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Friedel–Crafts Reaction of Indoles with Aldehydes Catalyzed by a Scandium-Based Coordination Polymer

Pennapa Tungjratthitikan,[1] and Hiroshi Furuno[2]

[1]*Interdisciplinary Graduate School of Engineering Sciences, Kyushu University*

[2]*Green Asia Education Center, Kyushu University*

Kasuga-koen, Kasuga, Fukuoka 816-8580, Japan,

Abstract

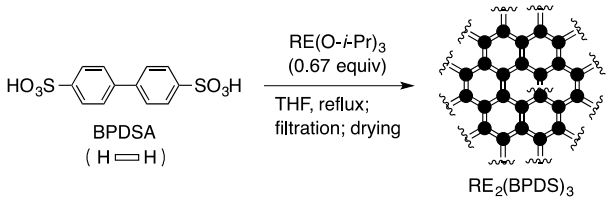
Air-stable scandium-based coordination polymer, trivalent scandium biphenyl-4,4'-disulfonate [$Sc_2(BPDS)_3$], effectively catalyzed the Friedel–Crafts reaction of indoles with aromatic aldehydes under heterogeneous conditions, and aryl(diindolyl)methanes were obtained in high chemical yields. After the reaction, the catalyst could be recovered and reused for the next reaction without serious loss of the activity.

1. Introduction

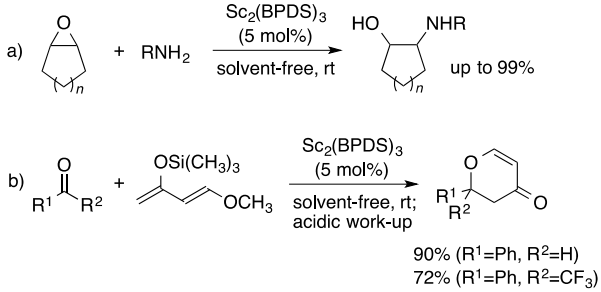
Utilization of heterogeneous catalysts in organic transformations has attracted much attention from environmentally-friendly practical and economical points of view because they generally have an advantage in recover and reuse over homogeneous ones. In particular, coordination polymer-type catalysts have recently attracted much attention due to easy preparation by simply mixing a metal ion, a multi-way ligand, and other components, relatively large surface areas with regularly dispersed active centers, and so on.

We have focused on the unique characteristics of the rare earth metal salts of strong acids, which could easily handle in air and effectively work as a Lewis acid catalyst even in the presence of Brønsted bases such as water and amines, and have synthesized rare earth arylsulfonates complexes, $RE_2(BPDS)_3$, as a rare earth metal-based coordination polymer (Scheme 1) [1–3]. The scandium complex could effectively catalyze the ring-opening of epoxides with amines, and the hetero-Diels–Alder reaction of aldehydes or ketones with the Danishefsky's diene under heterogeneous conditions (Scheme 2). These reactions smoothly proceeded at room temperature, particularly under solvent-free conditions, and the products were obtained in high yields. After the reaction, the catalysts could be easily recovered by simple filtration or centrifugation, and reused for the next reaction for several times without any loss of the catalytic activity.

We therefore applied the scandium catalyst to the Friedel–Crafts reaction of indoles with aromatic aldehydes under heterogeneous conditions, in order to extend usefulness of the coordination polymer as a reusable catalyst in organic syntheses.



Scheme 1. Preparation of rare earth coordination polymer complexes $RE_2(BPDS)_3$



Scheme 2. $Sc_2(BPDS)_3$-catalyzed reactions: (a) the ring-opening of epoxides with amines; (b) the hetero-Diels–Alder reaction of carbonyl compounds with the Danishefsky's diene

2. Results and Discussion

The Friedel–Crafts reaction was carried out by mixing pre-dried $Sc_2(BPDS)_3$ (2.5 mol%: 5 mol% for Sc), an indole (2 equiv) and an aldehyde in a solvent under argon. The scandium catalyst effectively promoted the reaction between various indoles and aromatic aldehydes under

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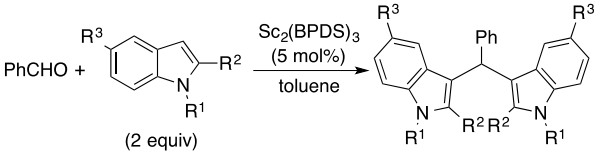
heterogeneous conditions, and the corresponding aryl[di(3-indolyl)]methanes were obtained in high yields (Tables 1 and 2). The reaction of 3-methylindole with benzaldehyde afforded di(2-indolyl)phenylmethane in high yield (Scheme 3). The $Sc_2(BPDS)_3$ also catalyzed the reaction of 7-azaindole (Scheme 3).

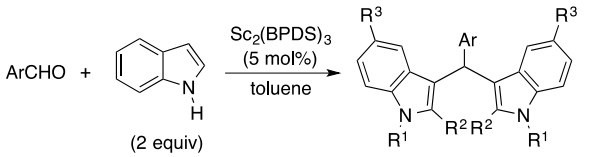
Table 1. $Sc_2(BPDS)_3$-catalyzed Friedel–Crafts reaction of indoles with benzaldehyde



Entry	R^1	R^2	R^3	Conditions	Yield (%)[a]
1	H	H	H	30 °C, 0.5 h	>99
2	Me	H	H	60 °C, 2 h	39
3	H	Me	H	100 °C, 25 h	42
4	H	H	Me	60 °C, 0.5 h	>99
5	H	H	OMe	60 °C, 0.5 h	>99
6	H	H	Br	30 °C, 12 h	>99
7	H	H	NO_2	100 °C, 48 h	50

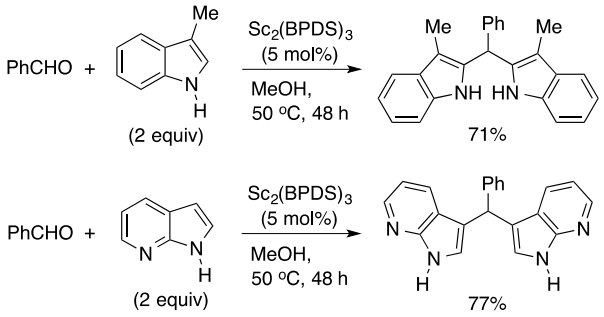
[a] Determined by NMR.

Table 2. $Sc_2(BPDS)_3$-catalyzed Friedel–Crafts reaction of indole with aromatic aldehydes



Entry	Ar	Conditions	Yield (%)[a]
1	2-HO-C_6H_4	30 °C, 24 h	72
2	4-HO-C_6H_4	30 °C, 24 h	>99
3	4-MeO-C_6H_4	30 °C, 24 h	>99
4	4-Br-C_6H_4	60 °C, 48 h	>99
5	4-F-C_6H_4	60 °C, 48 h	>99
6	4-NC-C_6H_4	60 °C, 24 h	95
7	4-O_2N-C_6H_4	100 °C, 24 h	54
8	2-HO-4-Br-C_6H_3	30 °C, 24 h	99

[a] Determined by NMR.



Scheme 3. $Sc_2(BPDS)_3$-catalyzed Friedel–Crafts reaction of 3-methylindole or 7-azaindole with benzaldehyde

The reusability of $Sc_2(BPDS)_3$ was also checked in the Friedel–Crafts reaction of 5-methylindole with benzaldehyde (30 °C, 6 h). After the reaction, the catalyst was separated from the product and substrates by centrifugation, and then reused for the next reaction after drying by heating. It was confirmed that $Sc_2(BPDS)_3$ could be used at least three times without serious loss of the catalytic activity (1st use: 99%, 3rd use: 82%).

3. Conclusion

We succeed in applying the scandium coordination polymer $Sc_2(BPDS)_3$ to the Friedel–Crafts reaction of various indoles with aromatic aldehydes. We also confirmed that the catalyst could be recovered and reused without serious loss of the catalytic activity even in the 3rd use.

Acknowledgment

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Reference

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Email: 3ES15030Y@ s.kyushu-u.ac.jp