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Eco-Efficient Strategies for Heterocyclic Compound Synthesis Through Green Chemistry Principles

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ABSTRACT

Eco-efficient strategies for heterocyclic compound synthesis emphasize the integration of environmental responsibility with synthetic innovation. Heterocyclic compounds play a crucial role in pharmaceuticals, agrochemicals, and advanced materials, yet their traditional synthesis often involves hazardous reagents, excessive solvent use, and energy-intensive steps. Green chemistry principles provide a sustainable framework to overcome these limitations by promoting atom economy, waste reduction, and safer reaction conditions. Techniques such as solvent-free synthesis, microwave and ultrasound-assisted reactions, and the use of biodegradable or recyclable catalysts have revolutionized heterocyclic synthesis. These methods not only reduce toxic byproducts but also enhance reaction efficiency and yield. Additionally, the adoption of renewable feedstocks, water-based reaction systems, and catalytic over stoichiometric pathways ensures minimal environmental footprint. By optimizing reaction conditions and embracing green solvents like ethanol, glycerol, and ionic liquids, chemists can achieve cleaner and more sustainable transformations. The pursuit of eco-efficient heterocyclic synthesis is therefore not just a scientific advancement but a moral imperative to protect ecosystems while maintaining chemical innovation. Through the continuous application of green chemistry principles, the synthesis of heterocyclic compounds can evolve into a model of sustainable and responsible chemical practice.