STEREOSELECTIVE \([\pi_4 s + \pi_2 s]\)-DIPOLAR CYCLOADDITION OF PYRIDINIUM YLIDES TO NITRILES OF THE \(\text{trans}-1,3\)-BUTADIENE SERIES. CRYSTAL AND MOLECULAR STRUCTURE OF 3-BENZOYL-1-(2,2-DICYANO-1-CYCLOPROPYLVINYL)-2-PHENYL-6-CYANO-1,2-\(\text{trans}-2,3\)-\(\text{trans}-1,9\)-\(\text{trans}-1,2,3,9\)-TETRAHYDROINDOLIZINE


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The interaction of substituted \(\text{trans}-1,1\)-dicyano-4-phenyl-1,3-butadienes with pyridinium ylides proceeds through the path of \([\pi_4 s + \pi_2 s]\)-dipolar cycloaddition, highly regioselective and stereoselective, with the formation of substituted 1-(2,2-dicyanovinyl)-2-phenyl-6-cyano-1,2-\(\text{trans}-2,3\)-\(\text{trans}-1,9\)-\(\text{trans}-1,2,3,9\)-tetrahydroindolizines. The stereoselectivity of these reactions is due to endo-addition of molecules of \(\text{trans}-1,3\)-butadienes to the anti form of the pyridinium ylides; it is confirmed by correlation analysis of the data from double PMR, mathematical calculations of torsion angles, and x-ray structural studies of the substituted tetrahydroindolizines.

In previous reports we examined reactions of azinium ylides with nitriles of the ethylene series [1-3]. It was established that the regioselectivity and stereoselectivity of these reactions depend on the structure of the original compounds; also, synthetic possibilities of the compounds were determined. The interaction of pyridinium carbanomylmethylylide or phenacylmethyllyide [generated in the reaction mixture by the action of bases on halides of 1-(carbamoylmethyl)pyridinium or 1-phenacylpyridinium] with arylmethylenemalononitrile proceeds stereoselectivity with the formation of substituted \(\text{trans}\)-cyclopropanes [1]. The introduction of arylmethylenean throttleamides into this reaction is accompanied by a change in the regioselectivity of interaction, leading to substituted 4-aryl-2-hydroxy-3-(1-pyridinio)-5-cyano-3,4-\(\text{trans}-1,2,3,4\)-tetrahydro-2-thiolates [2]. The interaction of isoquinolinium ylides, which are more \(\pi\)-deficient, with arylmethylenemalononitriles, proceeds with high stereoselectivity along the path of synchronous 1,3-dipolar cycloaddition with the formation of substituted 1,2-\(\text{trans}-1,2,3,4\)-tetrahydrobenzo[f]indolizines [3]. Here we are presenting results from an investigation of reactions of 3-cyano- and 3-ethoxycarbonylpyridinium ylides, for which the \(\pi\)-electron density in the ring is lower, with substituted \(\text{trans}-1,3\)-butadienes. Reactions of pyridinium ylides with butadienes had not been investigated previously [4-6].

The original butadienes were obtained by condensation of the unsaturated nitriles Ia, b with benzaldehyde in isopropanol in the presence of a base. The condensation proceeds stereoselectively with 68-71% yields of the substituted \(\text{trans}-1,3\)-butadienes IIa, b. In the IR spectra of these compounds, absorption bands of conjugated C==N groups are present in the 2223-2224 cm\(^{-1}\) region. In the PMR spectra, the signals of the protons of the butadiene fragment are manifested in the form of doublets in the 6.47-6.97 and 7.18-7.68 ppm regions, with a characteristic transoid SSCC \(3J = 15.8-16.0\) Hz.

The pyridinium ylides were not segregated as such, but were generated in the reaction mixture by treatment of the corresponding pyridinium salts III with an equimolar quantity of triethanolamine in ethanol.

\[
\begin{align*}
R & \quad \text{CH}_3 \quad \text{CN} \\
& \quad \text{CN} \\
\text{Ia, b} & \quad + \quad \text{C}_2\text{H}_5\text{CHO} \\
& \quad \text{CN} \\
& \quad \text{C}_6\text{H}_5 \\
\text{IIa, b} \\
\end{align*}
\]

R is cyclopropyl in Ia and IIa, phenyl in Ib and IIb.

Fig. 1. General view of molecule Va and bond lengths in molecule. The trans position can be seen for the pairs of atoms H(1) and H(2), H(2) and H(3), and H(3) and H(4).

TABLE I. Characteristics of Substituted Tetrahydroindolizines Va-d

<table>
<thead>
<tr>
<th>Compound</th>
<th>Empirical formula</th>
<th>mp, °C</th>
<th>IR spectrum, ( \nu, \text{cm}^{-1} )</th>
<th>Yield, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Va</td>
<td>C_{29}H_{22}N_{4}O</td>
<td>150...152</td>
<td>1638, 1697</td>
<td>2202, 2234</td>
</tr>
<tr>
<td>Vb</td>
<td>C_{29}H_{22}N_{4}O</td>
<td>148...150</td>
<td>1628, 1686</td>
<td>2205, 2226</td>
</tr>
<tr>
<td>Vc</td>
<td>C_{31}H_{27}N_{3}O_{2}</td>
<td>135...136</td>
<td>1622, 1672</td>
<td>2227</td>
</tr>
<tr>
<td>Vd</td>
<td>C_{31}H_{27}N_{3}O_{2}</td>
<td>122...124</td>
<td>1628, 1678</td>
<td>2232</td>
</tr>
</tbody>
</table>

*Compounds Va, c, d were crystallized from methanol, compound Vb from isopropanol.

The subsequent interaction of the ylides IV with the butadienes II proceeds along the path of synchronous 1,3-dipolar cycloaddition, regioselectively and stereoselectively, with the formation of the substituted tetrahydroindolizines V (Tables 1 and 2). Of the several possible products of regioselective addition with respect to the dipolarophile II, only one product is realized in practice, specifically, the product of \([\pi^4 s + \pi^2 s]-\text{cycloaddition}\) [7] of the ylides (IV) at the C(3)═C(4) bond of the molecules of the butadiene II.

In compounds III and IV, Z is CN (a) or COOC_{2}H_{5} (b). In compounds V, R and Z are (respectively) cyclopropyl and CN (a), C_{6}H_{5} and CN (b), cyclopropyl and COOC_{2}H_{5} (c) or C_{6}H_{5} and COOC_{2}H_{5} (d).