CURRENT ADVANCEMENTS IN CROSS-COUPLING REACTIONS CATALYZED BY NICKEL

Shagun Goyat*

Abstract

In contemporary synthetic chemistry, nickel-catalyzed processes have become indispensable instruments, providing effective and adaptable methods for assembling intricate organic compounds. Recent developments in nickel catalysis are highlighted in this article. Asymmetric catalysis, C-H functionalization, and cross-coupling reactions are just a few of the transformations in which nickel catalysts have proven to be remarkably effective. Furthermore, nickel is a cheaper and more readily available material for catalysis than precious metals. This abstract offers a succinct summary of the major advancements in nickel catalysis, highlighting the metal's usefulness in facilitating a variety of synthetic transformations and its potential to solve problems in modern organic synthesis.

Keywords: Nickel catalysis, Synthetic applications, Cross-coupling reactions, C-H activation

[*]AIJHM College Rothak

DOI: 10.53555/ecb/2022.11.4.054

Introduction

Nickel catalysis's adaptability, effectiveness, and affordability have made it a mainstay of contemporary organic synthesis.[1] Significant developments in nickel-catalyzed reactions over the last few decades have made it possible for chemists to access complex molecular architectures with previously unheard-of efficiency. An overview of the significance of nickel catalysis in modern synthetic chemistry is given in this introduction, along with information on its salient characteristics, synthetic uses, and applicability to sustainable chemical processes.[2] Due to its wide range of catalytic transformations, nickel, a transition metal that is widely available in nature, has gained interest as a catalyst. Because of its adaptable coordination chemistry and variable reactivity in a variety of oxidation states, nickel catalysts can be produced using a broad range of synthetic techniques. In addition, nickel's abundance and cheap price in relation to valuable metals like platinum and palladium make it a desirable substitute for catalytic applications.[3]

The ability of nickel catalysis[4] to efficiently promote cross-coupling reactions is one of its defining characteristics. This field has grown exponentially since the 1980s, when Miyaura and Suzuki published their groundbreaking work on the nickel-catalyzed cross-coupling of organoboron compounds with organic halides.[5] A wide range of coupling partners, such as aryl, alkyl, and heteroaryl substrates, can now be used in nickel-catalyzed cross-coupling reactions to create a variety of biaryl and polyfunctionalized compounds.[6]

Furthermore, it is impossible to overestimate the sustainable elements of nickel catalysis. Nickel's low toxicity and availability on Earth, along with its catalytic ability, make it an important catalyst for the development of environmentally friendly and sustainable chemical processes. Nickel catalysis supports the development of environmentally friendly synthetic techniques and is consistent with green chemistry principles by minimizing the need for rare and costly metals.[7] Nonetheless, nickel catalysis is a fundamental aspect of contemporary synthetic chemistry, providing effective and adaptable methods for assembling intricate organic compounds. Because of its adaptability, efficiency, and sustainability, nickel catalysis is essential for pushing the boundaries of chemical synthesis and solving the synthetic problems of the twenty-first century.

Literature Review

The scope and effectiveness of synthetic transformations have been increased by recent advances in nickel-catalyzed reactions, providing creative answers to challenging synthetic problems. Here, we highlight a few noteworthy approaches that have developed in the field:

Nickel-Catalyzed Cross-Coupling Reactions

Recent developments in nickel-catalyzed cross-coupling reactions have increased the efficiency of this revolutionary technique and expanded the range of substrates that can be used.[8] For example, aryl-aryl and aryl-alkyl bond formation have been achieved through the development of nickel-catalyzed Suzuki-Miyaura and Negishi couplings, respectively. Particularly for substrates that are difficult to couple with palladium catalysis, these reactions provide useful substitutes for conventional palladium-catalyzed cross-couplings.

C-H Functionalization

One effective method for directly functionalizing inactive C-H bonds is nickel-catalyzed C-H functionalization.[9] The synthesis of complex compounds with high efficiency and atom economy has been made possible by recent approaches that concentrate on the selective activation of particular C-H bonds under mild reaction conditions. Techniques like distant functionalization and controlled C-H activation have been developed to access a variety of structural motifs with good stereo- and regiocontrol.

Asymmetric Catalysis

Significant advancements in nickel-catalyzed asymmetric transformations have made it possible to synthesize highly selective enantioenriched molecules.[10] To manage the stereochemistry of processes catalyzed by nickel, chiral ligands and catalyst systems have been developed, making it easier to manufacture chiral building blocks and pharmaceutical intermediates. In this context, nickel-catalyzed asymmetric allylation, arylation, and hydrogenation processes have proven especially notable.

Reductive Cross-Electrophile Coupling

Reductive cross-electrophile coupling processes catalyzed by nickel have proven to be a flexible technique for forming C-C bonds from easily accessible starting materials.[11] In these reactions, two electrophilic partners are coupled under mild reaction conditions. Nickel catalysts are frequently used in conjunction with appropriate reducing agents. Complex molecules, such as heterocycles and biaryl compounds, can be synthesized with great efficiency and functional group tolerance using reductive cross-coupling processes.

Cascade Reactions

It has been discovered that nickel-catalyzed cascade reactions are effective methods for quickly assembling complicated chemical structures from straightforward precursors.[12] These reactions allow the synthesis of structurally varied compounds in a single operation by including several bond-forming processes catalyzed by a single nickel species. The synthesis of natural products, medications, and other bioactive molecules has made use of cascade reactions, demonstrating the effectiveness and usability of this synthetic method.

Therefore, by providing effective, sustainable, and selective methods for the synthesis of complex organic compounds, recent developments in nickel-catalyzed reactions have revolutionized synthetic chemistry. These approaches show a lot of promise for solving the present synthetic problems and moving the field toward more effective and ecologically friendly synthetic techniques. It is expected that nickel catalysis will become more and more important in the creation of novel synthetic techniques and their applications in numerous chemical synthesis and drug discovery fields as this field of study continues to advance.

Conclusion

In conclusion, nickel catalysis is a revolutionary force in modern organic synthesis, providing a host of advantages from adaptability and efficiency to sustainability. Furthermore, it is impossible to overestimate the sustainable elements of nickel catalysis. Because nickel is a common and affordable transition metal, it can be used as a substitute for precious metals in catalysis, which lessens the impact on the environment and the need for rare resources. Nickel catalysis supports the development of greener and more sustainable chemical processes by advancing the concepts of green chemistry, supporting international efforts to create a more sustainable future.

References

1. Phapale, V.B. and Cárdenas, D.J., 2009. Nickel-catalysed Negishi cross-coupling reactions: scope and mechanisms. *Chemical Society Reviews*, *38*(6), pp.1598-1607.
2. Yadav, M. and Sharma, R.K., 2019. Heterogenized nickel catalysts for various organic transformations. *Current Opinion in Green and Sustainable Chemistry*, *15*, pp.47-59.
3. Chiusoli, G.P. and Cassar, L., 1967. Nickel-Catalysed Reactions of Allyl Halides and Related Compounds. *Angewandte Chemie International Edition in English*, *6*(2), pp.124-133.
4. Tasker, S.Z., Standley, E.A. and Jamison, T.F., 2014. Recent advances in homogeneous nickel catalysis. *Nature*, *509*(7500), pp.299-309.
5. Han, F.S., 2013. Transition-metal-catalyzed Suzuki–Miyaura cross-coupling reactions: a remarkable advance from palladium to nickel catalysts. *Chemical Society Reviews*, *42*(12), pp.5270-5298.
6. Zhang, Y.F. and Shi, Z.J., 2018. Upgrading cross-coupling reactions for biaryl syntheses. *Accounts of Chemical Research*, *52*(1), pp.161-169.
7. Yadav, M. and Sharma, R.K., 2019. Heterogenized nickel catalysts for various organic transformations. *Current Opinion in Green and Sustainable Chemistry*, *15*, pp.47-59.
8. Diccianni, J.B. and Diao, T., 2019. Mechanisms of nickel-catalyzed cross-coupling reactions. *Trends in Chemistry*, *1*(9), pp.830-844.
9. Khake, S.M. and Chatani, N., 2020. Nickel-catalyzed C− H functionalization using a non-directed strategy. *Chem*, *6*(5), pp.1056-1081.
10. Sun, X.Y., Yao, B.Y., Xuan, B., Xiao, L.J. and Zhou, Q.L., 2022. Recent advances in nickel-catalyzed asymmetric hydrofunctionalization of alkenes. *Chem Catalysis*, *2*(11), pp.3140-3162.
11. Liu, Y., Li, P., Wang, Y. and Qiu, Y., 2023. Electroreductive Cross-Electrophile Coupling (eXEC) Reactions. *Angewandte Chemie International Edition*, *62*(45), p.e202306679.
12. Bhakta, S. and Ghosh, T., 2021. Nickel-Catalyzed Cascade Reactions. *European Journal of Organic Chemistry*, *2021*(29), pp.4201-4215.