

Published in final edited form as:

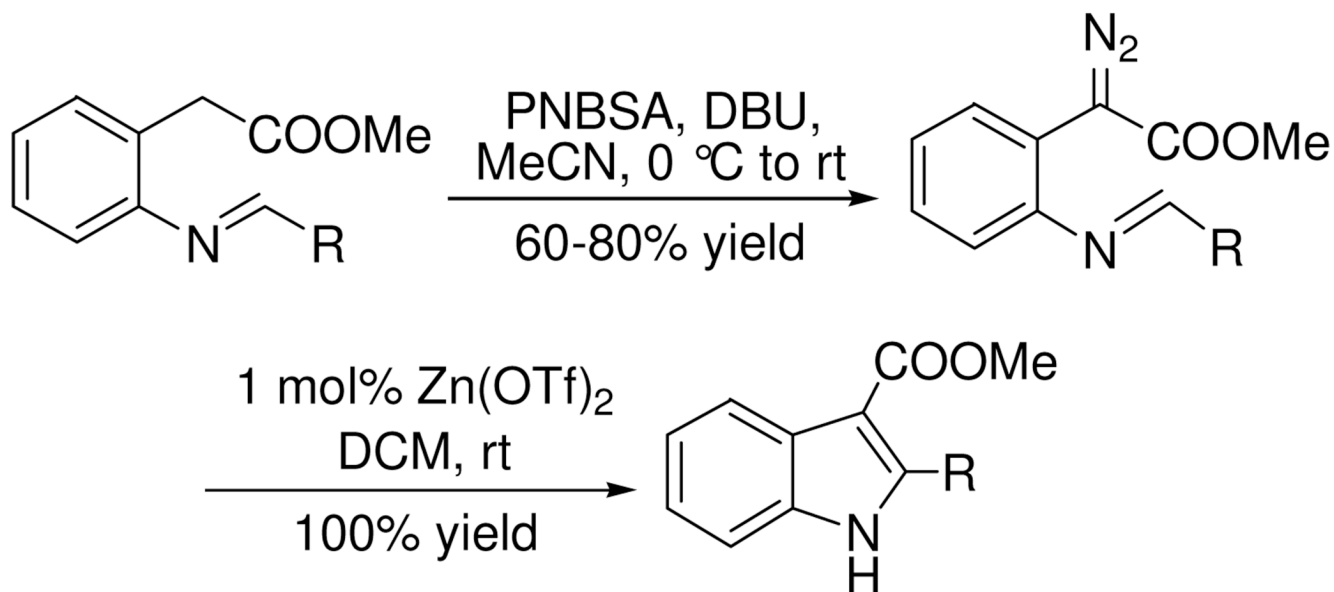
J Org Chem. 2009 December 4; 74(23): 9222–9224. doi:10.1021/jo902089e.

Lewis Acid-Catalyzed Indole Synthesis via Intramolecular Nucleophilic Attack of Phenyl diazoacetates to Iminium Ions

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Abstract



Lewis acids catalyze the cyclization of methyl phenyldiazoacetates with an ortho-imino group, prepared from *o*-aminophenylacetic acid, to give 2,3-substituted indoles in quantitative yields.

Indoles are referred as “privileged structures” in drug discovery because of their capacity of binding to many receptors with high affinity. The synthesis of indoles has been of considerable interest to organic chemists for more than a century.¹ Many powerful methodologies for the synthesis of these heterocycles have been developed, including the Fisherindole synthesis,² heteroannulation and cyclization of 2-alkynylanilines,³ a metal-catalyzed cascade reaction,⁴ intramolecular C-H amination of azidoacrylates,⁵ and a domino reaction of *N*-aryl amides with ethyl diazoacetate.⁶ However, efficient methods for the synthesis of indoles from simple precursors continue to be of great value. Diazoacetates and aryldiazoacetates have been widely employed under catalytic conditions for many organic transformations, including cyclopropanation,⁷ insertion,⁸ and ylide formation and subsequent reactions.^{9,10} Aziridination using imine and diazoacetate catalyzed by either Lewis acids¹¹ or Brønsted acids¹² is also well-known. In 2003 we reported the synthesis of dihydropyrroles from vinyl diazoacetates and imines, and in that report we provided evidence that copper(II) catalyzed formation of 2,5-

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Supporting Information Available: General experimental procedures and spectroscopic data for all new compounds. This material is available free of charge via the Internet at <http://pubs.acs.org>.

dihydropyrroles by activation of the imine towards electrophilic addition to the diazo carbon of the vinyl diazoacetate (Scheme 1).¹³ We now report an intramolecular analog of the imine-diazoacetate reaction that can be performed with a broad selection of inexpensive Lewis acids with catalyst loadings at/or below 1.0 mol %.

Methyl *N*-substituted iminophenyldiazoacetates (**2**) were synthesized efficiently by reactions of *p*-nitrobenzenesulfonylazide (PNBSA), DBU and methyl 2-arylmethyleneaminophenylacetates (**1**) that were prepared in quantitative yield from methyl *o*-aminophenylacetate and aryl and vinyl-substituted aldehydes (Scheme 2). In the simplest case methyl diazo(2-phenylmethyleneaminophenyl)acetate was treated with a broad spectrum of Lewis acids, each at 1.0 mol %. Reaction times and product yields are given in Table 1. Reaction times were determined by monitoring the reaction solution every five minutes. As can be seen from these results, a wide variety of catalysts are suitable, but two were selected for further investigation. No reaction occurred in the absence of acid.

No attempt was made to rigorously dry the Lewis acids employed, so different times could be suitable for complete reaction dependent on humidity and other relevant conditions. The use of lower amounts of catalyst was investigated. For instance, reaction was complete within 40 min when 1 mol % zinc triflate was used, but was complete at only 10 min when 5 mol % zinc triflate was employed. However, when the reaction is performed in the presence of only 0.1 mol % zinc triflate, for complete reaction 10 h was required.

The scope of the reaction with representative methyl 2-arylmethyleneaminophenylacetates (**1**) was examined. The reactant diazo compounds (**2**) were prepared according to Scheme 2 in 60–80% overall yields (Table 2). Cyclization catalyzed by zinc triflate or boron trifluoride etherate furnished indoles **3** in quantitative yields.

Consistent with these observations, the mechanism of the cyclization involves activation of the imine by the Lewis acid for electrophilic attack on the diazo carbon to form a diazonium ion intermediate. Expulsion of N₂ and dissociation of the Lewis acid furnishes the product indole (Scheme 3). The difference in base strength between imine and indole is the driving force for the highly efficient catalytic turnover.

A demonstration of the synthetic utility of this methodology is shown in Scheme 4. Indole **3f** was converted to biologically active¹⁴ indolo-quinolin-2(1*H*)-one **4** in high yield following reduction of the nitro group and cyclization in methanol. This synthetic strategy is highly efficient compared with the published method,¹⁵ which starts from the reaction of hydrozine with 4-hydroxyquinoline-2(1*H*)-one, followed by treatment with cyclohexanone, thermal Fischer indolization and dehydrogenation to afford indoloquinoline-2(1*H*)-one in low yield.

In summary, we have developed a general and efficient synthesis of functionalized indoles from Lewis acid-promoted intramolecular nucleophilic attack of imines by phenyldiazoacetates. Reaction conditions are mild, and product yields are good under low catalyst loading with inexpensive, commercially available Lewis acids. The approach proves to be very useful for the synthesis of biologically active and naturally occurring indole derivatives. Efforts are actually directed toward the extension of this methodology to natural products and drug synthesis.

Experimental Section

General Procedure for Diazo compound **2** Synthesis (Table 2)

To a stirred solution of **1** (1 mmol) and PNBSA (2–3 mmol) in MeCN (5 mL) was added DBU (4–6 mmol) at 0°C. The reaction mixture was then allowed to warm to room temperature. After

stirring for 12 h, the reaction mixture was quenched with aqueous NH_4Cl , extracted with diethyl ether, and dried over anhydrous Na_2SO_4 . The solvent was removed under reduced pressure and purified by flash column chromatography on silica gel to give the corresponding diazo compound **2**.

General Procedure for Indole 3 Synthesis (Table 2)

To a stirred solution of **2** (0.25 mmol) in DCM (5 mL) was added boron trifluoride etherate, or zinc triflate (1 mol%) at room temperature. The yellow reaction mixture was stirred until it turned pale yellow or colorless within 10–30 min. The mixture was then passed through a silica gel plug to remove the catalyst. After evaporation of the solvent, pure indole **3** was obtained as a light yellow solid in quantitative yield.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

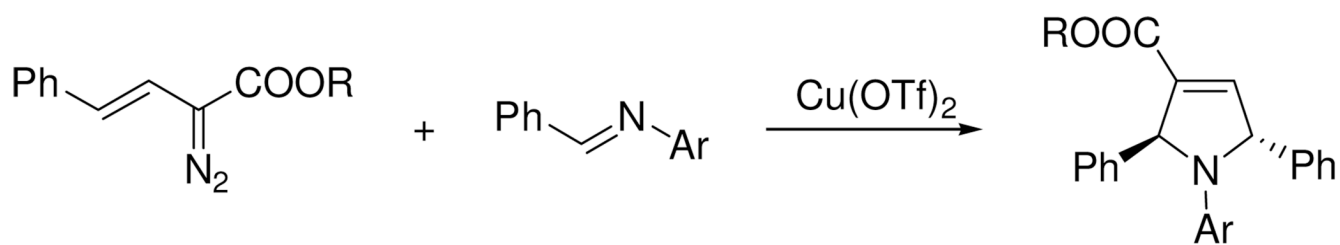
Acknowledgments

We gratefully acknowledge the financial support provided by the National Institutes of Health (GM46503) and the National Science Foundation.

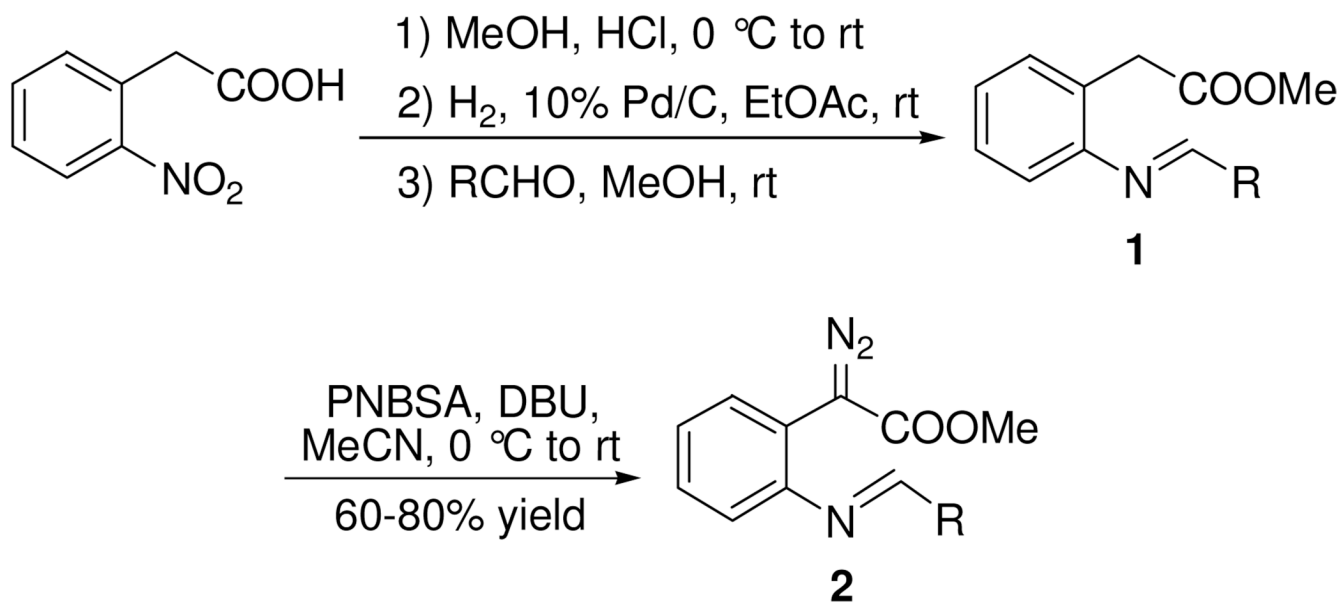
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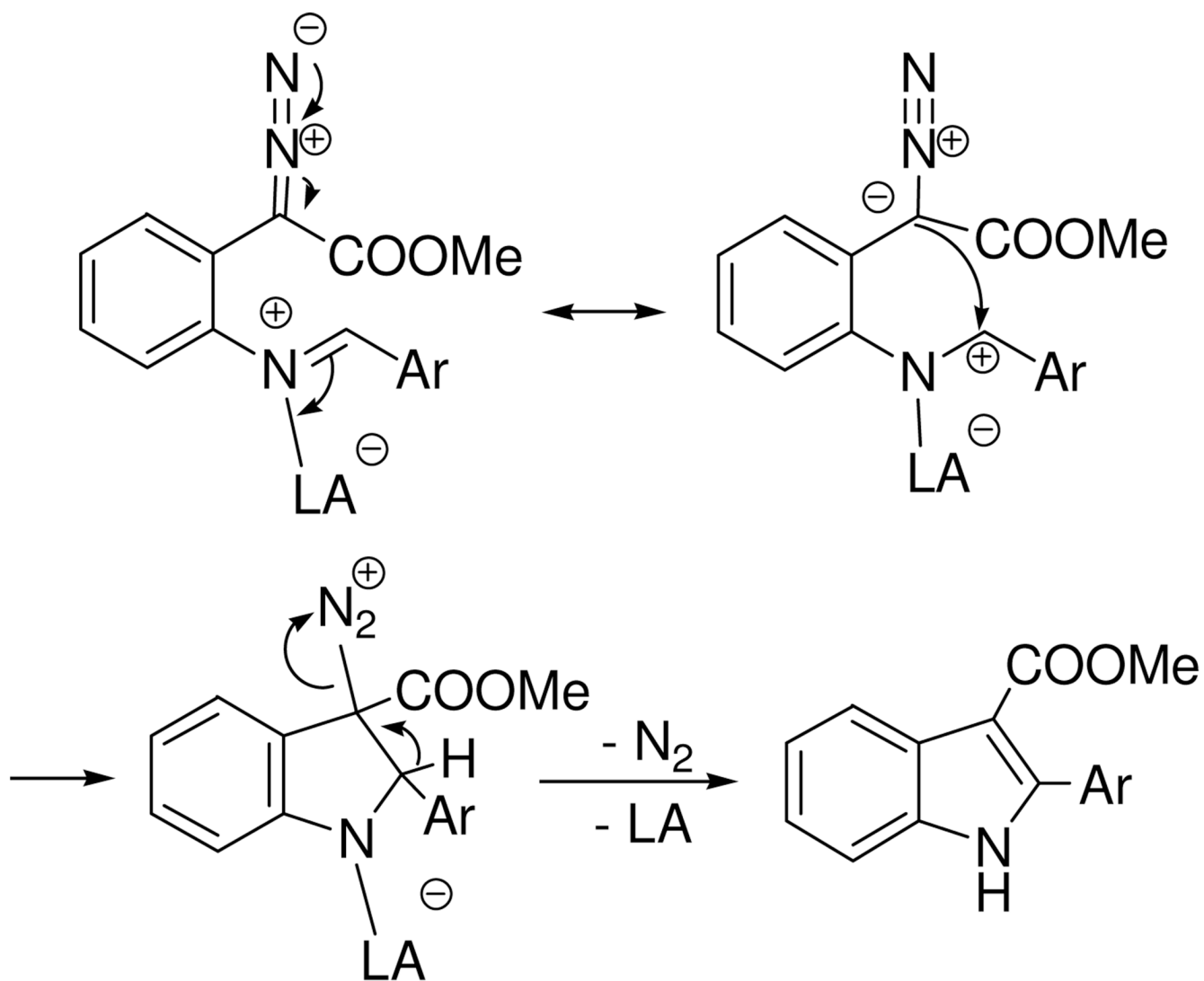
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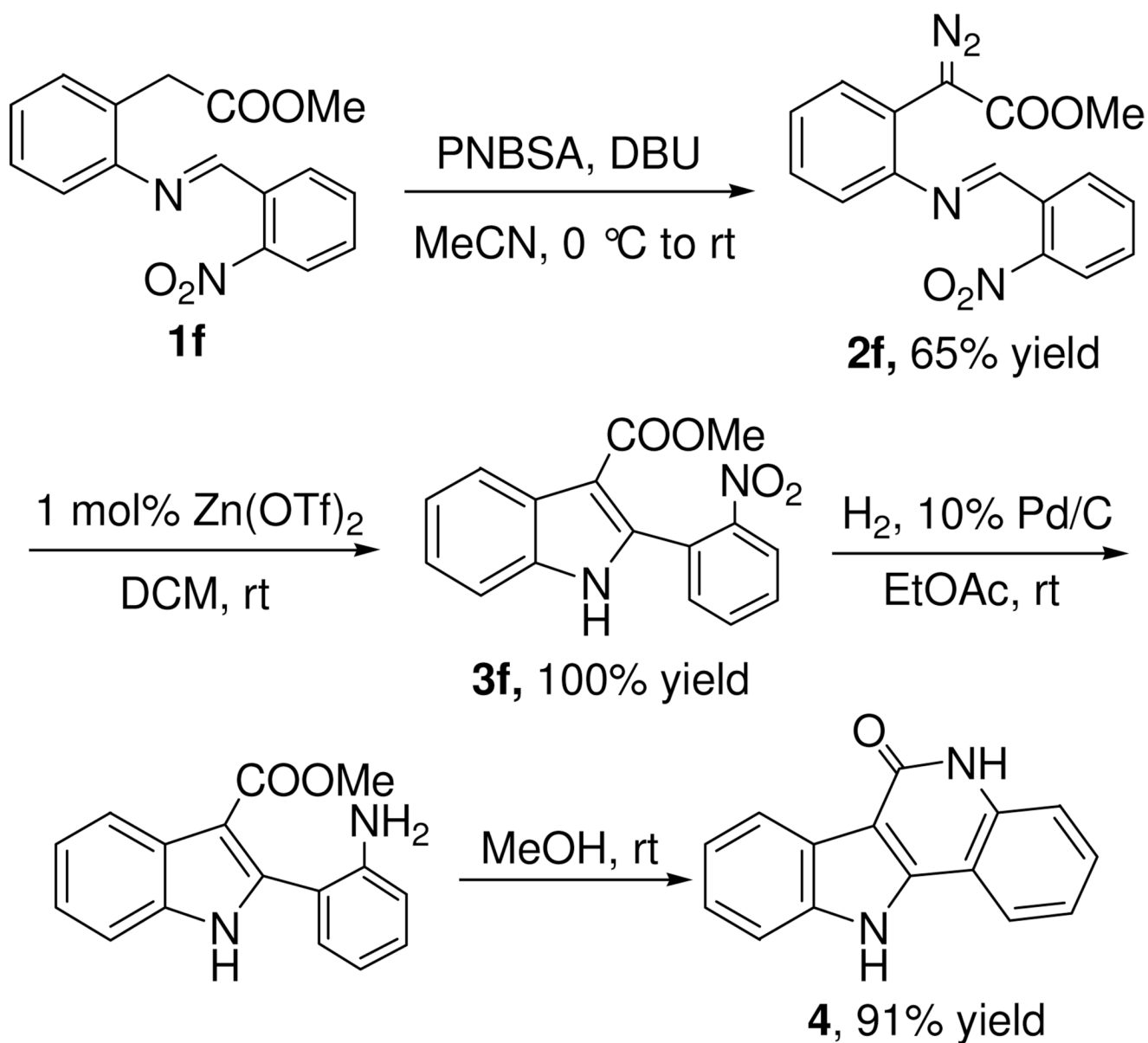
Scheme 1.
Copper(II)-catalyzed Formation of 2,5-Dihydropyrroles



Scheme 2.
Synthesis of Methyl *N*-Substituted Iminophenyldiazoacetates



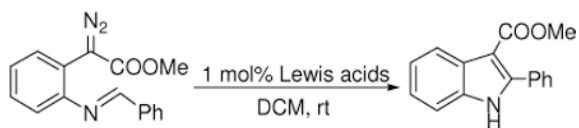
Scheme 3.
Mechanism of Lewis Acid-promoted Indole Synthesis



Scheme 4.
Synthesis of Indolo-quinolin-2(1H)-one

Table 1

Cyclization of Methyl diazo(2-phenylmethyleneaminophenyl)acetate Catalyzed by Lewis Acids

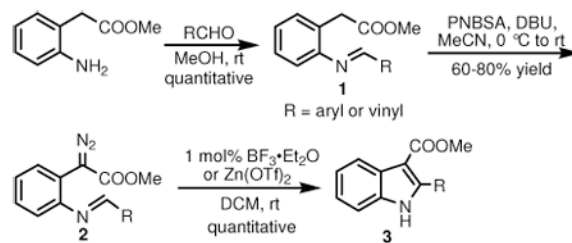


entry	Lewis acid 1 mol%	reaction time (min)	yield (%)
1	ZnCl ₂	60	very low conversion
2	BF ₃ •Et ₂ O	10	100
3	TiCl ₄	5	100
4	SnCl ₄	10	100
5	Mg(OTf) ₂	60	no conversion
6	Sn(OTf) ₂	15	100
7	In(OTf) ₃	5	100
8 ^a	Zn(OTf) ₂	40	100
9	Ni(OTf) ₂	15	100
10	Cu(OTf) ₂	5	100
11	Sc(OTf) ₃	5	100
12	La(OTf) ₃	60	very low conversion
13	Yb(OTf) ₃	20	100

^aReaction was complete in less than 10 min when 5 mol% Zn(OTf)₂ was used; reaction was complete in 10 h when 0.1 mol% Zn(OTf)₂ was used.

Table 2

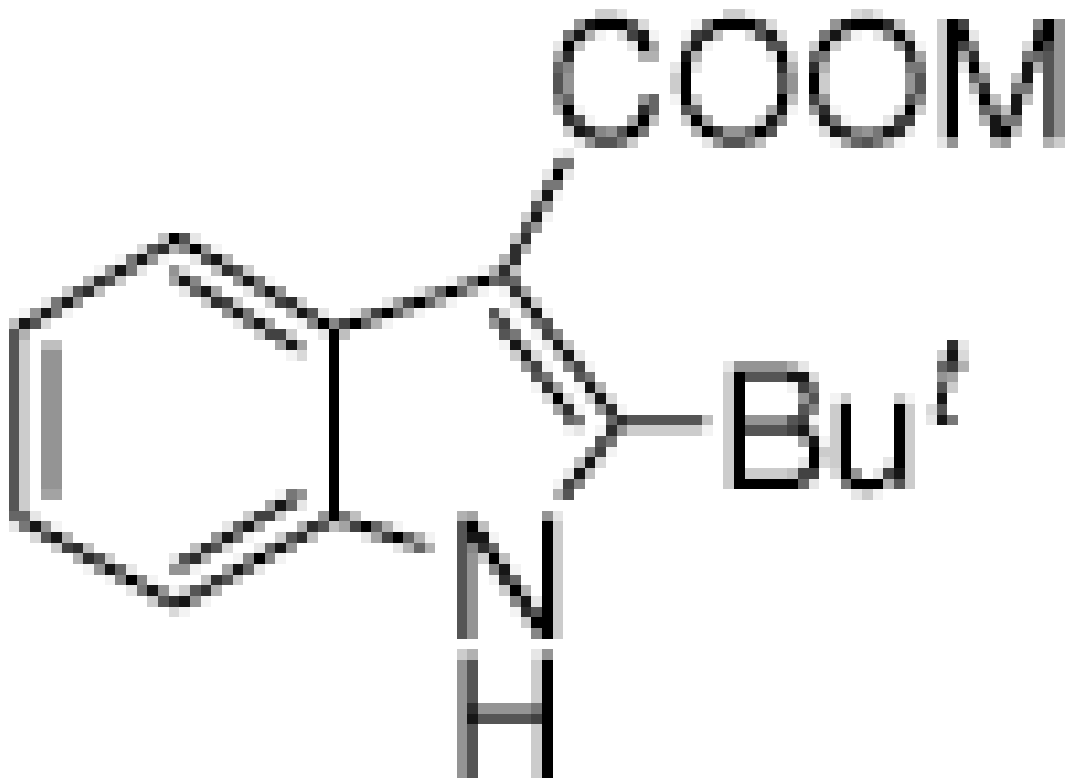
Indole Synthesis via Intramolecular Nucleophilic Attack of Imines by Phenylldiazoacetates



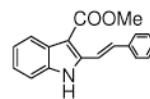
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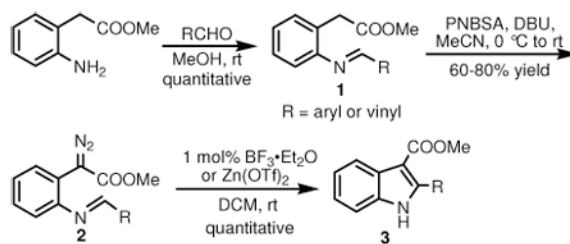
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a



b

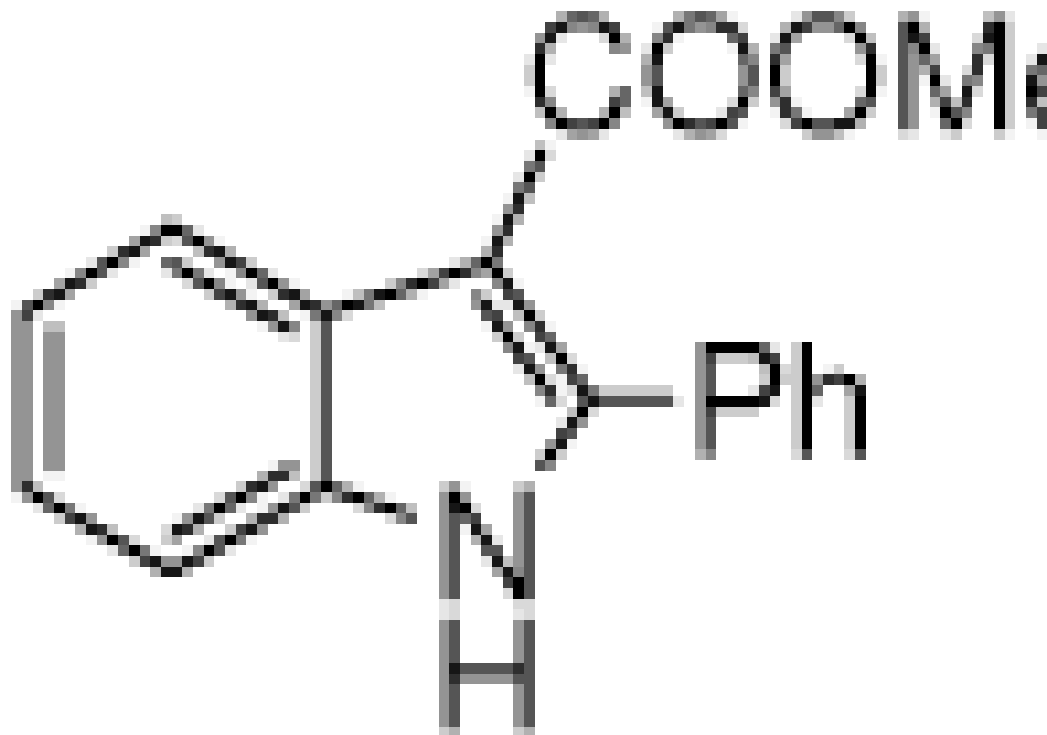


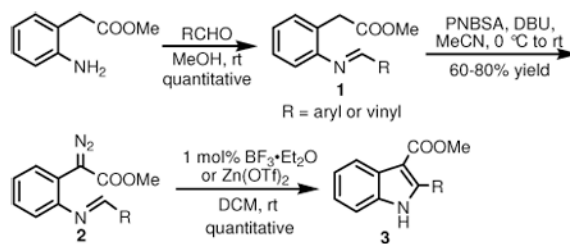


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c

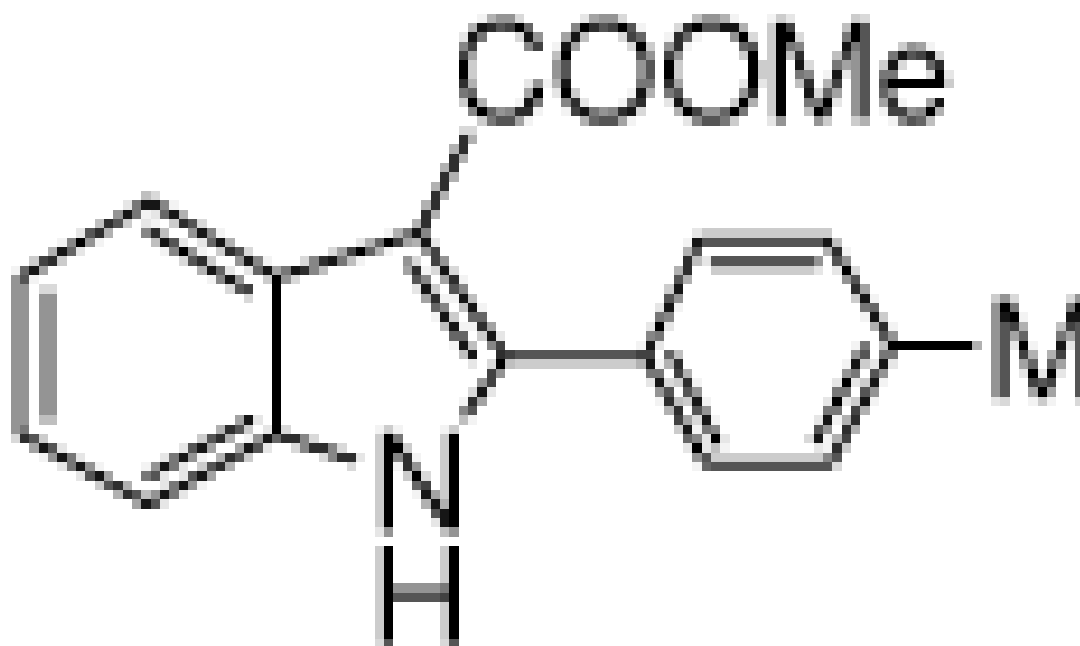


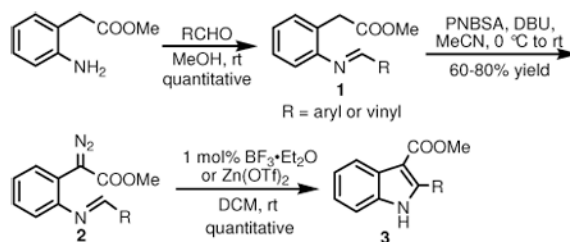


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3

d

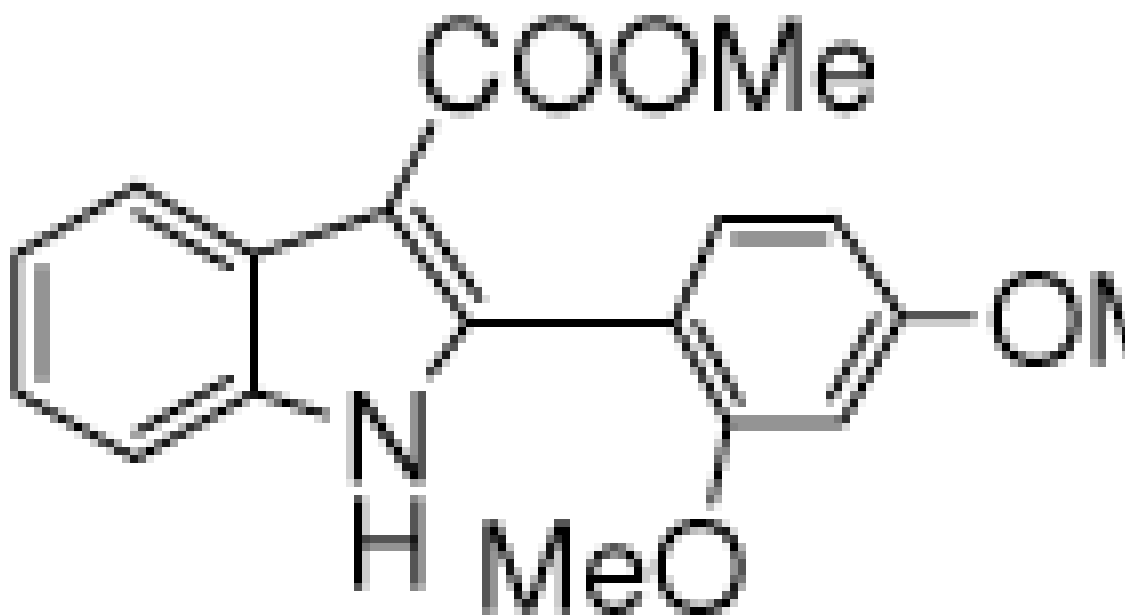


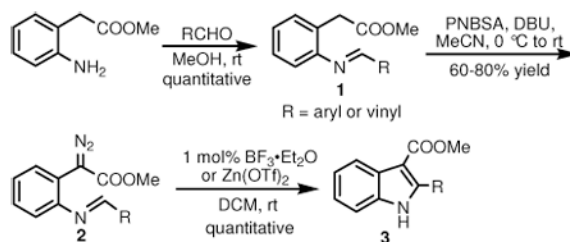


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e

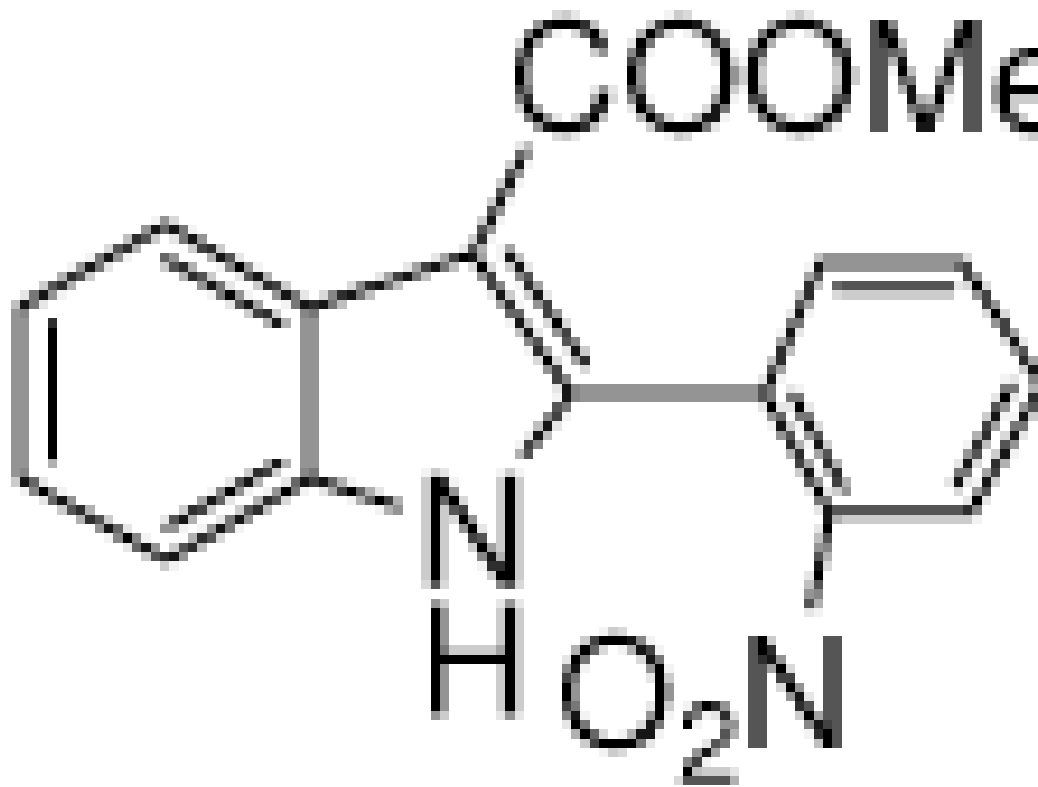


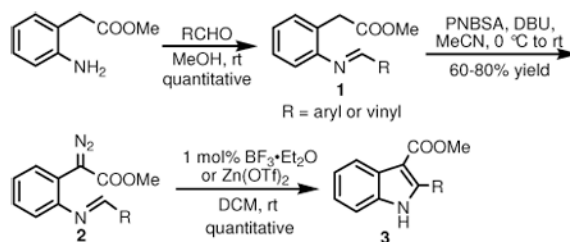


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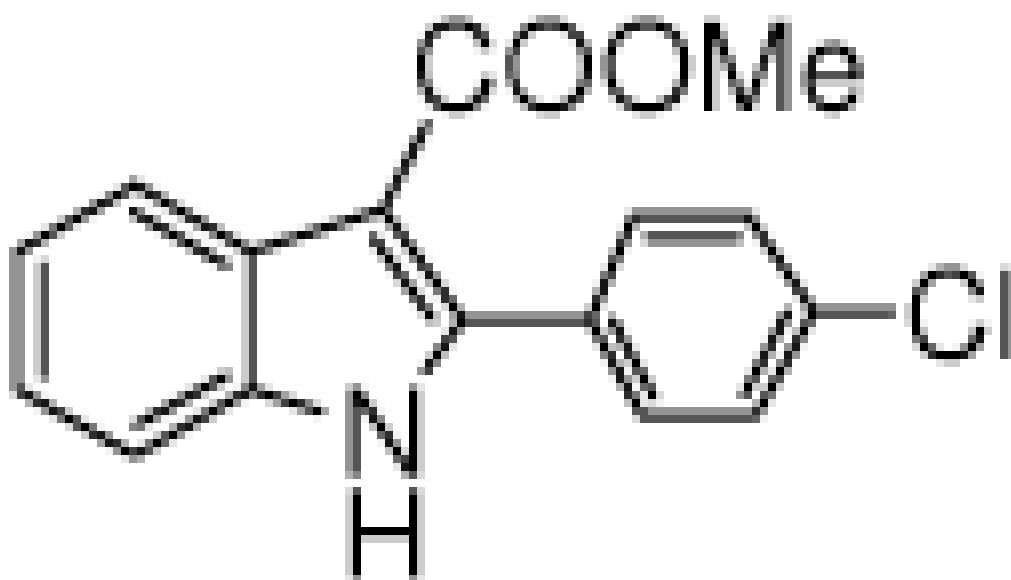




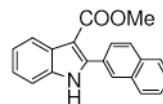
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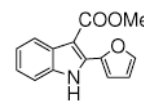
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h



i



^a Calculation of overall yield is based on compound 1.