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MILD, ASYMMETRIC DIELS-ALDER CYCLOADDITIONS OF ELECTRONICALLY MATCHED 2-PYRONES AND VINYL ETHERSGary H. Posner,* Jean-Christophe Carry,¹ Jae Kyoo Lee, D. Scott Bull, and Haiyan Dai²Department of Chemistry, School of Arts and Sciences,
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Summary: Silica gel and a TADDOL-complexed titanium IV Lewis acid are shown to promote mild, practical, asymmetric [4+2]-cycloadditions of electron-poor 2-pyrone-3-carboxylates with electron-rich vinyl ethers to form isolable and useful bicyclic lactone adducts.

For almost a decade, we have been exploring use of electronically matched 2-pyrones and vinyl ethers for mild Diels-Alder cycloadditions leading to isolable and synthetically useful bicyclic lactone adducts.³ Recently, others have begun to appreciate the synthetic potential of such inverse-electron-demand [4+2]-cycloadditions.⁴ To control the absolute stereochemistry of such Diels-Alder cycloadditions, we have successfully used chiral auxiliaries attached to the vinyl ether dienophiles and separately to the pyrone dienes, as well as chiral auxiliaries bound to Lewis acidic lanthanide shift reagents.³ To make these cycloadditions even more practical and operationally convenient, we have recently been exploring ways to use simple and readily available 2-pyrones and acid catalysts, and we now report some promising preliminary results.

Porous solids like silica,⁵ alumina,⁶ zeolites,⁷ as well as montmorillonite clays⁸ and molecular sieves^{9a} have been used to facilitate many organic reactions, including some [4+2]-cycloadditions. These studies of [4+2]-cycloadditions promoted by porous solids have generally focused on model reactions involving cyclopentadiene and a variety of simple dienophiles. Montmorillonite clay-promoted reactions using (-)-menthyl acrylate and (R)-O-acryloyl pantolactone have also been studied.^{8b} These dienophiles were shown to produce product *endo:exo* ratios of >9:1 with d.e. of 38% and 53%, respectively. In addition to these model studies, the synthetic utility of this methodology has been demonstrated in the preparation of (±)-verrucarol, with the key step involving an alumina-catalyzed intramolecular cycloaddition.^{6c} We have now found that commercial chromatography silica gel (EM Science #60, 5 g per mmol of pyrone) promotes effective Diels-Alder cycloadditions of commercial 3-methoxycarbonyl-2-pyrone (1a) with butyl vinyl ether and with benzyl vinyl ether at room temperature to form

In summary, the porous solid-promoted cycloadditions shown in eq. 1 and the homochiral Lewis acid-promoted cycloaddition shown in eq. 2 represent important initial progress in developing practical, simple, and environmentally benign asymmetric syntheses of versatile bicyclic lactones under reaction conditions mild enough to prevent loss of CO₂ from the initial bicycloadducts.^{30,13} We are continuing to explore ways to maximize operational simplicity and stereocontrol.

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