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Design of a Bifunctional Ir–Zr Based Metal–Organic Framework Heterogeneous Catalyst for the N-Alkylation of Amines with Alcohols

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The direct N-alkylation of amines with alcohols was performed with an Ir–Zr-based metal–organic framework multifunctional heterogeneous catalyst. This system is efficient and environmentally benign for the synthesis of various organic amines in

air in the absence of a base. The catalyst was recovered and reused without significant loss of activity, and only water was produced as a byproduct.

Introduction

The N-alkylation of amines is a reaction of fundamental importance in organic synthesis because the resulting higher amines are widely used as synthetic intermediates for pharmaceuticals, agrochemicals, fine chemicals, dyes, surfactants, and functionalized materials.^[1] The most frequently used method for the preparation of N-alkyl amines is the coupling of amines with alkyl halides^[2] in the presence of stoichiometric amounts of inorganic bases. An alternative environmentally benign approach to these methods is the N-alkylation of amines with alcohols as alkylating agents. The advantages of the use of alcohols instead of alkyl halides/carbonyl compounds are the availability of the former that produces only water as a byproduct, has high atom efficiency, and avoids toxic reagents and stoichiometric reducing agents.^[3,4] Although there are efficient homogeneous catalytic systems using metal salts and Ir,^[5] Ru,^[6] Rh,^[7] Pd,^[8] Au,^[9] Ni,^[10] Cu,^[11] Fe,^[12] and Os^[13] complexes, the still indispensable use of cocatalysts such as bases and stabilizing agents and limitations for catalyst recycling are factors that need improvement. Meanwhile, other syntheses with metal-free protocols require harsh reaction conditions to achieve reasonable yields of products.^[14]

Heterogeneous catalysts have some advantages over homogeneous catalysts, such as low cost, tolerance to a wide range of temperatures and pressures, easy and inexpensive removal from the reaction mixture through simple filtration or centrifu-

gation, easy and safe disposal, safe storage, long lifetimes, increased eco-friendliness, regenerability, and reusability. In the past few years, heterogeneous catalysts such as Pd/MgO^[15] or Fe₂O₃,^[8] Ag/Mo or Ag/Al₂O₃,^[16] Au/TiO₂,^[9] and copper–aluminum hydrotalcite^[17] were developed for the N-alkylation of amines. However, most of them required harsh reaction conditions.

Zr-based metal–organic frameworks (MOFs; UiO66-NH₂) have a large specific surface area and pore size as well as good chemical resistance to water and organic solvents, which result in desirable properties for catalytic applications.^[18] These new, highly stable materials, after the adequate postsynthetic modification, can act as heterogeneous catalysts that combine the properties of soluble organometallic complexes with those of the MOF as a support. We have described that Rh- and Ir–Zr-based MOFs can be used as multifunctional catalysts for one-pot and cascade reactions.^[19] Herein, we show that it is possible to develop an environmentally friendly synthetic method for the N-alkylation of amines with alcohols by using a bifunctional Ir–Zr-MOF and working under mild reaction conditions.

Results and Discussion

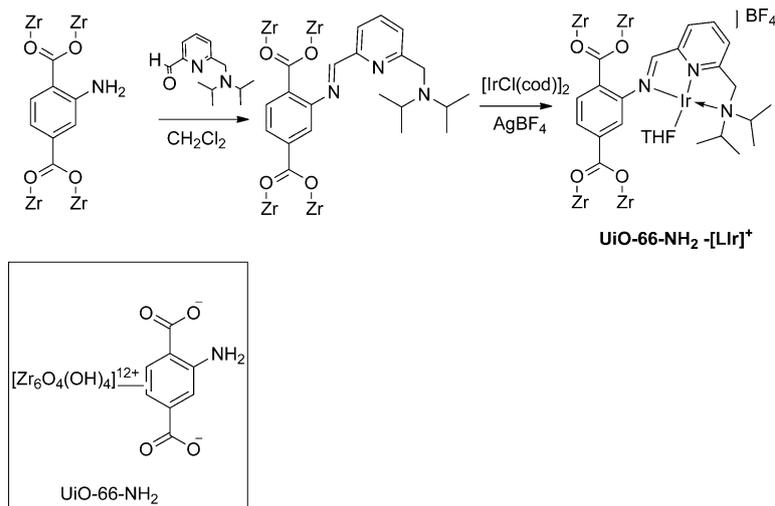
An Ir–Zr-MOF catalyst was prepared by using the method described previously (Scheme 1).^[19] The starting material was UiO66-NH₂^[18a–20] because the presence of NH₂ groups in the linker (2-aminoterephthalic acid) enables the functionalization of the material and generation of an Ir complex attached to UiO66-NH₂. In addition, UiO66-NH₂ possesses Lewis acid sites (Zr), which gives rise to a bifunctional catalyst that combines acidity and metallic sites. As described earlier,^[19] the ¹³C NMR (see Figures S1 and S2 in the Supporting Information) and FTIR (see Figures S3 and S4 in the Supporting Information) spectra of the resulting samples are dominated by the bands assigned to the parent groups and by the skeletal modes of MOFs (i.e., bands in the FTIR spectra at 1600–1585, 1500–1430, and 700 cm⁻¹). The functional groups obtained from the postsynthetic modification of the starting UiO66-NH₂ material can be

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Scheme 1. Preparation of Ir-Zr-MOF.

observed in the full spectral range, which is the intensity proportional to the level of conversion, particularly the band at 760 cm^{-1} , which is assigned to the C–C vibrational mode in aromatic compounds and which does not overlap with other vibrational modes. The stability of the modified UiO66-NH₂-MOFs was examined by using thermogravimetric analysis (Figure 1). The modified samples show thermal stabilities comparable with those of UiO66-NH₂ with decomposition tempera-

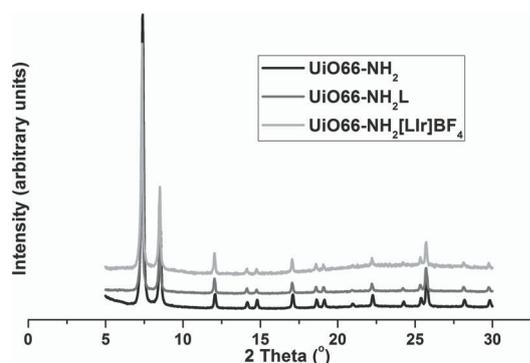


Figure 1. XRD patterns of UiO66-NH₂, UiO66-NH₂-L, and UiO-66NH₂-[LrIr]BF₄.

tures near $350\text{ }^{\circ}\text{C}$ in air (see Figure S7 in the Supporting Information). The results of N₂ adsorption further confirm the stability of the porous structure after the formation of the Ir complex attached to the framework (see Figure S8 in the Supporting Information).

The SEM images show that no textural changes in the materials occurred after the postsynthetic treatment. In any case, the observed Ir sites were homogeneously dispersed in the samples (Figure 2). The TEM image (Figure 3) does not confirm the presence of Ir nanoparticles.

X-ray photoelectron spectroscopy (XPS) analysis was performed on Zr-[LrIr]-MOF. The sample was kept in vacuum overnight before XPS measurements. The spectrum was calibrated with respect to the C 1s peak. The survey scan XPS spectrum of the Zr-[LrIr]-MOF samples (see Figure S12 in the Supporting Information) confirms the presence of Ir in addition to the UiO66 framework elements (Zr, C, N). The XPS spectrum shows N 1s (399.1 eV) and C 1s signals, and the latter comprises sp^2 carbon (284.6 eV) and sp^3 carbon neighboring oxygen (287.9 eV). The XPS core level for Ir (the Ir 4f region) shows peaks at 64.8 and 62.1 eV (assigned to Ir 4f_{7/2} and Ir 4f_{5/2}), which indicates the Ir³⁺ oxidation state in the samples.^[21]

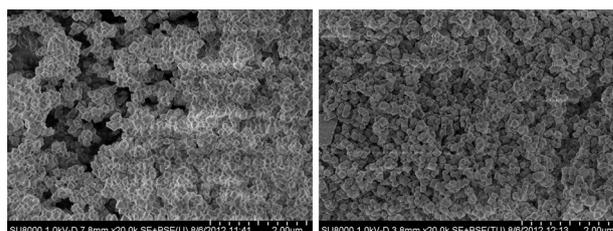


Figure 2. SEM images of a) UiO66-NH₂-L and b) UiO66-NH₂-[LrIr]BF₄.

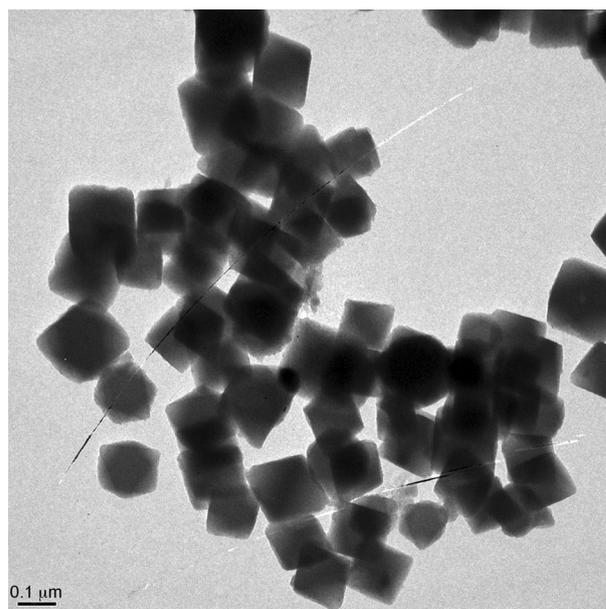
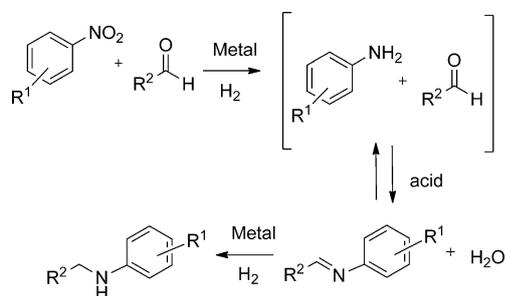


Figure 3. TEM image of UiO66-NH₂-[LrIr]BF₄.

Catalyst screening for the alkylation of amines with alcohols

Reaction with auxiliary H₂

We have shown that supported Au, Pt, Ni, and Ru nanoparticles can be used to perform the chemoselective amination of ketones and aldehydes with nitroarenes.^[22] In a recent paper,^[19a] we have reported on the use of the Ir-MOF catalyst for the atom economic synthesis of mono-*N*-alkyl amines through the reductive amination of aldehydes with nitroarenes in the presence of H₂. The process involves firstly a chemoselective reduction of the nitro compound to the corresponding amine with H₂ in the presence of the carbonyl substrate on the Ir site. Then, the condensation between the aromatic amine and the carbonyl group would occur on the acid sites of the catalyst (MOF support) (Scheme 2). Finally, the hydrogenation of the resulting imine with the Ir complexes would give the secondary amine.



Scheme 2. One-pot synthesis of secondary amines catalyzed by Ir-Zr-MOF in the presence of H₂. R¹ = H, 4-I, 4-Br, 4-OCH₃; R² = Ph, OCH₃Ph, C₆H₁₃.

As Ir complexes have shown to be active for performing the N-alkylation of amines with alcohols, we used the Ir-Zr-MOF catalyst for such a type of reaction because large pores of UiO66-NH₂ (2.69 nm) would allow free diffusion of reactants and products and thus the use of UiO66-NH₂ is an efficient way to heterogenize the Ir complex. Thus, the N-alkylation of amines was performed in 2-propanol (1 bar H₂ pressure; 1 bar = 100 kPa) with the neutral [LrCl] complex as a homogeneous catalyst and good conversion and selectivities were obtained (Table 1, entries 1 and 2). In contrast, the catalytic evaluation of Ir-MOF catalysts was performed by mixing them with nitrobenzene in 2-propanol in an Autoclave Engineers reactor (100 mL) at 80 °C under 4–6 bar H₂ pressure. Thus, the N-alkylation of the amine with the alcohol occurs, and with the use of the heterogeneous Zr-[LrCl] (0.4 mol%) complex as a catalyst, high conversion and selectivity were obtained, which were higher than those obtained with the homogeneous catalyst. The activity of the homogeneous catalyst could be increased significantly with the substitution of the chloride ligand by a less coordinating counterion such as [BF₄][−]. With the use of this anion, activity was also higher for the Zr-[IrL]BF₄ catalyst, which was again similar to the activity of the homogeneous catalyst. The temperature could be lowered to 50 °C; however, longer reaction time was needed to obtain high conversion.

Table 1. N-Alkylation of amines with alcohols^[a] with Ir-Zr-MOF-supported catalysts.^[a]

$R-NH_2 + R'-OH \xrightarrow[80^\circ C]{1-6 \text{ bar } H_2, \text{ Cat. } 0.2\%} R-NH-R'$				
Catalyst	H ₂ pressure [bar] ^[b]	R	R'	Yield [%] (h) ^[c]
1 [LrCl] (3 mol%)	1	Ph	Et	100 (6)
2 [LrCl] (3 mol%)	4	Ph	<i>i</i> Pr	99 (20)
3 Zr-[LrCl] (0.4 mol%)	4	Ph	<i>i</i> Pr	100 (20)
4 Zr-[LrCl] (0.4 mol%)	6	Cy	<i>i</i> Pr	70 (20)
5 Zr-[Lr] ⁺ (0.25 mol%)	6	Ph	2-Bu	100 (24)
6 Zr-[Lr] ⁺ (0.25 mol%)	6	Cy	2-Bu	85 (24)
7 blank	6	Ph	Et	5 (24)
8 [Lr] ⁺ (0.2 mol%)	4	Ph	Et	100 (10)
9 Zr-[Lr] ⁺ (0.2 mol%)	4	Ph	Et	100 (4)
10 [Lr] ⁺ (0.2 mol%)	4	Bn	<i>i</i> Pr	100 (23)
11 Zr-[Lr] ⁺ (0.2 mol%)	4	Bn	<i>i</i> Pr	70 (4)

[a] Reaction conditions: Autoclave Engineers reactor, 1 mmol of amine substrate, 40 mL of alcohol, T = 80 °C; [b] 1 bar = 100 kPa; [c] Yields are based on amine substrates.

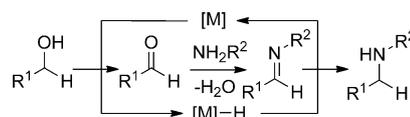
After identifying the potential of Zr-[Lr]BF₄ as a catalyst, we investigated the scope and limitations of this transformation. Various primary or secondary alcohols could be coupled with aniline, which gave monoalkylated amines in high yields. Although primary alcohols react to produce the corresponding amines in a few hours, secondary alcohols proved to be less reactive and longer reaction times were required.

For the N-alkylation of aniline with ethanol (Table 1, entries 1, 8, and 9), the supported Ir-Zr-MOF catalyst was superior to the corresponding soluble Ir complex, which indicates that the Ir complex moiety in the heterogeneous catalyst is crucial and the support material Zr-MOF also plays an important role in promoting the reaction. This effect can be related to the Lewis acidity of the Zr cluster, which promotes the imine formation and introduces an additional benefit from the point of view of increasing H₂ concentration and/or stabilizing the reaction transition state, as reported previously.^[23]

Reaction in the absence of H₂

Of all the catalysts examined before, Zr-[Lr]BF₄ demonstrated the best catalytic performance, and therefore, we decided to use this system for the N-alkylation of amines in the absence of H₂ by using a H₂ borrowing mechanism (Scheme 3).^[15,24,25]

The reaction was conducted with 0.2 mol% Zr-[Lr]BF₄ (based on Ir), and the scope of N-alkylation was explored with different combinations of substrates (primary, such as 1-hexylamine; reactive cyclic secondary amines, such as piperidine; and



Scheme 3. N-alkylation of amines with alcohols in the absence of H₂ and base.

Table 2. N-Alkylation of amines with alcohols catalyzed by Zr-[Llr]BF₄.

$$\text{R-NH}_2 + \text{R}'\text{-OH} \xrightarrow{\text{Cat. 0.2\%}} \text{R-NH-R}'$$

Entry	Alcohol	Amine	T [°C]	t [h]	Yield [%] ^[a]	TOF [h ⁻¹] ^[b]
1		H ₂ N-CH ₂ -C ₅ H ₁₁	80 ^[c]	2	100	940
2		H ₂ N-CH ₂ -C ₅ H ₁₁	80 ^[c]	24	100	22
3			80 ^[c]	2	100	450
4			80 ^[c]	2	100	570
5			80 ^[c]	6	10	–
6			120 ^[d]	2	100	202
7			80 ^[d]	6	10	–
8		H ₂ N-CH ₂ -C ₅ H ₁₁	120 ^[d]	0.5	100	980
9		H ₂ N-CH ₂ -C ₅ H ₁₁	180 ^[d]	24	10	–
10			125 ^[e]	2	42	105
11			150 ^[e]	2.5	90	180
12			150 ^[e]	2	0	–
			150 ^[e]	2	0	–

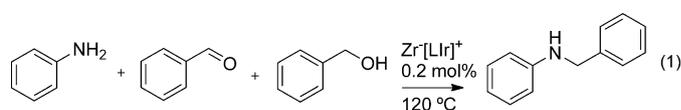
[a] Products were characterized by NMR, mass spectra, and yields of isolated products are based on amine substrates; [b] TOF = turnover frequency; $\text{mmol}_{\text{substrate}} \text{mmol}_{\text{catalyst}}^{-1} \text{h}^{-1}$. [c] Autoclave Engineers reactor, 0.20 mol % catalyst (based on Ir), 1 mmol of amine substrate, 40 mL of alcohol; [d] Glass microreactor (Supelco), 0.20 mol % catalyst (based on Ir), 1 mmol of amine substrate, 2 mL of alcohol; [e] Microwave reactor.

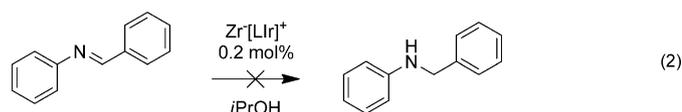
alcohols). Excess amount of the alcohol was used not only as a reactant but also as a solvent. Various amines reacted with different alcohols in the presence of Zr-[Lr]BF₄ and afforded moderate to excellent yields of the corresponding N-alkylated products (Table 2). The reaction of 1-hexylamine and piperidine with ethanol gives the desired product in high yields (Table 2, entries 1 and 3), whereas the reaction with an aliphatic secondary alcohols such as 2-butanol occurs only with 1-hexylamine (Table 2, entry 2). The reaction with tertiary *tert*-butanol does not occur.

The reaction of piperidine or hexylamine with benzyl alcohol occurs at 120 °C in high yields (Table 2, entries 6 and 8); however, the reaction with aniline was unsuccessful even at higher temperature (180 °C) (entry 9), and the application of microwave heating was necessary to achieve results comparable with those achieved using thermal heating for other substrates (entries 10 and 11). The reaction did not proceed in the absence of a catalyst or with UiO66-NH₂-L (before forming the Ir complex), which suggests that the reaction proceeds through the direct involvement of Ir.

The accepted mechanism for the alkylation of amines with alcohols in the absence of H₂ involves three steps: alcohol dehydrogenation, reaction of the resulting carbonyl with the amine to form the imine, and hydrogenation of the imine with the hydride complex formed in the first step (Scheme 3). In the reaction of alcohols with amines, we could not detect the intermediate imine product. This result indicates that either the hydrogenation of the imine formed in an external cycle is fast or that the entire catalytic cycle occurs with all the intermediates attached to the catalysts; in our case supported by the presence of an hemilabile amino group in the ligand,^[26] the intermediate aldehyde remains coordinated to the Ir complex and reacts with the amine to give the hemiaminal group, which is also attached to the catalyst; dehydration to the imine and reduction to the product amine would also occur without breaking the coordination to the catalyst, as has been proposed by Yamaguchi et al.^[27] and Madsen et al.^[28]

To support these mechanistic approach, we performed the reaction of aniline (1.0 mmol) with benzaldehyde (1.0 mmol) in benzylic alcohol in the presence of catalytic amounts of Zr-[Lr]BF₄ at 100 °C for 1 h and obtained *N*-benzylaniline quantitatively [Eq. (1)] (see Figure S12). Moreover, the reduction of benzylideneaniline (1.0 mmol) in the presence of catalytic amounts of Zr-[Lr]BF₄, with 2-propanol as a sacrificial alcohol to form the iridium hydride intermediate, resulted in the formation of traces of *N*-benzylaniline [Eq. (2)], whereas the preformed imine is reacted exactly under the same reaction conditions with 4 bar H₂ pressure (see Figure S12 in the Supporting Information). This result suggests that the uncoordinated imine could not undergo transfer hydrogenation with the present catalytic system. Thus, the fact that the imine was never detected makes us favor a reaction mechanism using the MOF catalyst in which the entire catalytic cycle occurs with all the intermediates attached to the catalyst.^[27,28]





Catalyst leaching and recycling

An experiment was performed to check whether the metal or the metal complex leaching occurs during the reaction and whether the leached species are totally or partially responsible for the catalyst activity. Then, the reaction of hexylamine with ethanol was stopped by hot filtration of the catalyst at 30% of the amine formation. No further reaction occurred if the filtrate was used to continue the reaction (Figure 4). This result indi-

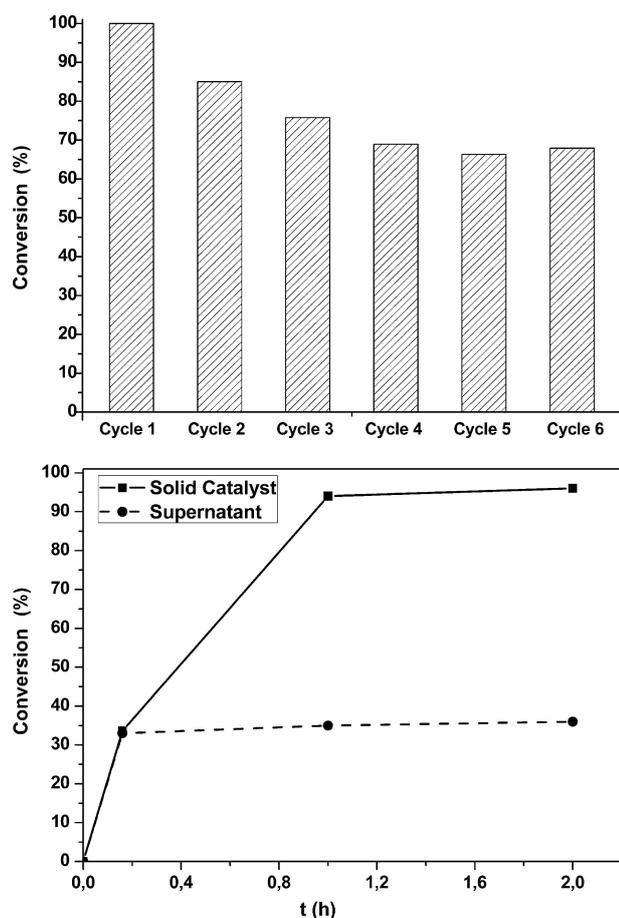


Figure 4. Results of the a) recycling experiment and b) hot filtration test.

cates that the catalytic process is heterogeneous. Furthermore, the inductively coupled plasma analysis of the filtrate confirms that the Ir content was below the detection limit (< 0.10 ppm). The used catalyst was also analyzed by using XRD, SEM, and TEM, and the results are presented in Figures 5–7, which indicate that the catalyst remains structurally stable during the catalytic process.

From the point of view of their reusability, the results presented in Figure 4 indicate a decrease in activity during the

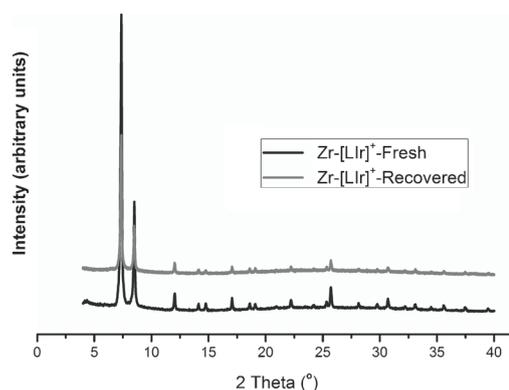


Figure 5. Powder XRD patterns of Zr-[Llr]⁺-Fresh and Zr-[Llr]⁺-Recovered.

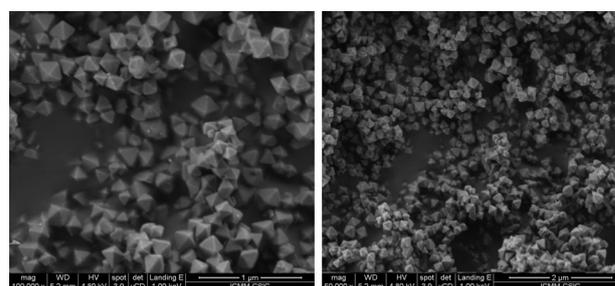


Figure 6. SEM images for a) Fresh UiO-66-NH₂-[Llr]BF₄ and b) UiO-66-NH₂-[Llr]BF₄ recovered from the reaction

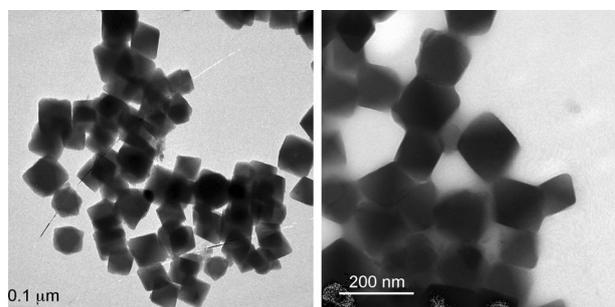


Figure 7. TEM images of a) fresh UiO66-NH₂-[Llr]BF₄ and b) recovered UiO66-NH₂-[Llr]BF₄.

first four cycles, which remains stable or decays much more slowly after four cycles. The used catalyst has also been studied by using FTIR spectroscopy, and the presence of new bands related to amino groups indicates that some of the reaction products can remain adsorbed on the catalyst and this may affect the loss of activity observed, especially in the initial cycles.

Conclusions

We have found that the Ir-Zr-based metal–organic framework is a highly efficient catalyst for producing higher amines from amines and alcohols. Notably, this system readily catalyzes the

N-alkylation of aliphatic alcohols. Notable advantages offered by this method are broad substrate scope, high atom economy (only water is a byproduct), reusability of the catalyst, environmentally benign, higher yields of the desired products, and a simple workup procedure, which makes it an attractive and useful methodology for organic synthesis. The use of recycled UiO66-NH₂-[Llr]BF₄ for N-alkylation reactions with different substrates also produces the desired products in high yields. The fact that the integrity and bifunctionality of both the Ir complex and the Zr metal-organic framework support are maintained in consecutive runs meets the objective set to combine the properties of a homogeneous and a heterogeneous catalyst system into those of one sustainable hybrid catalyst system.

Experimental Section

Reagents and materials

Starting materials were purchased and used without further purification from commercial suppliers (Sigma-Aldrich and Alfa Aesar). Dried, distilled, and deoxygenated solvents were used. All the chemicals were used as-received. Postsynthetic modification reactions were performed by using standard Schlenk techniques.

Synthesis of Ir-Zr-MOF

The synthesis of UiO66-NH₂, a Zr-based MOF, was performed by using a method similar to that described elsewhere.^[17a]

Synthesis of Zr-L-MOF, [Zr₆O₄(OH)₄(BDC-NH₂)_{6-x}L_x] (L = 6-(diisopropylamino)methyl)picolinaldehyde)

UiO66-NH₂ (1.5 g, 1.6 mmol) was dispersed in CH₂Cl₂ (15 mL). To this slurry, a solution of an aldehyde (375.0 mg, 1.7 mmol) in CH₂Cl₂ (5 mL) was added dropwise at RT, and the mixture was stirred for additional 6 h. The sample was collected by centrifugation, washed twice with CH₂Cl₂, and dried in air at 70 °C. Elemental analysis was performed on samples outgassed under vacuum (100 °C, 12 h).

Elemental analysis calcd (%) for Zr₆O₄(OH)₄(BDC-NH₂)_{5.7}(BDC-L)_{0.3} (corresponding to ≈ 5% amine functionalization): C 34.35, H 2.19, N 5.09; found: C 34.45, H 2.64, N 5.07; ¹³C NMR (400 MHz, CP-MAS): δ = 17.8 (CH₃_{ipr}), 45.8 (CH_{ipr}), 50.6 (CH₂), 116.1, 123.0, 132.1, 138.5, 151.4, 162.8 (imine C=N), 171.2 ppm (COO).

Synthesis of Zr-[Llr]BF₄-MOF, [Zr₆O₄(OH)₄(BDC-NH₂)_{6-x}-[Llr]BF₄]_x

AgBF₄ (8.7 mg, 0.044 mmol) was added to a solution of [IrCl(cod)]₂ (cod = 1,5-cyclooctadiene; 15 mg, 0.022 mmol) in THF (10 mL) at RT, and the mixture was stirred for 1 h. Then, AgCl was filtered and the solution containing [Ir(cod)]BF₄ was added to a suspension of UiO66-NH₂-L (100 mg) in THF (10 mL). The mixture was stirred for 10 h; the solid was collected by centrifugation, washed twice with THF, and dried in air at 70 °C. Elemental analysis was performed on samples outgassed under vacuum (100 °C, 4 h).

Elemental analysis calcd (%) for Zr₆O₄(OH)₄(BDC-NH₂)_{5.7}[Llr]BF₄_{0.3}: C 33.65, H 2.25, N 4.80; found: C 32.92, H 2.56, N 4.54. The amount of Ir in the final solid was determined by using inductively coupled

plasma atomic emission spectroscopy. Calcd (%): Ir 2.99; found: Ir 2.7.

Characterization

All the samples were characterized systematically by applying various analytical and spectroscopic techniques; details can be found in the Supporting Information.

Catalytic measurements

Method a

The N-alkylation reaction was performed in an Autoclave Engineers reactor (100 mL). The amines were added to the catalyst suspension (0.2 mmol of Ir) in the alcohol (40 mL). The reactor was hermetically sealed, pressurized with H₂ (4 bar), and heated under continuous stirring. Small liquid aliquots (≈ 100 μL) were taken. The progress of the reaction was monitored by using GC-MS. The reaction mixture was filtered, and the solvent was removed under reduced pressure to give the crude product.

Method b

The N-alkylation reaction was performed in a glass microreactor (2.0 mL, Supelco Analytical) equipped with a magnetic bar and sensors for both temperature and pressure control. The amine (1 mmol) was added to the catalyst suspension (19.2 mg, 0.002 mmol of Ir) in the alcohol (1 mL). The reactor was hermetically sealed and heated at 80–120 °C under continuous stirring. Small liquid aliquots (≈ 10 μL) were taken. The progress of the reaction was monitored by using GC-MS. After disappearance of the amine, the reaction mixture was cooled to RT. The catalyst was removed by filtration and rinsed with ethyl acetate; the removal of the solvent in vacuum yielded a crude residue. All the products were identified on the basis of NMR and mass spectral data.

Recycling of Zr-[Llr]BF₄-MOF

After the completion of the reaction, the catalyst was recovered through the separation of solid Ir-MOF from the liquid by extensive centrifugation. The recovered catalyst was washed thrice with CH₂Cl₂ and then with ether, and finally the catalyst was dried at 100 °C for 12 h and reused. The Zr-[Llr]BF₄-MOF catalyst showed consistent activity for five cycles.

Hot filtration test of Zr-[Llr]BF₄-MOF

A mixture of Zr-[Llr]BF₄ (2.4 mg, 0.0002 mmol of Ir), the amine (2.2 μL, 0.02 mmol), and the alcohol (1.0 mL) was placed in a closed glass reactor (2.0 mL, Supelco) and stirred vigorously at 80 °C for 30 min. The conversion was approximately 30%. Then, the solid catalyst was quickly separated after filtration of the reactant mixtures. And the liquid was kept at 80 °C under vigorous stirring for 2 h. The conversion was 32%. The conversion in the blank thermal reaction without any catalyst at 80 °C was approximately 2%.

Acknowledgements

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Keywords: bifunctional catalyst · heterogeneous catalyst · iridium · N-alkylation · Zr-based MOF

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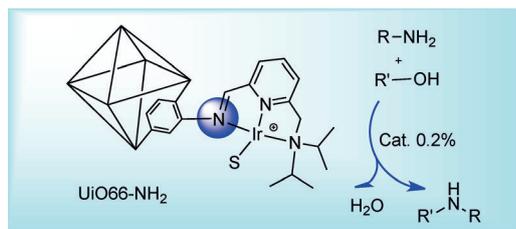
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FULL PAPERS

A. M. Rasero-Almansa, A. Corma,*
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 **Design of a Bifunctional Ir–Zr Based Metal–Organic Framework Heterogeneous Catalyst for the N-Alkylation of Amines with Alcohols**



Better be direct than elusive: The direct N-alkylation of amines with alcohols is performed with an Ir-Zr-based metal-organic framework multifunctional heterogeneous catalyst. This system is efficient and environmentally benign

for the synthesis of various organic amines in air in the absence of a base. The catalyst is recovered and reused without significant loss of activity, and only water is produced as a byproduct.