SCHOOL OF APPLIED SCIENCES
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INNOVATIVE RESEARCH WRITE UP

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Abstract

The chemical synthesis in our environment is increasing day by day. Advancements in chemistry have led to the production of medicines to alleviate our pain, polyester to keep us warm, and fertilizers to provide our crops with nutrients. These same advancements have also generated numerous toxic chemicals, from the insecticides sprayed on our crops to the compounds found in water-based paints. Green chemistry is a field of chemistry focused on the development of sustainable and environmentally friendly methods for the synthesis of chemicals. One area of research in green chemistry is the synthesis of benzimidazoles, a class of heterocyclic compounds with various biological activities. Benzimidazoles have been found to have potential applications in medicine, agriculture, and materials science. They have been studied as potential anti-cancer and anti-inflammatory agents, as well as fungicides and herbicides.

They have also been used in the synthesis of polymers and other materials. The traditional methods for synthesizing benzimidazoles involve the use of harsh conditions and toxic reagents. However, green chemistry approaches have been developed to reduce the environmental impact of these synthesis methods. One example of a green chemistry method for the synthesis of benzimidazoles is the use of microwave-assisted synthesis. This method uses microwaves to heat the reactants, reducing the need for high temperatures and reducing the amount of energy required for the reaction. Another example is the use of catalysts derived from renewable resources, such as enzymes or biomass-derived compounds. These catalysts can promote the formation of benzimidazoles with less toxicity and waste generation compared to traditional methods. Overall, the use of green chemistry methods for the synthesis of benzimidazoles can greatly reduce the environmental impact of this process and make the production of these compounds more sustainable. Further research in this area is needed to continue to develop green chemistry methods for the synthesis of benzimidazoles and other compounds.

INTRODUCTION

Benzimidazole is a heterocyclic aromatic organic compound with the molecular formula C_7H_6N2. It is a white or off-white powder that is insoluble in water. Benzimidazoles have a wide range of biological and pharmaceutical applications, including anthelmintics, fungicides, and human and veterinary medicine. They also have the potential as anticancer, anti-inflammatory, and antiparasitic agents. In research, benzimidazoles have been studied for their potential to inhibit protein-protein interactions, which makes them a promising target for drug discovery.

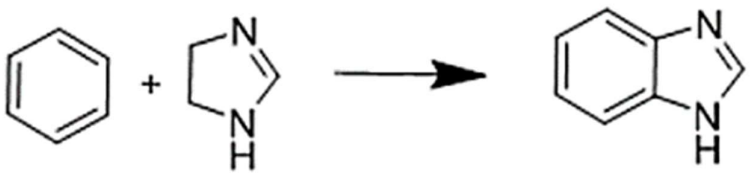
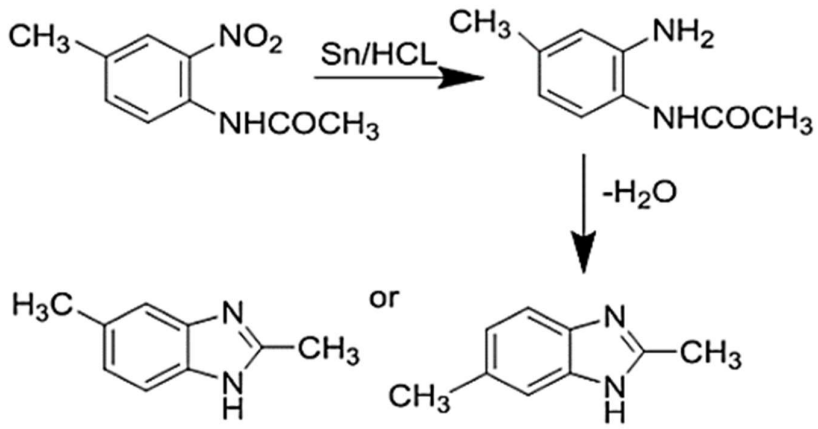


Fig 1: Structure of Benzimidazole.

The first benzimidazole was prepared by Bonebreaker, who obtained 2,5-dimethyl benzimidazole or 2,6- dimethyl benzimidazole by the reduction of 2-nitro-4-methyl acetanilide.



It plays a very important role in medical science having plenty of useful therapeutic activities such as: anti-ulcer, anti-hypertensive, analgesic, anti-inflammatory, anti-viral, antifungal, anticancer, and anti-bacterial.

Almost, all methods for the synthesis of benzimidazoles started with benzene derivatives possessing nitrogen-containing functions. The synthesis of novel benzimidazole derivatives remained a main focus of medicinal research. There is still scope for more research work to be done in this field to find a novel agent. The versatility of the new generation of benzimidazole would represent a fruitful pharmacophore for the further development of better, safe, and more potent biological agents. The discovery and development of drugs with benzimidazole moiety is now an important and attractive subject of interest given their huge therapeutic values. Heterocyclic compounds offer a high degree of structural diversity and have proven to be broadly and economically useful as therapeutic agents. In recent ars, remarkable attention has been directed towards the advancement of benzimidazole heterocyclic molecules as an antihistaminic 5-HT3 antagonist, e.g. lerisetron), antimicrobial (antibiotic, e.g. ridinilazole)antiulcer (proton pump inhibitor (PPI), e.g. ilaprazole), antihypertensive (calcium channel blocker, e.g. mibefradil), antiviral (non-structural protein inhibitor (NS5A), e.g. samatasvir), antiparasitic (specifically anthelmintic, e.g. Albendazole, antipsychotic (D2 receptor antagonist, e.g. clopimozide), analgesic (opioid analgesic, e.g. clonitazene), phosphodiesterase inhibitor (PDE3 inhibitor e.g. adibendan) and anti-cancer.

Research Studies

In 1990, Paul Anastas and John Warner defined Green Chemistry: as "The design of chemical products and processes that reduce or eliminate the use and generation of hazardous ozone depletion, air pollution, global climate change, soil and water pollution, acid rain, the depletion of natural resources, and the accumulation of hazardous waste. There are twelve principles of Green Chemistry. Paul T. Anastas and John C. Warner first published their 12 principles of Green Chemistry in their book, Green Chemistry: Theory and Practice, in 1998. Both serve as members of the California Green Chemistry Science Advisory Panel. In summary, the 12 principles are:

1. Prevent waste rather than treat it or clean it up.
2. Incorporate all materials used in the manufacturing process in the final product.
3. Use synthetic methods that generate substances with little or no toxicity to people or the environment.
4. Design chemical products to be effective, but reduce toxicity.
5. Phase-out solvents and auxiliary substances when possible.
6. Use energy-efficient processes, at ambient temperature and pressure, to reduce costs and environmental impacts.
7. Use renewable raw materials for feedstocks.
8. Reuse chemical intermediates and blocking agents to reduce or eliminate waste.
9. Select catalysts that carry out a single reaction many times instead of less efficient reagents
10. Use chemicals that readily break down into innocuous substances in the environment.
11. Develop better analytical techniques for real-time monitoring to reduce hazardous substances.
12. Use chemicals with low risk for accidents, explosions, and fires.

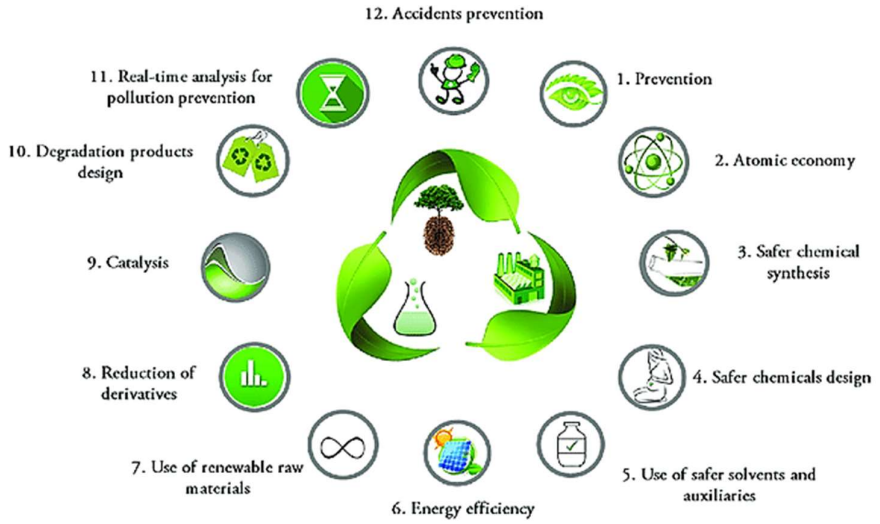


Fig. 4: Principals of Green Chemistry.

Challenges/Limitation

Some limitations and challenges of green chemistry in the synthesis of benzimidazoles include:

1. Difficulty in finding suitable and cost-effective green alternatives to traditional synthetic methods, which often rely on hazardous chemicals and solvents.
2. Limited availability of renewable and non-toxic raw materials for use in green synthetic methods.
3. The inefficiency of some green synthetic methods compared to traditional methods can lead to increased costs and longer synthesis times.
4. The difficulty in scaling up green synthetic methods for industrial production.
5. Limited data is available on the environmental impact of green synthetic methods.
6. The need to consider the entire lifecycle of a molecule, not only the synthetic process, which may require a multidisciplinary approach.

Some alternatives to common methodologies of benzimidazole synthesis are reported in the literature, utilizing enzyme catalysis, microorganisms, or relying on greener reducing agents and protecting groups.

Green Synthesis of Benzimidazole Derivatives

A.P. Tayade et al., 2020 One pot mono-condensation of O-phenylenediamine and aldehyde the presence of sodium hypophosphite as a catalyst gives the 2- substituted benzimidazole and its derivative. This method is time-saving and cost-effective. inexpensive, and easy to handle, this method gives important advantages in terms of simplicity of performance in ethanol and follows a long line of green chemistry.

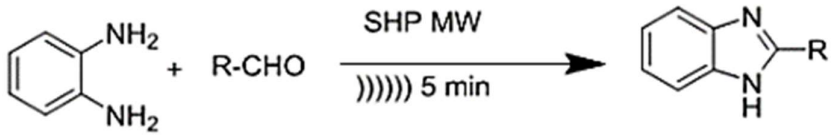


Fig.: One-photosynthesis of 2-substituted benzimidazole using catalyst SHP from various aldehyde.

Innovative Idea

Benzimidazoles are a class of heterocyclic compounds that have a wide range of biological activities, including anti-inflammatory, anti-cancer, and anti-parasitic properties.

An innovative method for the synthesis of benzimidazoles is through the use of enzymes. For example, the use of hydantoins, an enzyme that catalyzes the hydrolysis of hydantoins, can be used to synthesize benzimidazoles by converting hydantoins to the corresponding aminobenzimidazoles in an aqueous solution. This method is attractive due to its mild reaction conditions and high selectivity.

Future scope

The synthesis of benzimidazoles has a wide range of applications in various fields, including medicinal chemistry, materials science, and agriculture. In the field of medicinal chemistry, benzimidazoles have been shown to have anti-inflammatory, anti-tumor, and anti-parasitic properties and are therefore of interest as potential therapeutics. In materials science, benzimidazoles have been used as precursors for the synthesis of various electronic and optoelectronic materials. In agriculture, benzimidazoles are used as fungicides to protect crops from fungal infections.

Some of the Futuroscope for the synthesis of benzimidazoles could include the development of new and more efficient synthetic methods for the production of these compounds. Another area of research could involve the exploration of the potential medicinal applications of benzimidazoles and the development of new drugs based on these compounds. Additionally, more research can also be conducted to evaluate the environmental and ecological impact of benzimidazoles.

Overall, the future for the field of benzimidazoles looks promising, as there are many potential applications for these compounds and ongoing research efforts are likely to uncover new and exciting possibilities for their use.

CONCLUSIONS

Benzimidazoles have a wide range of biological and pharmaceutical applications, making them an important class of compounds for research and development. However, the traditional synthesis methods for benzimidazoles can produce harmful by-products and consume large amounts of energy and resources. Green chemistry approaches for the synthesis of benzimidazoles, such as using sustainable solvents and reagents, can minimize the environmental impact of their production. Additionally, recycling and reusing reaction components can further decrease the overall waste and resources used. With the growing awareness of the importance of sustainable practices in chemistry, the development of green chemistry methods for the synthesis of benzimidazoles is an important area of research.

The synthesis of benzimidazoles using biosynthetic pathways by using Microorganisms, enzymes, and fermentation processes can be a greener approach, which will be a sustainable alternative for the production of these important compounds. Therefore, green chemistry approaches for the synthesis of benzimidazoles can not only benefit the environment but also improve the efficiency and cost-effectiveness of the synthesis process.

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