

INFORMATION ABOUT THE NEW CONTRIBUTIONS AND NOVELTY OF THE ACADEMIC, THEORETICAL THESIS

- PhD Student: **NGUYEN VAN TU**
- Thesis name: Introducing fluorine and trifluoromethyl group into organic compounds under heterogeneous transition metal catalysis
- Major: Chemical Engineering
- Major Code: 62.52.03.01
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- The abstract of new contribution in relation to the academic, theoretical aspects and the novelty of the thesis:

The purpose of the thesis is to develop the novel and more effective strategies to furnish fluorine containing compounds employing readily, inexpensive and effective methods under heterogeneous transition metal catalysis. Moreover, the wide scope and functional group tolerance are also under our consideration. From our knowledge, there has been no work utilizing the heterogeneous catalysts to introduce fluorine into organic molecules so far.

The contributions and novelty of the thesis might be generalized as following:

In this thesis, the introduction of fluorine into organic compounds was successfully conducted. Specifically, the deboronative trifluoromethylation of boronic acids was accomplished under the heterogeneous catalysis of the metal organic frameworks (MOFs) $\text{Cu}(\text{INA})_2$, and the decarboxylative fluorination of the aliphatic acids was successfully carried out using nanoparticles AgFeO_2 as the heterogeneous catalyst. The MOFs $\text{Cu}(\text{INA})_2$ and nanopowder AgFeO_2 were synthesized based upon the former researches. From our perspective, these are the novel approaches without any publications in the literature precedent.

$\text{Cu}(\text{INA})_2$ was prepared by the solvothermal process. The material characterization was determined by several modern techniques inclusive of XRD, FT-IR, TGA and ICP-MS. The characterization results revealed that our $\text{Cu}(\text{INA})_2$ had the same structures as that of $\text{Cu}(\text{INA})_2$ in various preceding publications. These results also confirmed that the building block unit of the framework is composed of Cu(II) square-pyramidal geometry linked by five isonicotinate ligands while the carboxylate oxygen atoms from the other two isonicotinate ligands occupy the rest of the two vertices. There was notably each free oxygen atom on every carboxylate unit, which made the MOFs structure more compatible with the trifluoromethylation reaction. This structure would also result in weak interaction between copper centers within the network

structure, which could help the $\text{Cu}(\text{INA})_2$ more stable in the fluorine containing environment. Using $\text{Cu}(\text{INA})_2$ for the deboronative trifluoromethylation was the first approach in the scientific community from our consideration.

Silver ferrite oxide AgFeO_2 nanoparticles was also synthesized and used for the decarboxylative fluorination of aliphatic acids. From our perspective, that was also the first approach in the fluorine chemistry, which has not had a publications ever before yet. The AgFeO_2 was prepared by the co-precipitation in the aqueous media, and was then heated at 180°C during 24 h. They were characterized by a variety of techniques including XRD, SEM, TEM, XRF and TGA. The characterization results exhibited the similarity among the synthesized AgFeO_2 and the standard spectrum of JCPDS PDF 21-1081 and others from preceding developments. Interestingly, AgFeO_2 nanoparticles were previously employed in some approaches applied to pharmaceutical and anti-bacterial industry relying on the anti-bacterial property of silver. The previous publications witnessed the vital role of silver in the fluorination of various compounds, whereas iron had the key role toward the acceleration of the decarboxylation reaction. Therefore, the combination of silver and iron in the fluorodecarboxylation reaction was paid attention to. And in fact, the results of our experiments were unexceptionally obtained with that combination.

Reactions using two materials as stated above as catalysts were conducted to select the best conditions inclusive of temperature, solvent, ligand, etc. The chosen catalysts were compared to other potential ones to show off their compatibility with the reaction conditions. The heterogeneity and recycleability were also carried out in the conditions. Moreover, they were used many times in the same reaction conditions without any considerable degradation in the reaction yields. The two reactions were as following:

Reaction 1: Deboronative trifluoromethylation of boronic acids under the heterogeneous $\text{Cu}(\text{INA})_2$ catalysis. The reaction was conducted at the room temperature in 2 hours. The isolated yields for various substrates with different substitutions were 40 - 80%. The catalyst was reused 4 times without any significant degradation in the reaction yields. The characterization of recycled catalyst revealed the structural stability of this catalyst in the reaction conditions.

The results from this reaction were published on the MOLECULAR CATALYSIS ISI magazine as following information: “Tu V. Nguyen, Toan D. Ong, Anh H.M. Lam, Vu. T. Pham, Nam T.S. Phan, Thanh Truong, *Nucleophilic trifluormethylation of aryl boronic acid under heterogeneous $\text{Cu}(\text{INA})_2$ catalysis at room temperature: The catalytic copper-based protocol*. Molecular Catalysis, 2017. **436**: p. 60-66. (DOI: 10.016/j.mcat.2017.04.010) (**IF = 4.0**)”

Reaction 2: Fluorodecarboxylation of the aliphatic acids under the heterogeneous AgFeO_2 catalysis. The reaction was conducted at the room temperature in 3 hours. The isolated yields for various substrates with different substitutions were 41 - 93%. The catalyst was reused 6 times without any significant degradation in the reaction yields. The characterization of

recycled catalyst revealed the structural stability of this catalyst compared to the initial sample in the reaction conditions. The roles of silver and iron were also investigated, and the discovering experiments exhibited the main catalyst of silver and additional acceleration of iron in the decarboxylation reaction. The cooperativity of two metals in nanoparticles illuminated the reaction progress with higher yield compared to using them separately.

The results from this reaction were published on the JOURNAL OF CATALYSIS ISI magazine as following information: “Tu V. Nguyen, Vu T. Pham, Tin V.T. Nguyen, Nam T.S. Phan, Thanh Truong, *Decarboxylative fluorination of aliphatic carboxylic acids under heterogeneous delafossite AgFeO₂ nanoparticle catalysis: the utilization of bimetallic cooperativity*. Journal of Catalysis, 2018. **360**: p. 270–276. (DOI: 10.1016/j.jcat.2018.02.018) **(IF = 7.0)**”

The expected products of each reaction were determined by GC-MS, ¹H-NMR, ¹³C - NMR và ¹⁹F - NMR.

The novelty of the thesis is that the usage of MOFs Cu(INA)₂ in the deboronative trifluoromethylation of boronic acids and AgFeO₂ nanoparticles in the fluorodecarboxylation of aliphatic acids were the first approaches in the fluorine chemistry from our perspective. The chosen catalysts exhibited the unexpected compatibility with the reaction conditions, which was showed via the wide substrate scope, high to excellent yields with most of the compounds and the catalyst recyclability over times without any significant degradation.

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