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A comprehensive study of azo compounds and their chemosensing potential

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Abstract
It was previously reported that azo compounds are vigorous and chemically stable compounds and a well-known chromophore. So these review high lights the Azo based sensors that have been developed in last two decades for detection which can deteact reactive ions in various biochemical environments. These chemosensors provides low cost and effective approach toward sensing and detecting cyanides ions via changing colors usually in a fraction of seconds and which we sometimes observe even through naked eye. These sensing approach is simple, cost effective, precise and provide reliable quantitative and qualitative statistics of an analyte presents even in any complex environment**.** This review highlights the sensing application of azo dyes there commercial and forensic use. Chemosensing behaviour with future scope.

Keywords: Chemosensors, azo-compounds, detections etc

Introduction

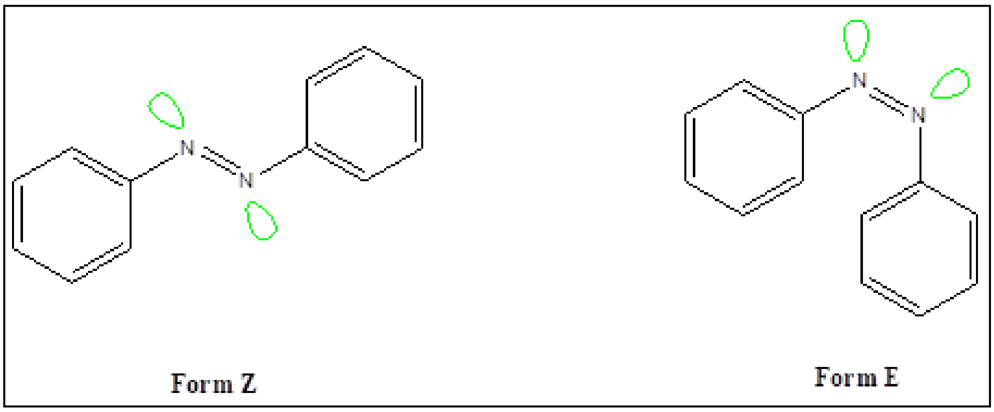
Azo dyes are compound that bond comprising one or more azo (-N=N-) bonds and a wrapped in a combined diazotize, with low molecular weights (between 300 and 700). Azo dye compounds, the largest class of commercially produced organic dyes, have numerous uses that include textile dyes, biological-medical studies, computational studies, non-linear optical systems, dye-sensitized solar cells, photochromic materials and photo-sensitizers [1, 11].

Particularly in current decade, the computational and structural studies on diazo compounds have sparked interest in dye chemistry and coloring business because they uncover the structure-performance link of dyes [12, 16]. The chemosensing behaviour of azo compounds is notably pronounced in their interplay with liquid crystalline materials, especially in the context of chiral nematic (cholesteric) and twist-bend nematic phases. This literature review synthesizes recent advances in the study of azo compounds as chemosensors, with particular emphasis on their chemosensing behaviour, the review elucidates molecular mechanisms, macroscopic phenomena, and prospective applications.

Theoretical Background of azo compound.

1. Isomerism

Whenever a molecule undergoes isomerization, it is converted into a new molecule with the exact same atoms but an entirely distinct positioning of atoms. Isomerization occurs naturally in some compounds and in specific situations. The isomerization of the azo linkage between E configuration and Z form gives azobenzene its intriguing uses [17, 21]. In the case of o/p substituted azobenzene in an azo moiety, azo phenol quinone hydrazone tautomerism is a notable phenomenon [22].



Isomerism in azo benzene molecule

Combination of the azo compounds attributes and several kinds of substituted aromatic ligands. Additionally, it is known that these dyes play a role in a collection of many biological processes, including the conquering of DNA replication, RNA and protein synthesis, carcinogenesis, and nitrogen fixation [23]. The stability in physico-chemical and optical qualities of azo dyes proven variety of uses in nanotubes and liquid crystals, are further characteristics.

Azo Compounds and Chemosensing

Azo compounds derive their distinctive characteristics from the azo (-N=N-) linkage, which facilitates reversible trans-cis photoisomerization. This process, triggered by ultraviolet (UV) or visible (Vis) irradiation, alters the molecular conformation, dipole moment, and, consequently, the material's bulk properties. In chemosensing, this molecular transformation translates to changes in optical, electrical, or mechanical signals, enabling detection and actuation at the molecular level.

The building blocks of chemosensors are receptors and fluorophores that are linked or integrated to perform 'grip-and-tell' actions (Fig.1). The initial association between an electron and a charge will be upset when a sensor binds to a visitor. Connection between the reporter and receptor in the ground state or stimulated state of the sensor, and lastly, adjust the strength or wavelength of emission [24].

Chemosensing Mechanisms: Light- and Field-Tunable Behavior

Sensor components

The chemosensor is typically composed of three major parts: a receptor that performs analytical recognition through a variety of bonding pathways, including dative bonds, hydrogen bonds, and solvophobic interactions. The analytical detection process uses two distinct processes that occur in the chemical sensor: molecular recognition and emission transduction. In certain instances, a spacer can modify the complex's shape and adjust the absorption spectra between the two distinct substances.

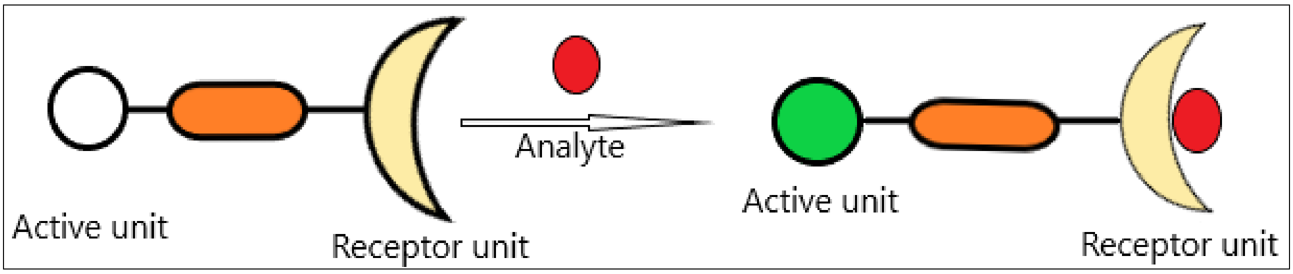


Fig 1: Sensor components

Despite their popularity, these conventional sensors exhibit critical limitations, including low sensitivity, poor selectivity, and susceptibility to environmental interferences. For instance, ISEs, while robust, often suffer from limited detection ranges and interference from other ions. Similarly, fluorescence-based sensors can be affected by photobleaching and require sophisticated instrumentation, whereas colorimetric sensors often lack the sensitivity needed for trace-level detection [25].

A. Photoisomerization-Induced Switching

The chemosensing behaviour of azo compounds is their reversible trans-cis photoisomerization. Due to irradiation of UV light, the trans-isomer interconverts to there cis-isomer, resulting into the changes in molecular isomerism and there dipole moment, [26, 27].

Comparison with Other Tunable Materials

While azo-doped crystal structure has specific advantages in terms of reversibility, multistate control, and integration with photonic systems, other classes of tunable materials—such as transparent conducting oxides—have also been invested for ultrafast optical modulation [28].

Challenges, Limitations, and Future Directions

While the previously reported studies reveal remarkable progress and development in understanding and applying the chemosensing activities of azo dyes in LC systems, there are several challenges and opportunities for future research remain.

Unlike traditional sensors such as fluorescence probes, this sensor addresses several limitations and offers the following advantages:

- **Enhanced Selectivity:** The Schiff base molecular framework and azo-functionalized groups provide selective binding to target analytes like charged ions or neutral molecules like sugar, amino acids or fatty acids detection which minimizing interference from competing other species.
- **High Sensitivity:** The sensor exhibits significantly shows shifts in UV-Visible absorption spectra on capturing analytes and, assisting their detection at trace levels.
- **Ease of Synthesis and Cost-Effectiveness:** The sensor is designed and synthesized using readily available reagents through a simple diazotization process, making it convenient and more suitable for large-scale production commercially.
- **Versatility:** It is capable of detecting multiple analytes under adverse or complex environmental conditions, which broaden its applicability across various fields.
- **Real-Time Monitoring:** The rapid and naked eye interaction between the sensor and analytes helps us in real-time detection, which can prove their important advantage for environmental and medical applications.

Material Design and Stability

The long-lasting stability of azo-probes under frequent cycle of photoisomerization, resistance toward photodegradation, are necessary considerations for practical and real time applications. More Efforts should be done towards designing of azo-compounds with enhanced resistance, higher, and customizing there absorption profiles.

Speed up and Reversibility of sensing

More planning to speedup response times, such as optimizing molecular structures or incorporating nanoparticle additions, grounds further investigation.

Multiplexed and Multimodal Sensing

Adding of microfluidic platforms, patterned electrodes, and advanced photonic architectures can help us to expand the scope of chemosensing applications.

Fundamental Understanding

Advanced level of characterization methodology (e.g., X-ray diffraction method, time-resolved spectroscopy) and computational modelling methods can able to provide underlying insights into structure–binding stoichiometry or cordinations.

Future Scope

The chemosensor opens up a promising door for advancing the level of analytical chemistry and environmental science. Future directions for this research include:

- **Involving use of Portable Devices:** Incorporating the sensor into portable devices like in UV-Vis spectrometers for field applications in forensic or medical field.

- **Broadening the Analyte Range:** developing the more efficient sensor's structure to capture additional ions and molecules.

- **Complex environment Testing:** investigating sensor potential in real-world samples such as industrial wastewater and biological fluids can be very useful.

- **Automation and Commercialization:** Developing automated sensing systems for continuous monitoring and scaling up for commercial applications.

Conclusion

Azo compounds, by virtue of their unique molecular structure and reversible photoisomerization, serve as versatile chemosensors in liquid crystal systems. Their role as chiral dopants enables the induction and dynamic control over sample analysis in very complex environment. The interplay of molecular design, external stimuli (light, electric field), and supramolecular assembly underpins a multifaceted chemosensing response with significant implications for photonic device engineering, optical sensing, and adaptive materials.

While challenges remain in terms of material stability, response speed, and integration, the foundational principles and experimental advances reviewed herein underscore the promise of azo compounds as central players in the evolving landscape of chemosensing and smart materials**.** This work lays the groundwork for the next generation of sensors with broad applications in environmental, industrial, and biomedical fields.

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