

# Cycloaddition Reactions of Iodonium Ylides of Cyclic $\beta$ -Diketones with 1,3-Dienes: Evidence for a Stepwise Mechanism.

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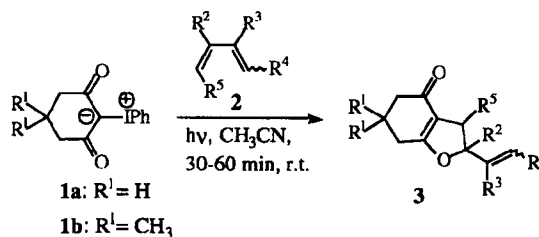
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**Abstract:** The irradiation of a cyclic  $\beta$ -dicarbonyl iodonium ylide with 1,3-diene in acetonitrile gives substituted dihydrofurans in moderate to high yields, presumably via a stepwise mechanism.

**Key words:** hypervalent iodine, 1,3-cycloaddition, ylide, 1,3-diene, dihydrofuran.



Scheme 1

Iodonium ylides<sup>1</sup> are considered as synthetic equivalents of the corresponding diazo compounds, without major drawbacks such as explosion, toxicity, and/or carcinogenicity. Furthermore,  $\beta$ -dicarbonyl and  $\beta$ -disulfonyl iodonium ylides are readily prepared<sup>2,3</sup> in high yields from the related active methylene compounds and a hypervalent iodine precursor. The photochemical and/or metal-catalyzed decomposition of these stable iodonium ylides generated reactive intermediates, which undergo several types of reactions, i.e. transylation<sup>1</sup> with various nucleophiles, cycloaddition reactions leading either to the formation of cyclopropanes<sup>3,4</sup> or five-membered heterocycles<sup>5</sup>, etc.

Following our studies directed towards the development of new synthetic applications of iodonium ylides<sup>6</sup>, we thought that heavily substituted dihydrofurans could be easily obtained by the reaction of a  $\beta$ -dicarbonyl iodonium ylide and a conjugated diene. The use of 1,3-diene has been emerging from the point of view that an extra double bond moiety in the dihydrofuran could lead to further interesting transformations, as well as that the presence of

this extra olefinic moiety should influence the behaviour of the reacting double bond. We have previously published<sup>6a,d</sup> the synthesis of dihydrofurans starting from iodonium ylide **1a** and alkenes. Based on these results, we now wish to report the synthesis of 1,5-dienes **3** by the reaction of iodonium ylides **1a,b** with 1,3-dienes **2**.

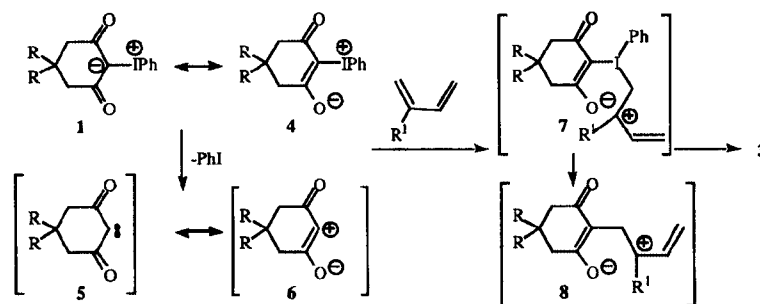
Irradiation of a suspension of iodonium ylide **1a**, and 1,3-diene **2a** in CH<sub>3</sub>CN for 60 min at room temperature afforded<sup>7</sup> dihydrofuran<sup>8</sup> **3a** in 83% yield (Scheme 1). The reaction was extended to iodonium ylide **1b** and a variety of 1,3-dienes **2b-f**, which underwent facile cycloadditions, affording the related dihydrofurans **3** in moderate to excellent yields (Table). When the reactions were repeated thermally, in the presence of catalytic amounts of Cu(acac)<sub>2</sub>, complex mixtures of inseparable products were isolated instead.

It is noteworthy that the reaction proceeds without the use of an inert atmosphere. Acyclic **2a-d**, with varied degree

Table Photochemical Cycloadditions<sup>a</sup> of Iodonium Ylides **1** with 1,3-Dienes **2**

Entry	Ylide	Diene	R <sup>1</sup>	R <sup>2</sup>	R <sup>3</sup>	R <sup>4</sup>	R <sup>5</sup>	Time(min)	Product	Yield (%) <sup>b</sup>
1	<b>1a</b>	<b>2a</b>	H	CH <sub>3</sub>	H	H	H	60	<b>3a</b>	83
2	<b>1b</b>	<b>2a</b>	CH <sub>3</sub>	CH <sub>3</sub>	H	H	H	60	<b>3b</b>	76
3	<b>1a</b>	<b>2b</b>	H	H	H	CH <sub>3</sub>	H	60	<b>3c</b>	68
4	<b>1b</b>	<b>2b</b>	CH <sub>3</sub>	H	H	CH <sub>3</sub>	H	60	<b>3d</b>	89
5	<b>1a</b>	<b>2c</b>	H	CH <sub>3</sub>	CH <sub>3</sub>	H	H	60	<b>3e</b>	56
6	<b>1b</b>	<b>2c</b>	CH <sub>3</sub>	CH <sub>3</sub>	CH <sub>3</sub>	H	H	30	<b>3f</b>	51
7	<b>1a</b>	<b>2d</b>	H	CH <sub>3</sub>	H	CH <sub>3</sub>	H	35	<b>3g</b>	90
8	<b>1b</b>	<b>2d</b>	CH <sub>3</sub>	CH <sub>3</sub>	H	CH <sub>3</sub>	H	35	<b>3h</b>	89
9	<b>1a</b>	<b>2e</b>	H	H	H	CH <sub>2</sub>		40	<b>3i</b>	74
10	<b>1b</b>	<b>2e</b>	CH <sub>3</sub>	H	H	CH <sub>2</sub>		30	<b>3j</b>	59
11	<b>1a</b>	<b>2f</b>	H	H	H	CH <sub>2</sub> CH <sub>2</sub>		40	<b>3k</b>	50
12	<b>1b</b>	<b>2f</b>	CH <sub>3</sub>	H	H	CH <sub>2</sub> CH <sub>2</sub>		60	<b>3l</b>	76

<sup>a</sup>All the reactions were performed in CH<sub>3</sub>CN by irradiation with a 400 W Hg medium pressure lamp. <sup>b</sup> Isolated Yield.



Scheme 2

of substitution, as well as cyclic dienes **2e,f** were found to undergo cycloaddition. Although diene **2b** was a commercial 1:2 mixture of *cis*-, *trans*-isomers, the corresponding dihydrofurans **3c,d** were isolated as a 3:10 mixture of *cis*- and *trans*-isomers. Similarly, from diene **2d**, a 1:10 mixture of *cis*-, *trans*-dihydrofurans **3g,h** were isolated.

It is clearly demonstrated that the reactivity of an iodonium ylide towards dienes follows the reactivity order: 1,2-disubstituted double bond [1,2-DDB] < monosubstituted double bond [MDB] < 1,1-disubstituted double bond [1,1-DDB]. We assumed that MDB and 1,1-DDB bonds react much more faster than 1,2-DDB due to steric hindrance, while 1,1-DDB reacts faster than MDB due to the fact that a tertiary carbocation is much more stable than a secondary.

Our results suggest that the reaction proceeds via a stepwise mechanism. A plausible mechanism is shown in Scheme 2. Upon irradiation, the iodonium ylide [either the keto or enol form **1**, **4** respectively] could generate, with expulsion of iodobenzene, the corresponding carbene **5** or the 1,3-dipolar intermediate **6**. More likely, intermediate **6** is trapped by the double bond of the diene to give zwitterion **8**, which cyclizes to dihydrofuran **3**. We postulated that the reaction proceeds via the **6**→**8**→**3** sequence, although reactive intermediates similar to **4** have been postulated<sup>9</sup> for a  $\beta$ -disulfonyl iodonium ylide.

In conclusion, the present method is a useful extension of the reactivity pattern of iodonium ylides for the isolation of new substituted dihydrofurans in moderate to high yields, which because of its experimental simplicity and its selectivity should find wide application.

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- (7) General procedure for the preparation of dihydrofurans **3**: A suspension of iodonium ylide **1** (2.0-10.0 mmol) and excess of 1,3-diene **2** in  $\text{CH}_3\text{CN}$  (10-30 mL) was irradiated [400W medium pressure Hg lamp] for 30-60 min [or until the yellow color of the resulting solution darkens]. The solvent and the excess diene were then removed under reduced pressure. The residue, purified by flash chromatography (flash silica gel, 4:1 v/v  $\text{CH}_2\text{Cl}_2/\text{AcOEt}$ ) afforded dihydrofuran **3**.
- (8) Selected spectroscopical data for representative compound **3a**:  $^1\text{H NMR}$  ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  = 1.46 (s, 3H), 2.00 (q, 2H,  $J$  = 6.4 Hz), 2.28-2.31 (m, 2H), 2.37-2.42 (m, 2H), 2.61 (dt, 1H,  $J$  = 1.8, 14.4 Hz), 2.77 (dt, 1H,  $J$  = 1.8, 14.4 Hz), 5.07 (d, 1H,  $J$  = 10.8 Hz), 5.19 (d, 1H,  $J$  = 17.3 Hz), 5.93 (dd, 1H,  $J$  = 10.8, 17.3 Hz).  $^{13}\text{C NMR}$  ( $\text{CDCl}_3$ , 100 MHz):  $\delta$  = 21.6, 24.0, 26.3, 36.3, 37.8, 91.0, 112.3, 113.1, 140.6, 176.0, 195.6.
- (9) The postulation of such intermediates was based on the observation that various alkenes and alkynes reacted with a  $\beta$ -disulfonyl iodonium ylide in the absence of light, see: Hadjarapoglou, L.P. *Ph.D Thesis*, University of Thessaloniki, Gogonas, E.P.; Hadjarapoglou, L.P. unpublished results. No reaction was observed, when the  $\beta$ -dicarbonyl iodonium ylide **1** was used instead.

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