Sequential One-Pot $InBr_3$-Catalyzed 1,4- then 1,2-Nucleophilic Addition to Enones

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Low sensitivity toward traces of moisture and high tolerance of different functional groups make indium tribromide suitable for carrying out multistep synthetic sequences. In particular, we have realized a 1,4-conjugated addition of indoles/thiols to α,β-unsaturated ketones mediated by a catalytic amount (10 mol %) of $InBr_3$ obtaining the desired β-substituted ketones in good yields. The Lewis acidity of indium salts was not affected by coordinating and acid nucleophiles; therefore, the subsequent catalytic 1,2-addition of Me_3SiCN to carbonyl compounds can be performed in one pot. With the optimized atom-efficient protocol, several polyfunctionalized α-silyloxy cyanohydrins were synthesized in good to excellent yields (up to 97%) and a notable level of simple 1,3-diastereoselection (up to 84:16) was recorded in the case of 2-cyclohexen-1-one **2c**.

Synthetic multistep procedures for the synthesis of two carbon−carbon bonds catalyzed by single multiacting Lewis acids are poorly documented,[1] and several manipulations of functional groups (protection, activation, etc.) are required.[2] With the aim of designing a Lewis acid-mediated one-pot multistep transformation, we have focused our efforts on the identification of a Lewis acid capable of catalyzing two subsequent synthetic transformations without deactivation by the presence of coordinating compounds. Recently, indium salts have emerged as powerful catalysts in many chemical processes both in aqueous and organic media.[3] For instance, indium halides are effectively used in promoting the rearrangement of epoxides,[4] in the synthesis of α-amino phosphonates[5] and quinolines,[6] in transesterification processes,[7] and in the opening reaction of epoxides with nucleophiles.[8]

In this context, it is worthy to note that, due to the remarkable tolerance of indium salts toward coordinating functional groups, even strong coordinating amines can be used in the presence of indium trichloride.[9] We have taken advantage of this compatibility in developing a practical and simple methodology for the cyanation reaction of ketones bearing strong coordinating groups using Me_3SiCN as the cyano source.[10]

The conjugate addition of nucleophiles to enones produces a carbonyl substrate that could react subsequently with Me_3SiCN (Scheme 1). However, only particular nucleophiles are suitable for this purpose. In fact, the nucleophile should contain an acidic proton capable of protonating the intermediate metallo-enolate of the Michael addition (Scheme 2a). On the other hand, if the intermediate enolate is quenched by a scavenger (i.e., a silylating agent) that traps the carbonyl group, the successive 1,2-addition reaction cannot take place (Scheme 2b). Indoles and thiols are adapted to this purpose.

Conjugate Addition of Indoles to α,β-Unsaturated Ketones Catalyzed by $InBr_3$. In the last few years, several Lewis acid-mediated Friedel−Crafts-type additions of electron-rich aromatic compounds (i.e., indoles) to enones, in the presence of a catalytic or stoichiometric amount of Lewis acids, have been published.[11,12]

This class of aromatic substitution reactions plays a relevant role in organic synthesis. In fact, the β-indolylketones obtained are highly interesting building blocks for the synthesis of biologically active compounds and natural products. We found that indoles smoothly reacted with enones at room temperature in the presence of a catalytic amount of $InBr_3$ (10 mol %) affording the desired adduct in high yields (Scheme 3).[13]

Substituted and unsubstituted indoles can be utilized in the optimized procedure (Table 1). 2-Methyl-indole **2c** furnished higher conversions in comparison to other

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(2) Nicolaou, K. C.; Vourloumis, D.; Winssinger, N.; Baran, P. S. *Angew. Chem., Int. Ed.* **2000**, *39*, 44.

(3) (a) Ranu, B. C. *Eur. J. Org. Chem.* **2000**, 2347. (b) Chauhan, K. K.; Frost, C. G. *J. Chem. Soc., Perkin Trans. 1* **2000**, 3015.

(4) Ranu, B. C.; Jana, U. *J. Org. Chem.* **1998**, *63*, 8212.

(5) Ranu, B. C.; Hajra, A.; Jana, U. *Org. Lett.* **1999**, *1*, 1141.

(6) Ranu, B. C.; Hajra, A.; Jana, U. *Tetrahedron Lett.* **2000**, *41*, 531.

(7) Ranu, B. C.; Dutta, P.; Sarkar, A. *J. Org. Chem.* **1998**, *63*, 6027.

(8) (a) Amantini, D.; Fringuelli, F.; Pizzo, F.; Vaccaro, L. *J. Org. Chem.* **2001**, *66*, 6734. (b) Fringuelli, F.; Pizzo, F.; Vaccaro, L. *J. Org. Chem.* **2001**, *66*, 3554.

(9) Reddy, L. R.; Reddy, M. A.; Bhanumathi, N.; Rao, K. R. *New J. Chem.* **2001**, *25*, 221.

(10) Bandini, M.; Cozzi, P. G.; Melchiorre, P.; Umani-Ronchi, A. *Tetrahedron Lett.* **2001**, *42*, 3041.

(11) (a) Clay catalyst: Iqbal, Z.; Jackson, A. H.; Rao, K. R. N. *Tetrahedron Lett.* **1988**, *29*, 2577. (b) $BF_3{\cdot}OEt_2$: Dujardin, G.; Poirier, J.-M. *Bull. Soc. Chim. Fr.* **1994**, *131*, 900. (c) $Yb(OTf)_3$: Harrington, P. E.; Kerr, M. A. *Synlett* **1996**, 1047. (d) $Sc(DS)_3$: Manabe, K.; Aoyama, N.; Kobayashi, S. *Adv. Synth. Catal.* **2001**, *343*, 174.

(12) For a comprehensive review focused on the asymmetric catalytic arylation reaction, see: Bolm, C.; Hildebrand, J. P.; Muñiz, K.; Hermanns, N. *Angew. Chem., Int. Ed.* **2001**, *40*, 3284.

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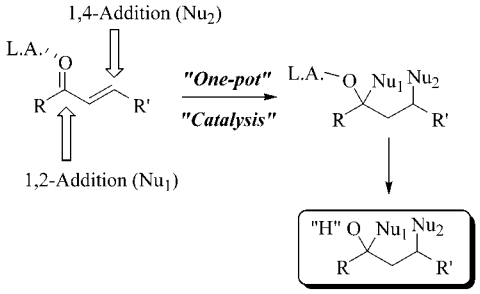
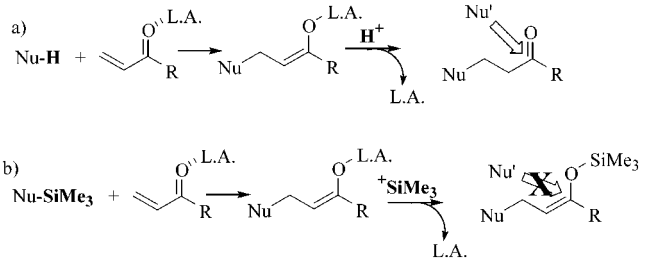
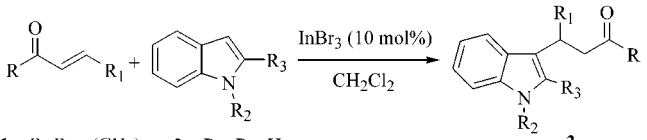
Scheme 1



Scheme 2



Scheme 3



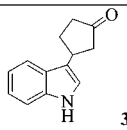
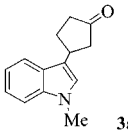
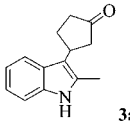
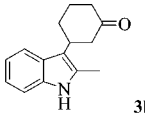
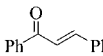
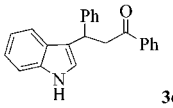
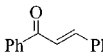
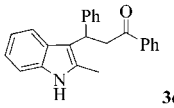
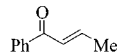
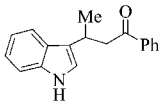
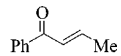
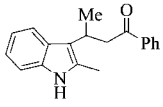
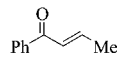
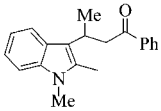
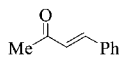
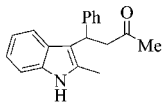
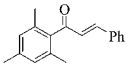
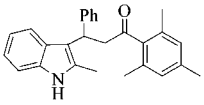
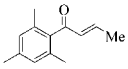
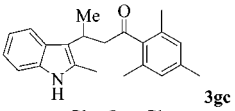
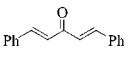
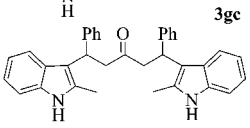
3

1a: R=R$_1$: -(CH$_2$)$_2$- **2a**: R$_2$=R$_3$: H
1b: R=R$_1$: -(CH$_2$)$_3$- **2b**: R$_2$: Me, R$_3$: H
1c: R: Ph, R$_1$: Ph **2c**: R$_2$: H, R : Me
1d: R: Ph, R$_1$: Me **2d**: R$_2$=R$_3$: Me
1e: R: Me, R$_1$: Ph
1f: R: Mes, R$_1$: Ph
1g: R: Mes, R$_1$: Me
1h: R: -CH=CHPh, R$_1$: Ph

indoles **2a** and **2b** (entries 1 and 3, Table 1). The catalytic action of the indium tribromide is evident by comparing the procedure for the 2-cyclohexen-1-one (InBr$_3$ 10 mol %, 2-Me-indole 1.5 equiv, yield = 95%) with the same reaction in the absence of catalyst. In this case, the reaction did not occur at all after 3 days (entry 4). The reaction seems to occur via a classic Friedel−Crafts alkylation pathway.[12] The NH proton of the indole does not play a significant role in the turnover of the catalytic cycle (entries 2 and 9, Table 1). The reaction can be also performed using reagent-grade CH_2Cl_2 and does not require strictly anhydrous conditions (entries 3, 4, 6, and 8, Table 1).

When α,β-unsaturated carbonyl compounds are used, the procedure appeared to be effective for both cyclic and acyclic substrates, and no significant effects of bulky aromatic substituents toward the carbonyl moiety were observed (entries 11 and 12). Of special interest is the result obtained with the symmetric enone dibenzylidenacetone (entry 13, Table 1). In this case, the presence of 10 mol % InBr$_3$ guarantees the double-conjugate 1,4-addition forming two C−C bonds in one pot in excellent isolated yield (95%). Finally, when the procedure did not afford acceptable conversions (entries 1, 2, 4, and 8), for instance, when the less electron-rich indole **2a** was utilized as the nucleophile, the presence of an external proton source (3 equiv of ^{i}PrOH) was beneficial for improving the chemical yields (entries 1 and 2).

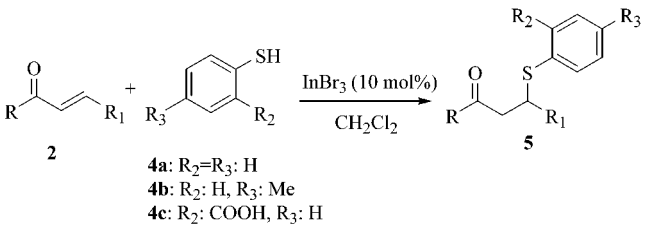
Table 1. Michael Addition of Indoles to Enones Catalyzed by InBr$_3$[a]

Entry	Enone	Indole	Product	Yield[b]
1		**2a**	 **3aa**	0[c] 45 85[d]
2		**2b**	 **3ab**	52 68[d]
3		**2c**	 **3ac**	87 67[e]
4		**2c**	 **3bc**	0[c] 95 85[e]
5		**2a**	 **3ca**	52[d]
6		**2c**	 **3cc**	73 60[e]
7		**2a**	 **3da**	89
8		**2c**	 **3dc**	83 77[e]
9		**2c**	 **3dd**	61
10		**2c**	 **3ec**	69
11		**2c**	 **3fc**	75
12		**2c**	 **3gc**	90
13		**2c**	 **3hc**	95

[a] All reactions were carried out in anhydrous CH_2Cl_2 at room temperature, employing 10 mol % InBr$_3$. [b] Chemical yields are given on the isolated product after chromatographic purification. [c] Reaction was run in the absence of catalyst. [d] Dry ^{i}PrOH was added (3 equiv with respect to the enone). [e] Undried CH_2Cl_2 was utilized as the solvent.

(13) During the preparation of this paper, J. S. Yadav et al. independently described the catalytic addition of pirroles and indoles to electron-deficient olefins in the presence of InCl$_3$: Yadav, J. S.; Abraham, S.; Reddy, B. V. S.; Sabitha, G. *Tetrahedron Lett.* **2001**, *42*, 8063. Yadav, J. S.; Abraham, S.; Reddy, B. V. S.; Sabitha, G. *Synthesis* **2001**, 2165.

Scheme 4



2 **5**

4a: R_2=R_3: H
4b: R_2: H, R_3: Me
4c: R_2: COOH, R_3: H

Table 2. Michael Addition of Aryl Thiols to Enones Catalyzed by $InBr_3$[a]

Entry	Enone	Thiol	Product	Yield (%)[b]
1	**1a**	PhSH	**5aa**	6[c] 80
2	**1a**	*p*-MePhSH	**5ab**	73
3	**1b**	PhSH	**5ba**	74
4	**1c**	PhSH	**5ca**	67
5	**1c**	*p*-MePhSH	**5cb**	61
6	**1e**	*p*-MePhSH	**5eb**	78
7	**1h**	*p*-MePhSH	**5hb**	63
8	**1c**	**4c**	**5cc**	90

[a] All reactions were carried out in anhydrous CH_2Cl_2 at room temperature, employing 10 mol % $InBr_3$. [b] Chemical yields are given on the isolated product after chromatographic purification. [c] Reaction was run in the absence of catalyst.

Conjugate Addition of Thiols to α,β-Unsaturated Ketones Catalyzed by $InBr_3$. 1,4-Selective addition of thiols is a very important reaction for the synthesis of biologically active products such as the calcium antagonist diltiazem.[14] In the literature, a large number of conjugate additions based on the activation of thiols by bases have been reported.[15] In contrast, only a few reports on the addition of thiols by activation of acceptors with Lewis acids are known.[16] Addition of sulfur nucleophiles to enones has been carried out in a similar way by the use of $InBr_3$ (Scheme 4). In Table 2 we report a list of representative results obtained with aromatic thiols (**4a**−**c**) and with numerous cyclic and acyclic ketones. Products **5** were isolated in good yields (65−90% after flash chromatography) and fully characterized. Even in the case of thiols, the reaction outcome is strictly correlated to the presence of $InBr_3$. In fact, the uncatalyzed procedure (**1a**, PhSH 1.5 equiv) gave after 2 days only 6% of the desired ketone (entry 1, Table 2). Finally, it is interesting to note that the indium-catalyzed procedure allowed also the addition of substituted aryl thiols such as the commercially available thiolsalicylic **4c** acid to **1c** affording the desired product in excellent yield after crystallization (entry 8, Table 2).

The One-Pot 1,2−1,4-Addition of Indoles/Thiols and TMSCN to α,β-Unsaturated Ketones. The excellent results obtained by $InBr_3$ in promoting both the cyanation process and the 1,4-addition prompted us to design and optimize synthetic strategies for one-pot atom-efficient catalyzed processes. The optimized reaction conditions involve the initial catalytic 1,4-Michael addition of the appropriate nucleophile to the enone (checked by TLC and GC, 16−24 h) and the subsequent 1,2-addition of TMSCN. The one-pot addition of Me_3SiCN to the resulting β-substituted ketone took place smoothly as shown by the data in Table 3.

Noteworthy is the simple stereoselectivity obtained using 2-methyl-indole **2c**. In fact, while with unsubstituted indole **2a** and acyclic enones a 1:1 mixture of diastereoisomers was generally obtained (entries 1, 2, 5, and 6, Table 3), with 2-methyl indole **2c**, the α-silyloxy-γ-indolyl nitriles **8** and **9** were isolated with good diastereoselection (74:26 and 84:16 *cis*-1,3-OTMS↔Ind as the major diastereoisomer) for 2-cyclopenten-1-one and 2-cyclohexen-1-one, respectively (entries 3 and 4, Table 3). The relative configuration of the prevalent 1,3-*cis* diastereoisomer **9** was assigned by X-ray analysis (see Supporting Information).

The simple diastereoselection observed is notable because, although the asymmetric induction of stereogenic centers near to the carbonyl moieties are well studied, 1−3 inductions are less investigated. The stereochemical trend observed, however, appeared to be strictly affected by the nature of the ketone as well. In fact, with the more flexible 2-cyclopenten-1-one, the diastereoselection obtained after the cyanation process was lower (entry 3, Table 3).

In general, the products were isolated as silylated cyanohydrins after flash chromatography in good yields. The power of the process is summarized by the one-pot procedure carried out with 2-cyclohexen-1-one. In this case, the desired indolyl-cyano derivative **9** was isolated in 87% yield using only 1 mol % $InBr_3$ (entry 4, Table 3). Moreover, the ability of $InBr_3$ in promoting double-conjugate addition and cyanation sequential on the dibenzylidenacetone allows the one-pot formation of three carbon−carbon bonds with an almost quantitative yield (97%, entry 6, Table 3).

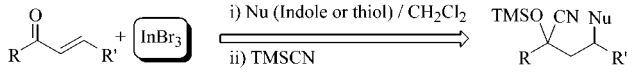
This $InBr_3$-promoted one-pot multistep process can be carried out for 1,4-Michael addition of thiols to an enone and subsequent 1,2-cyanation reaction of the carbonyl moiety. In Table 3 (entries 6−8), we collected some representative results obtained for the case of α,β-unsaturated cyclic and acyclic enones **11**−**13**. Noteworthy is the reaction of 2-cyclohexen-1-one **1b** and *p*-Me-thiophenol in the presence of 10 mol % catalyst that gave the desired α-silyloxy-γ-thiophenol nitriles **13** with moderate 1,3-diastereoselectivity (75:25, yield = 69%).

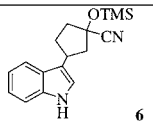
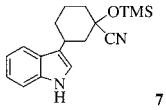
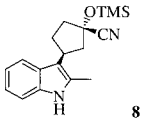
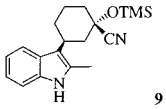
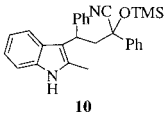
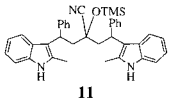
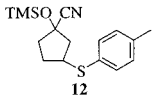
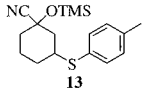
(14) Sheldon, R. A. *Chirotechnologies, Industrial Synthesis of Optically Active Compounds*; Dekker Publishing: New York, 1993.

(15) Chiral bases such as amino alcohols, lithium thiolate complexes of amino bis-ether, and lanthanoid (binaphthoxide) were also extensively utilized in promoting the 1,4-addition. See: Hiemstra, H.; Wiberg, H. *J. Am. Chem. Soc.* **1981**, *103*, 417. Suzuki, K.; Ikekawa, A.; Mukaiyama, T. *Bull. Soc. Chem. Jpn.* **1982**, *55*, 3277. Yamashita, H.; Mukaiyama, T. *Chem. Lett.* **1985**, 363. Nishimura, K.; Ono, M.; Nagaoka, Y.; Tomioka, K. *J. Am. Chem. Soc.* **1997**, *119*, 12974. Emori, E.; Arai, T.; Sasai, H.; Shibasaki, M. *J. Am. Chem. Soc.* **1998**, *120*, 4043.

(16) Kanemasa, S.; Oderaotoshi, Y.; Wada, E. *J. Am. Chem. Soc.* **1999**, *121*, 8675 and refs cited therein.

Table 3. One-Pot 1,2−1,4-Addition to Enones Catalyzed by $InBr_3$



Entry	R, R'	Nucleophiles	Product	Yield (%)[b]	d.r. *cis:trans*
1	R=R'= -$(CH_2)_2$-	**2a** / TMSCN	 **6**	52[d]	50:50
2	R=R'= -$(CH_2)_3$-	**2a** / TMSCN	 **7**	47[d]	50:50
3	R=R'= -$(CH_2)_2$-	**2c** / TMSCN	 **8**	55	74:26[c]
4	R=R'= -$(CH_2)_3$-	**2c** / TMSCN	 **9**	87[e]	84:16[c]
5	R=R' = Ph	**2c** / TMSCN	 **10**	52	61:39[f]
6	R= CH=CHPh R' = Ph	**2c** / TMSCN	 **11**	97	1:1:1:1
7	R=R' = -$(CH_2)_2$-	**4b** / TMSCN	 **12**	58	50:50
8	R=R' = -$(CH_2)_3$-	**4b** / TMSCN	 **13**	69	75:25[f]

[a] All reactions were carried out in anhydrous CH_2Cl_2 at room temperature, employing 10 mol % $InBr_3$. [b] Chemical yields are given on the isolated product after chromatographic purification. [c] Relative configuration was assigned on the basis of GC retention times and ^1H and ^{13}C NMR signals in comparison to the *cis*/*trans* diastereoisomers **9**. [d] Reaction was carried out in dry toluene. [e] Reaction was run in the presence of 1 mol % $InBr_3$. [f] Relative configuration was not assigned.

In summary, the unique properties of indium tribromide allowed us to introduce new concepts of one-pot multistep organic synthesis mediated by Lewis acids and suggest indium salts as a possible answer for the increasing demand of clean and atom-efficient carbon−carbon bond-forming processes. In fact, such a class of weak Lewis acids could be the right choice for performing subsequent organic transformations with high overall yields. Further studies addressing the extension of these concepts to different organic reactions and to an enantioselective version of chiral Lewis acid-catalyzed transformations will be explored in our laboratory.

Experimental Section

General. Chemical shifts of ^1H NMR spectra are given in parts per million with respect to TMS, and coupling constants *J* are measured in hertz. Data are reported as follows: chemical shifts, multiplicity (s = singlet, d = douplet, t = triplet, q = quartet, br = broad, m = multiplet). ^{13}C NMR spectra were with complete proton decoupling. Chemical shifts are reported in parts per million from TMS with the solvent as the internal standard (deuteriochloroform δ = 77.0 ppm; deuteriodimethyl sulfoxide δ = 39.0 ppm). GC-MS spectra were recorded with GC injection and EI ionization at 70 eV. They are reported as *m*/*z* (relative intensity). Flash column chromatographies were run over 270−400 mesh silica gel. Anhydrous CH_2Cl_2 was purchased and used as received. All the commercially available ketones were freshly distilled or crystallized before use. The α,β-usaturated ketones **1d**,[17] **1e**,[18] **1f**,[17] and **1g**[17] were synthesized following the literature. X-ray analysis was performed on a diffractomer equipped with a CCD detector and graphite monochromated Mo Kα radiation (λ = 0.71073 Å). The data handling was performed using the SMART software package. IR spectra of neat compounds are expressed as wavenumbers (cm^{-1}).

Typical Experimental Procedure for the Catalytic Addition of Thiophenols and Indoles to α,β-Unsatured Ketones Mediated by Anhydrous $InBr_3$. A flamed two-necked flask was charged, under a nitrogen atmosphere, with 2 mL of anhydrous CH_2Cl_2, $InBr_3$ (11 mg, 0.03 mmol), and 0.3 mmol of carbonyl compound. The mixture was stirred until the indium tribromide was completely dissolved. Finally, the desired nucleophile (0.45 mmol) was added.[19] This clear solution was then stirred at room temperature until the disappearance of the ketone (16−24 h, checked by TLC). Then, the reaction was quenched with a saturated solution of $NaHCO_3$ (3 mL) and extracted with Et_2O (3 × 3 mL). The organic phases were combined, dried over Na_2SO_4, and concentrated under reduced pressure, and the crude mixture was purified by flash chromatography.

3-(3-Indolyl)-cyclopentan-1-one (3aa): yield 85% (with 3 equiv of *i*PrOH); 6:4 *c*Hex/Et_2O; ^1H NMR (200 MHz, $CDCl_3$) δ 2.14−2.33 (m, 2 H), 2.37−2.52 (m, 3 H), 2.72−2.85 (m, 1 H), 3.63−3.3.82 (m, 1 H), 7.00 (d, *J* = 2.2 Hz, 1 H), 7.16−7.26 (m, 2 H), 7.38−7.42 (m, 1 H), 7.63 (dd, *J* = 1.1 Hz, *J* = 7.6 Hz, 1 H), 8.06 (br, 1 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 29.74, 33.56, 38.07, 45.21, 111.27, 118.06, 118.82, 119.12, 119.90, 121.99, 126.36, 136.50, 219.67; GC-MS *m*/*z* (rel intensity) 63 (8), 89 (10), 115 (25), 143 (100), 156 (22), 170 (36), 199 (69); IR (neat) 3409, 2957, 2924, 1733, 1457, 1400, 1229, 742 cm^{-1}; Anal. Calcd for $C_{13}H_{13}NO$: C, 78.36; H, 6.58; N, 7.03. Found: C, 78.21; H, 6.52, N, 7.01.

Typical Experimental Procedure for the Catalytic One-Pot Addition of Thiophenols/Indoles and TMSCN to α,β-Unsatured Ketones Mediated by $InBr_3$. A flamed two-necked flask was charged, under a nitrogen atmosphere, with 2 mL of anhydrous CH_2Cl_2, $InBr_3$ [0.03 mmol (1 mol %) or 0.3 mmol (10 mol %)], and 3 mmol of carbonyl compound. The mixture was stirred until the indium tribromide was completely dissolved, and then the desired nucleophile [thiol or indole (4.5 mmol)] was added. This clear solution was then stirred at room-temperature overnight (about 18 h) until the disappearance of the starting α,β-unsatured ketone (checked by TLC and GC-MS). The chromatographic analysis detected the formation of the 1−4 conjugate addition adduct. TMSCN (9 mmol) was added by syringe, and the mixture was stirred at room temperature for 3 h. Finally, the reaction was quenched with a saturated solution of $NaHCO_3$ (3 mL) and extracted with Et_2O (3 × 3 mL). The organic phases were combined, dried over Na_2SO_4, and concentrated under reduced pressure, and the crude mixture was purified by flash chromatography.

1-Cyano-1-trimethylsilyloxy-3-(2-methyl-3-indolyl)-cyclohexane (9): yield 87%; 85:15 *c*Hex/Et_2O; diastereomeric mixture = 84:16; ^1H NMR (200 MHz, $CDCl_3$) δ 0.25 (s, 9 H), 1.65−1.98 (m, 4 H), 2.18−2.35 (m, 2 H), 2.42 (s, 3 H), 2.38−2.44 (m, 2 H), 3.07−3.18 (m, 1 H), 7.05−7.15 (m, 2 H), 7.27−7.30 (m, 1 H), 7.59−7.64 (m, 1 H), 7.74 (br, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ (major diasteroeisomer) 1.51, 11.97, 23.46, 26.87, 30.90, 39.39, 45.39, 71.98, 100.12, 110.47, 113.49,

(17) Pitts, M. R.; Harrison, J. R.; Moody, C. J. *J. Chem. Soc., Perkin Trans. 1* **2001**, 955.
(18) Kohler, B. *J. Am. Chem. Soc.* **1933**, *55*, 6920.
(19) For the procedure employing *i*PrOH, the secondary alcohol was added after the nucleophiles.

118.74, 120.58, 121.74, 130.29, 135.19; (minor diastereoisomer) δ 1.22, 12.05, 20.75, 29.29, 99.89, 110.17, 114.07, 122.68, 130.09; GC-MS *m*/*z* (rel intensity) 59 (2), 73 (15), 115 (12), 130 (20), 144 (100), 157 (41), 170 (41), 184 (31), 221 (16), 258 (30), 283 (39), 311 (9), 326 (72); IR (neat) 3410, 3049, 2942, 2864, 2250, 1692, 1613, 1461, 1253, 1124, 848, 735 cm^{-1}; Anal. Calcd for $C_{19}H_{26}N_2OSi$: C, 69.89; H, 8.03; N, 8.58. Found: C, 69.77; H, 7.97; N, 8.57.

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Supporting Information Available: Physical properties and spectroscopic data for the compounds **3ab**, **3ac**, **3bc**, **3ca**, **3cc**, **3da**, **3dc**, **3dd**, **3ec**, **3fc**, **3hc**, **3gc**, **5aa**, **5ab**, **5ba**, **5ca**, **5cb**, **5eb**, **5hb**, **5cc**, **6**−**8**, and **10**−**13**; tables of crystal data for the compound **9** (bond lengths and angles, atomic coordinates, and anisotropic thermal parameters); and the relative configuration of the prevalent 1,3-*cis* diastereoisomer **9**. This material is available free of charge via the Internet at http://pubs.acs.org.

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