**SYNLETT Spotlight 301**

This feature focuses on a reagent chosen by a postgraduate, highlighting the uses and preparation of the reagent in current research.

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**Ytterbium Triflate: A Green Catalyst**

Compiled by Carina I. C. Crucho

Carina I. C. Crucho was born in Almada, Portugal in 1985. She received her Applied Chemistry Degree from the Faculdade de Ciências e Tecnologia of Universidade Nova de Lisboa in 2007. Presently she is working towards her M.Sc. degree in bioorganic chemistry under the supervision of Prof. Manuela Pereira at the same university. Her research is focused on ligand design and asymmetric organocatalysis.

**REQUIMTE, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal.**

E-mail: carinacrucho@gmail.com

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**Introduction**

Ytterbium triflate (1) is known to be a useful mild, versatile, and environmentally friendly Lewis acid catalyst. With the ever-increasing interest in the sustainable development, Yb(OTf)₃ benefits from its characteristic features: High efficiency in green media, such as water and ionic liquids, recovery after reaction completion, and reusing without loss of activity. Contrary to other Lewis acids, Yb(OTf)₃ is effectively used in catalytic amounts and is widely employed in organic synthesis promoting several carbon–carbon and carbon–heteroatom bond formation, which include the aldol condensations, Mannich-type reaction, Diels–Alder cycloadditions, Friedel–Crafts acylation or alklylation, and heterocycle synthesis. Moreover, taking its advantage of the affinity to nitrogen-containing compounds, which deactivate most Lewis acids, Yb(OTf)₃ enhances the reactivity of the imine group and catalyses an imine ene reaction providing useful homoallylic amines, and also increases the yield of the Ugi four-component coupling.

**Preparation**

Ytterbium triflate is commercial available but can also be readily prepared from ytterbium oxide (Yb₂O₃) and a solution of trifluoromethanesulfonic acid (TfOH) in deionized water (1:1 v/v).

**Scheme 1 Preparation of ytterbium triflate (1)**

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**Abstracts**

(A) **One-Pot Synthesis of Dihydropyrimidines (DHPMs):**

The highly efficient chiral ytterbium catalyst 5 has been developed and successfully employed in the multicomponent Biginelli reaction providing an enantioselective synthesis of chiral DHPMs 6. This one-pot cyclocondensation of 1,3-ketoester 2, aldehyde 3, and urea or thiourea 4, is accomplished in high yields and excellent enantioselectivity as well as high atom economy and safe waste as the catalyst could be recovered and reused several times without loss of ee. The DHPMs scaffold is an important pharmacophore and can be converted into other derivatives with potential pharmaceutical application.

(B) **Synthesis of 1,3-Oxazolidines:**

Yb(OTf)₃ promotes the solvent-free reaction of N-arylimines 8 and epoxides 7 to yield the corresponding [3+2] cycloaddition products 9. This easy and environmentally sound method gives the products in high yields. 1,3-Oxazolidines are often used as chiral auxiliaries and intermediates in organic synthesis.

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(C) Oxidation–Cannizzaro Reaction:
An eco-friendly method for the synthesis of either isopropyl esters 11 or α-hydroxyarylacetic acids 13 from substituted aromatic glyoxals 10 and aryl methyl ketones 12, respectively, in the presence of Yb(OTf)_3 was reported. The products were isolated in good to excellent yields.\(^7\)

\[
\text{Ph}CHO + \text{ArCH}_2\text{CH}_2\text{OH} \xrightarrow{\text{Yb(OTf)}_3, \text{i-PrOH}, 80 \degree C} \text{Ph}COOCH\text{CH} = \text{CH} = \text{COOH}
\]

\[
\text{Yb(OTf)}_3, \text{dioxane-H}_2\text{O, 90 \degree C} \xrightarrow{} \text{Ph}COOH + \text{CO}_2\text{H}
\]

\[
\text{OH} \xrightarrow{R = 4-\text{t-BuC}_6\text{H}_4, \text{2-pyridyl}, \text{i-Bu}} \text{Yb(OTf)}_3 (10 \text{ mol\%}) \xrightarrow{\text{MeCN, 0 \degree C, 90 min}} \text{OH} + \text{O}
\]

\[
\text{CO}_2\text{Me} \xrightarrow{\text{Yb(OTf)}_3 (5 \text{ mol\%})} \text{OMe}
\]

\[
\text{OH} + \text{CO}_2\text{R}_4 \xrightarrow{\text{Yb(OTf)}_3, \text{CuCl(OH), TMEDA or CuCl-(S)Phbox, THF, O}_2, \text{r.t.}} \text{OH} + \text{CO}_2\text{R}_4
\]

\[
\text{N} \xrightarrow{\text{Yb(OTf)}_3 (10 \text{ mol\%})} \text{N}
\]

(D) Catalytic Pictet–Spengler Reaction:
Kobayashi and co-workers have developed an efficient regioselective synthesis of synthetically useful isoquinoline derivatives (16). The cyclization between m-tyramine (14) and various aldehydes (15) occurred mainly at the para position to the phenolic hydroxyl group and gave the products in good to excellent yields.\(^8\)

(E) Conjugate Addition of β-Ketoesters to Activated Quinones:
Kimpe and co-workers reported the conjugated addition of various β-ketoesters 17 to activated 1,4-naphthoquinones 18 mediated by catalytic amounts of Yb(OTf)_3. The adducts 19 were obtained in excellent yields.\(^9\)

(F) Selective Oxidative Cross-Coupling:
Yb(OTf)_3 is used along with an achiral or a chiral copper complex in the synthesis of naphthol derivatives 22. Employing this binary catalyst system the cross-coupling proceeded in a specific manner. In addition, when the copper complex was chiral the enantioselectivity were significantly affected. The latter procedure allows the synthesis of versatile chiral auxiliaries that have been successfully employed in asymmetric synthesis.\(^10\)

(G) Mild and Efficient Aza-Diels–Alder (ADA) Reaction:
Six-membered nitrogen heterocycles display a wide range of potent biological activity and have aroused great synthetic interest. Recently, a very convenient route towards the synthesis of quinoline and phenanthridine derivatives 25 from the reaction of cyclopentadiene or cyclo-1,3-hexadiene 24 with various N-arylimines 23 by using Yb(OTf)_3 as catalyst was described. The conversion into an ionic liquid as a green reaction medium was also conducted.\(^11\)

\[
\text{R} = 4-\text{t-BuC}_6\text{H}_4, \text{2-pyridyl}, \text{i-Bu}
\]

\[
\text{OMe}
\]

\[
\text{CO}_2\text{Me}
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\[
\text{OH}
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\text{N}
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References