black, K. A.; Vogel, P. *J. Org. Chem.* **1986**, 51, 5341.
- (19) Lautens, M.; Mancuso, J. *Org. Lett.* **2002**, 4, 2105.
- (20) Hadjirapoglou, L.; Varvoglis, A. *J. Chem. Res., Synop.* **1988**, 306.