Chapter-22
Metal-Ligand Nanocarriers: A Breakthrough Approach to Targeted Pharmaceutical Administration Frameworks

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Abstract

In the realm of targeted drug delivery systems, metal-ligand nanocarriers have become an advanced and effective platform. These nanocarriers provide improved drug stability, controlled release, and increased site specificity by fusing the concepts of coordination chemistry with nanotechnology. Because metal–ligand interactions are controlled, it is possible to rationally create multifunctional nanocarriers that can react to biological stimuli like pH, redox potential, and enzyme activity. The goals, methods, experimental results, and medicinal significance of metal–ligand nanocarriers are comprehensively discussed in this chapter, emphasizing their potential to increase therapeutic efficacy and lower systemic toxicity.

Keywords-Metal–ligand complexes; Nanocarriers; Targeted drug delivery; Coordination chemistry; Nanomedicine

Introduction

Low accessibility, quick drug breakdown, poor solubility, non-specific distribution, and serious adverse effects are some of the major drawbacks of conventional drug delivery methods. Poor patient compliance and decreased therapeutic efficacy are results of these difficulties. Targeted drug delivery systems, which aim to deliver therapeutic drugs preferentially to sick tissues while preserving healthy cells, have been thoroughly investigated as a solution to these problems. The development of precise drug delivery systems has been reshaped by nanotechnology. Numerous benefits are provided by nanocarriers, including regulated release profiles, extended circulation times, and drug degradation mitigation. Metal-ligand nanocarriers have drawn a lot of interest among other types of nanocarriers because of their distinct coordination-driven design, structural modification, and multifunctionality.These systems are particularly appropriate for monitored and stimuli-responsive drug delivery because metal ions can establish stable but reversible connections with organic ligands.

Objectives

principal objectives are to describe the fundamental concepts of metal–ligand nanocarriers as well as the data generation and methodology used in their synthesis and characterization. to evaluate results of biomedical research and talk about drug loading, targeting, and release processes.Focus on the difficulties, limitations, and potential applications of metal-ligand nanocarriers in targeted pharmaceutical delivery.

Data and Methodology

The most common method for creating metal–ligand nanocarriers is coordination-driven self-assembly. Under carefully regulated experimental circumstances, metal ions like iron, zinc, copper, silver, gold, and platinum are mixed with appropriate organic ligands such heterocyclic compounds, Schiff bases, carboxylates, phosphonates, and biomolecules. A number of analytical methods are used to characterize the produced nanocarriers. FTIR spectroscopy offers proof of coordination bonding, whereas UV-visible spectroscopy verifies the development of metal–ligand complexes.

Particle size and morphology are examined using electron microscopy (SEM and TEM), while X-ray diffraction techniques help in the identification of crystalline structure. Colloidal stability and size distribution have been evaluated using dynamic light scattering. Encapsulation, surface adsorption, or coordination bonding between the drug and metal center are the methods employed to load drugs. To assess pH-sensitive, redox-responsive, and enzyme-triggered release behavior, in vitro drug release experiments are carried out under physiologically mimicked settings.

Results and Discussion

Research has shown the superior structural stability and high drug loading efficiency of metal-ligand nanocarriers. While surface functionalization improves targeting efficiency, their nanoscale dimensions allow to enhance cellular absorption. In tumor applications where acidic circumstances encourage selective medication release, pH-responsive drug release has proven very successful. Metal-ligand nanocarriers show enhanced cytotoxicity against cancer cells with markedly decreased damage to healthy tissues in cancer therapy. Strong efficacy against drug-resistant bacteria is revealed by antimicrobial studies, which relate this to the synergistic action of loaded medicines and metal ions. Furthermore, therapeutic applications which combine diagnosis and treatment on a single platform are made possible by metal-based nanocarriers that contain imaging agents.

Conclusion

In the area of specific drug delivery systems, metal–ligand nanocarriers are a potential and adaptable strategy. Their controlled release behavior, structural flexibility, and special coordination chemistry work together to improve therapeutic efficacy and minimize adverse effects. It is anticipated that ongoing interdisciplinary research will enable their successful translation into clinical applications despite present obstacles associated with toxicity assessment, large-scale synthesis, and regulatory approval.

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