Supporting Information

N-Heterocyclic carbene-catalyzed [4+2] cyclization of α,β-
unsaturated carboxylic acids bearing γ-H with isatins: An
enantioselective synthesis of spirocyclic oxindole–dihydropyranones

Ling Zhu, Chenxia Yu, Tuanjie Li, Yuhong Wang, Yinan Lu, Wenjing Wang and Changsheng Yao*
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1. General methods

Common reagents and materials were purchased from commercial sources and purified by recrystallization or distillation. Melting points were determined in open capillaries and were uncorrected. IR spectra were taken on a FT-IR-Tensor 27 spectrometer in KBr pellets and reported in cm\(^{-1}\). \(^1\)H NMR spectra were measured on a Bruker DPX 400 MHz spectrometer in CDCl\(_3\) (100 MHz, \(^1\)C NMR) with chemical shift (\(\delta\)) given in ppm relative to TMS as internal standard. High-resolution mass spectra (HRMS) were obtained on a microTOF-Q II HRMS/MS instrument (Bruker) with the technique of electrospray ionization.

2. Abstract

An NHC-catalyzed asymmetric [4+2] annulation of isatins and \(\alpha,\beta\)-unsaturated carboxylic acids bearing \(\gamma\)-H gave spirocyclic oxindole–dihydropyranones successfully via in situ activation strategy. This protocol featured easy availability of raw materials, good yields and excellent enantioselevities (up to 99% ee).

3. Experimental section

An oven-dried 10-mL Schlenk tube equipped with a magnetic stir bar was charged with triazolium salt 4b (12.6 mg, 0.03 mmol), Cs\(_2\)CO\(_3\) (130 mg, 0.4 mmol), \(\alpha,\beta\)-unsaturated carboxylic acid 1 (0.3 mmol), isatin 2 (0.2 mmol) and HATU (228 mg, 0.6 mmol). This tube was closed with a septum, evacuated, and refilled with nitrogen. To this mixture was added freshly distilled toluene (2 mL) with a syringe. Then the mixture was stirred at 0 °C until completion (monitored by TLC). After removal of the solvent under reduced pressure, the resulting crude residue was purified by column chromatography (silicagel, mixtures of petroleum ether/ethyl acetate, 3:1, v/v) to afford the desired product 3.
4. X-ray structure of 3a

The crystal of compound 3a was prepared from the solution in petroleum ether/ethyl acetate (M.P.: 207-208 °C). Crystallographic data (excluding structure factors) for the structures in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC 1046964. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB21EZ, UK (fax: +44 1223 336033 or email: deposit@ccdc.cam.ac.uk).
5. NMR Spectures
新增化合物 3o
6. HPLC Spectures

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Area Percent Report

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Sorted By: Signal
Multiplier: 1.0000
Dimension: 1.0000
User Multiplier & Dimension Factors with ISIDes

Signal 1: MP61 C, Ret=254.8 Da=950.180
Peak Ret Time Trunc Width Area Height Area
# [Min] [Min] [WAV] [RAW] %
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1 27.997 BB 0.7812 4128.0258 86.30252 69.5885 3.37724 99.8819 0.0000
2 38.936 BB 1.1116 4294.9068 58.90717 59.4613 3.37724 99.8819 0.0000
Totals: 8383.00146 146.28597
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*** End of Report ***

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Area Percent Report

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Sorted By: Signal
Multiplier: 1.0000
Dimension: 1.0000
User Multiplier & Dimension Factors with ISIDes

Signal 1: MP61 D, Ret=234.15 Ret=300.160
Peak Ret Time Trunc Width Area Height Area
# [Min] [Min] [WAV] [RAW] %
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1 28.457 BB 0.8287 3.590435 556.40282 95.7478 3.37724 99.8819 0.0000
2 40.357 BB 1.0262 1610.9493 24.55796 4.2352
Totals: 5.054356 551.19998
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*** End of Report ***

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18
Area Percent Report

Sorted by: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier x Dilution Factor with ISTDs

Signal Int. WD: 5%, Sig>54.16 Ref>360.160

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### Area Percent Report

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**End of Report**
Area Percent Report

Signal 1: MWO B, Exp=364.16 Ref=366.100

Peak Ret.Time Width Area Height Area %
# (min) (s) (min) (mmHg) (AU)
1 12.50 0.75 0.300784 546.12290 55.1541
2 20.45 0.95 0.190368 344.39194 49.0499
Total : 4.65280E4 796.60454

--- End of Report ---

Signal 2: MWO B, Exp=364.16 Ref=366.100

Peak Ret.Time Width Area Height Area %
# (min) (s) (min) (mmHg) (AU)
1 33.03 0.75 0.7672 42.52946 7.1279
2 39.94 0.41 0.011347 3.913858 0.4909
Total : 5.64816E4 335.20071

--- End of Report ---
### Chromatogram

#### Integration Results

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### Chromatogram

#### Integration Results

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<th>Area (mAU:min)</th>
<th>Height (mAU)</th>
<th>Relative Area (%)</th>
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