DOI: 10.5281/zenodo.15295884

CHAPTER 12

Importance of Heterocyclic Compounds in Chemical Sciences

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Received: 24 February 2025; Received in revised form: 11 March 2025; Accepted: 11 March 2025; Available online: 28 April 2025

Abstract: Heteroaromatic compounds are vital members of organic chemistry. Nowadays their way of synthesis as well as their number increases continuously. So heterocyclic compounds become an important arena for researchers as they also possess various biomedicinal properties. In this chapter, we look towards the new methods for chalcone synthesis and their different biological activities such as antioxidants, antifungal, anticancer and many more.

Keywords: Heteroaromatic derivatives, Pharmacological Importance

Introduction

Heterocyclic compounds are cyclic compounds with the presence of heteroatoms like N, O and S. The number of heteroaromatic compounds are increased day by day. These compounds are commonly available in nature and also involved in various important bioprocesses. Some of them are hemoglobin

Frontiers in Chemical Sciences (Vol. 1) - Pravin S. Bhale (Ed.)

ISBN: 978-93-95369-49-7 (electronic) 978-93-95369-48-0 (paperback) | © 2025 Advent Publishing. All rights reserved.

https://doi.org/10.5281/zenodo.15295884

having Fe and chlorophyll having Mg as a central atom with porphyrin rings, nucleic acids having heterocyclic ring compounds namely pyrimidines, purines, ascorbic acid and essential vitamins such as B_1, B_2, B_3, B_6, amino acids, carbohydrate, alkaloids, plant pigments. This is the main reason why researchers focus on the synthesis and evaluation of bioactivities of heteroaromatic compounds.

Medicinal chemistry is an important field in chemistry because of the joining between chemistry and medical life issues by trying to study common diseases and how should we solve them. This branch of chemistry starts from the isolation and purification of natural components using plant as well as animal materials. They have diverse biological activities and their ability to interact with biological systems makes them a key focus in medicinal chemistry research.

Types of Heterocyclic Compounds

Types of heterocyclic compounds depend on the type and position of the heteroatom in a cyclic molecule. In a cyclic system, at least one heteroatom must be present.

Following is the heterocyclic analogous of Benzene containing one or more heteroatoms like pyridine (with one N), pyrimidine, pyridazine, pyrazine (with two N), 1,2,3-triazine, 1,3,5-triazine, 1,2,4-triazine (with three N), 1,2,4,5-tetrazine (with four N).

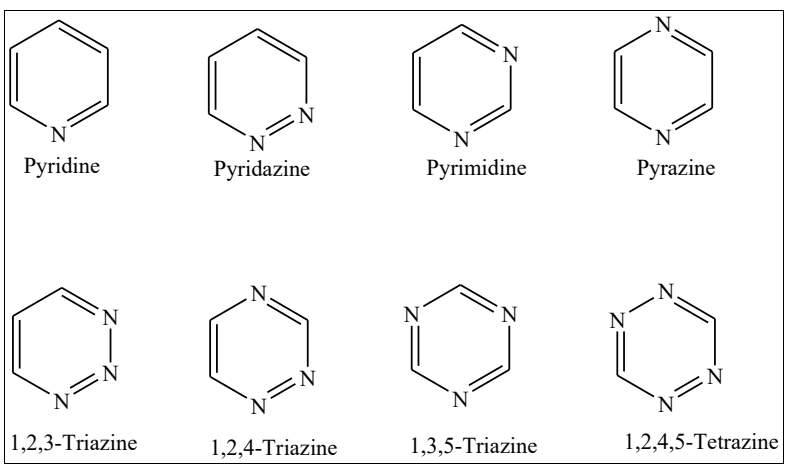

Fig. 1: Six-atom, Six--electron heteroaromatic compounds

Following are some of five-membered heterocyclic compounds containing one heteroatom in a cyclic system. E.g. Thiophene (with one S), Pyrrole (with one N), Furan (with one O) and five membered two heteroatom-containing cyclic compounds such as Thiazole (with one N and one S), Oxazole (with one N and one O), 1*H*-imidazole (with two N), 1*H*-pyrazole (with two N). The compound containing four heteroatoms in five-membered ring compound is 1*H*-tetrazole (with four N).

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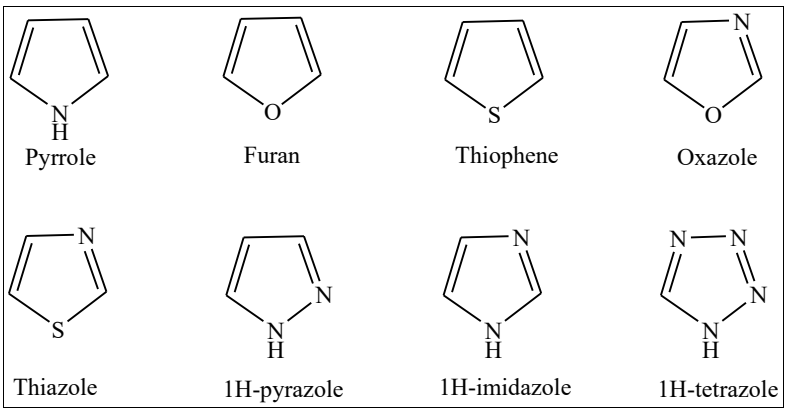

Fig. 2: Five-atom, Six--electron heteroaromatic compounds

Some of the heterocyclic compounds are fused ring aromatic systems containing one or more heteroatoms like quinoline, isoquinoline, quinazoline, cinnoline, phthalazine, quinoxaline, benzimidazole, indole, isoindole, etc.

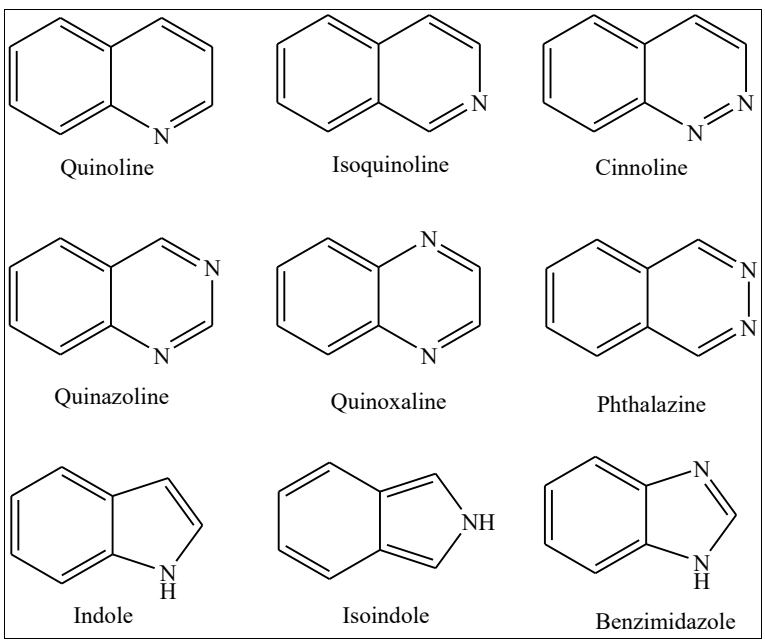

Fig. 3: Fused heteroaromatic compounds

All above discussed compounds are unsaturated heteroaromatic compounds. Along these compounds, heterocyclic nonaromatic compounds are also known. In such compounds, delocalization of p-electrons is not possible and these compounds also suffer from angle strain due to their small size. Such nonaromatic saturated heterocyclic compounds are tetrahydrofuran, aziridine, oxetane thiolane,

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pyrrolidine, oxirane, etc. Partially saturated heterocyclic compounds are oxetane, azirine, dihydropyrrole, etc.

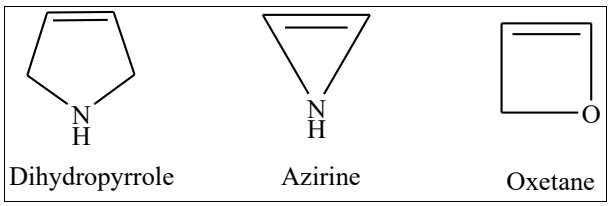

Fig. 4: Unsaturated nonaromatic heterocyclic compounds

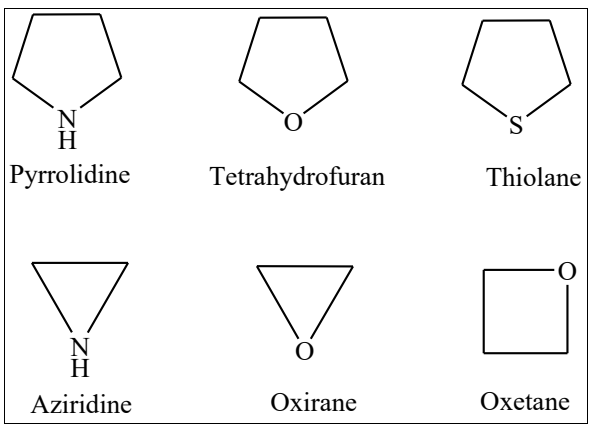

Fig. 5: Saturated nonaromatic heterocyclic compounds

Importance of Some Heterocyclic Compounds

Indole

Indole is one nitrogen containing heterocyclic compound with molecular formula C_8H_7N. Indole is two ring fused system namely Benzene and Pyrrole. Indole and Indole containing compounds show wide range of biological properties such as antioxidant, antiviral, antitubercular, anti-inflammatory, anticancer, antimicrobial, anti-HIV, etc. It is also present in natural amino acids and drug compounds as Sumatriptan, Etodolac, Tryptamine[1-7], etc. By using various synthetic routes, we can synthesize indole derivatives. Some of the ways are discussed below.

Significance of Indole Compounds

Sonal Deswal[8] and co-workers have synthesized the derivatives of triazole having indole moiety with halo-substitution. The synthesis is carried out by click reaction. All the synthesized compounds were screened for antibacterial and antifungal activity. The synthesis was also supported by DFT and molecular docking studies. Synthesized compounds show good biological activity.

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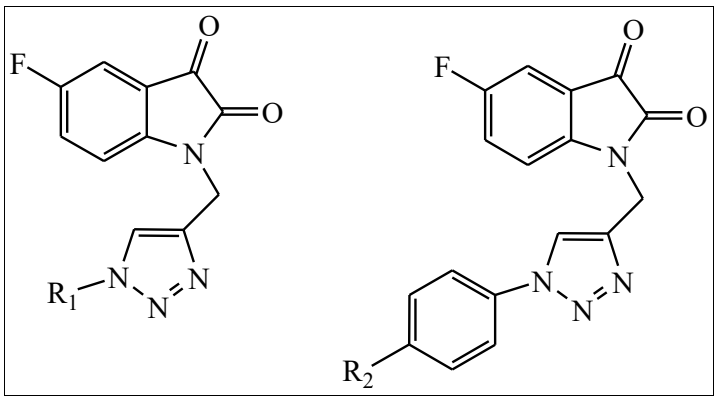
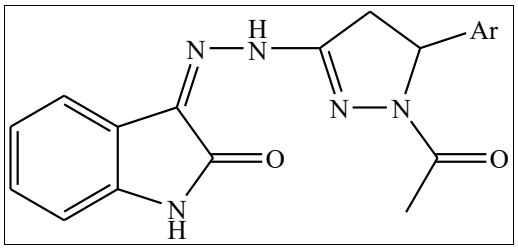
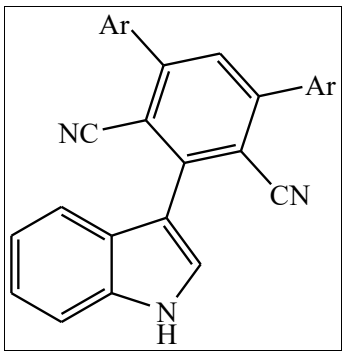


Deweshri Kerzare and coworkers have synthesized some new indole-linked pyrazole derivatives and evaluated them for anti-depressant, anticonvulsant and anti-anxiety activity[9]. The derivatives containing 4-chlorophenyl substituted indole was proven the most active compound against the standard drug diazepam.



The multicomponent synthesis of pyridyl containing indole derivatives and their screening for antimalarial studies were reported by Heba Elshemy and coworkers[10]. Fluorine and methoxy containing indole derivatives showed good antimalarial activity.



Navaneetha Depa and coworkers have reported a one-pot synthesis of 3-aminoalkyl indole derivatives. The reaction was performed by using a molecular iodine catalyst. They obtained good product yield within a short reaction time[11].

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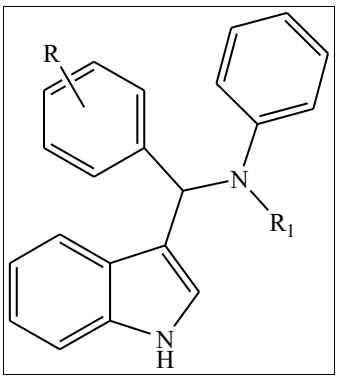
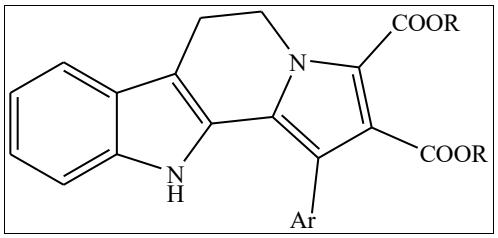


Fariba Peyam and coworkers have synthesized novel substituted dihydro indole compounds and screened them for α-glucosidase inhibitors[12]. All the derivatives are synthesized by a one-pot reaction and mild conditions. Among all the compounds, diethyl and dimethyl derivatives showed good anti-α-glucosidase activity.

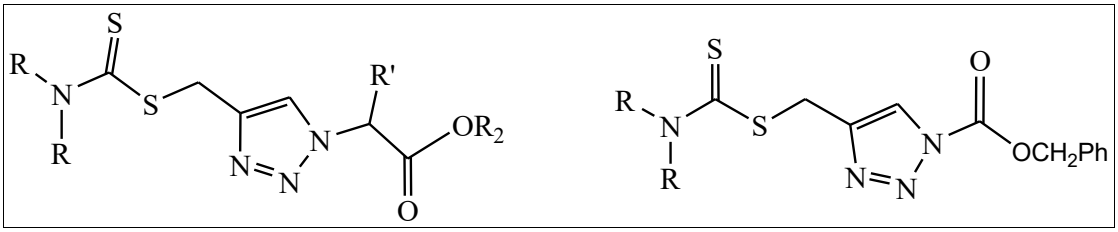


Triazole

Triazole is also known as pyrrodiazole five-membered cyclic compound containing three nitrogen heteroatoms with molecular formula $C_2H_3N_3$. The 1,2,3-triazole and 1,2,4-triazole are two isomeric structures of triazole. Triazole is a vital core in the synthesis and medicinal field. They possess various biological activities like antimicrobial[13], anti-MRSA[14], anticancer[15], antimalarial[16], antitubercular[17], etc.

Significance

Karbasi[18] and coworkers have synthesized dithiocarbamate containing 1,2,3-triazole derivatives with their DFT study.



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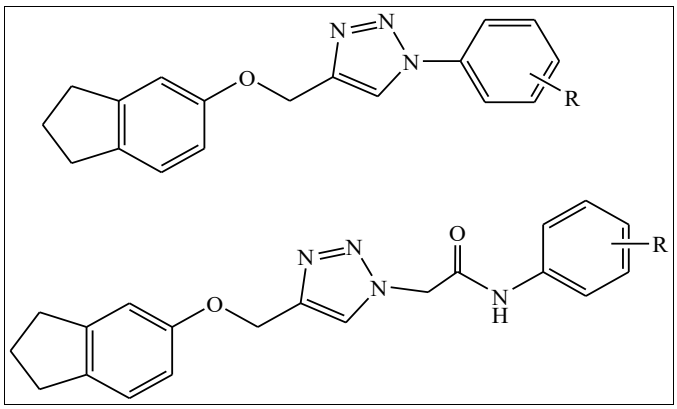
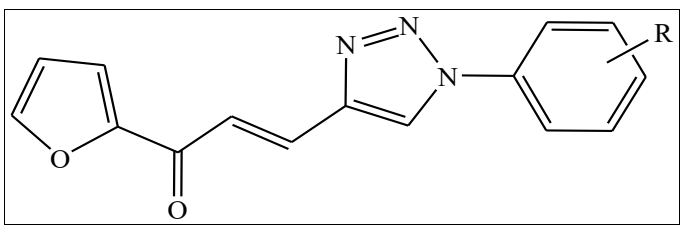
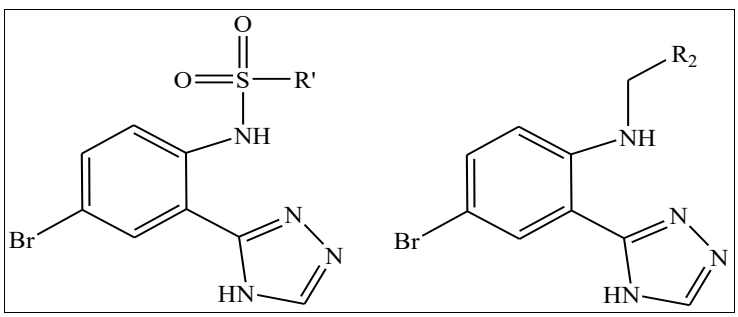
A novel series of indanol 1,2,3-triazole derivatives was synthesized by Pramod S. Phatak and his coworkers[19]. All the synthesized compounds were tested for antitubercular (In Vitro) and antimicrobial properties. The molecular docking as well as pharmacokinetic properties are studied. The compounds showed good to moderate antitubercular activity.



Kodide and coworkers20 have reported the novel 1,2,3-triazole-furan hybrid chalcone derivatives by Claisen Schmidt condensation reaction in the presence of a base catalyst. The synthesized compounds were tested for antimicrobial activity. The compounds having fluorine and hydroxy groups show good antimicrobial activity.



Khan and coworkers[21] have synthesized a series of triazole compounds and evaluated them for various activities as anthelmintic, antifungal, antibacterial, and cytotoxic. The binding pattern of molecules is examined by Molecular Docking studies. All the synthesized derivatives show moderate to good biological activities.



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Applications of Heterocyclic Compounds

Medicinal applications

A vast majority of modern drugs contain heterocyclic rings in their structure, making them crucial for treating various ailments like bacterial infections, viral diseases, cancer, pain, and neurological disorders.

Diverse biological activity

Heterocyclic compounds show various biological activities, including antifungal, antibacterial, anti-inflammatory, antiviral, antioxidant, and anti-cancer properties, depending on their structure and functional groups.

Natural product basis

Many naturally occurring biologically active molecules, like vitamins, alkaloids, and nucleic acids, contain heterocyclic rings, making them important models for drug development.

Agrochemical applications

Heterocyclic compounds are used extensively in agriculture as insecticides, herbicides, and fungicides due to their potent pesticidal activity.

Synthetic versatility

The structural diversity of heterocyclic compounds allows for easy modification and synthesis of new molecules with tailored properties, which is crucial in drug discovery.

Conclusion

Due to the great application of heterocyclic compounds in the medicinal field as a drug molecule, nowadays researchers target the synthesis and do their biological evaluation. This chapter focuses on the importance of various biological properties namely antitubercular, antifungal, anticancer, antimicrobial, antiallergic, anti-inflammatory, etc. with the synthesis of different substituted heterocyclic compounds that becomes potent drug molecules on further structural modification.

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