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From Coordination Chemistry to Metal-Organic Materials: Structural Principles, Stability, and Emerging Roles in Energy and Functional Materials

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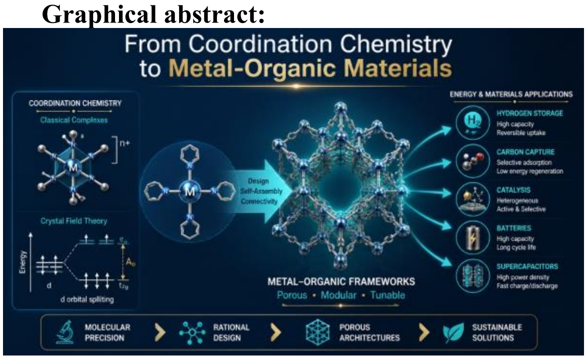
Abstract:

Coordination compounds and, more broadly, metal-organic materials have become central to modern chemistry because of their structural tunability, modular synthesis, and broad functional applications. The reviewed paper provides a clear foundation by explaining the nature of the coordinate bond, the role of ligands, coordination number, geometry, stability, and reactivity. These principles are directly relevant to the design of metal-organic frameworks and related materials for energy storage, gas separation, catalysis, sensing, and biomedical applications. In particular, the ability to combine metal nodes with organic linkers in a predictable way has enabled the creation of porous, crystalline architectures with high surface area and adjustable pore environments. Such features make these materials especially promising for hydrogen storage, carbon capture, methane adsorption, batteries, and electrocatalysis. The recent Nobel Prize recognition of Omar Yaghi further highlights the global importance of reticular chemistry and metal-organic frameworks as a transformative platform in materials science. This mini-review summarizes the key concepts from the reference review and extends them to emphasize the importance of metal-organic compounds in energy and advanced materials.

Graphical abstract:



1 .Introduction

The reviewed article offers a well-structured overview of coordination compounds, beginning with the core concepts of the central metal atom, ligands, coordination number, bonding models, and structural stability. It explains how coordination chemistry emerged from the study of metal–ligand interactions and developed into a highly predictive branch of inorganic chemistry. The significance of this field is not limited to classical complex formation; it also provides the conceptual basis for modern metal-organic materials. From this perspective, coordination chemistry is not merely descriptive but deeply design-oriented. It allows chemists to construct structures with controlled geometry, reactivity, and function.

2 .Structural Principles

One of the strongest points of the reviewed paper is its explanation of coordinate bonding and ligand behavior. Ligands act as Lewis bases and donate electron pairs to metal centers, which serve as Lewis acids. This interaction gives rise to structures with specific coordination numbers and geometries, such as linear, trigonal planar, tetrahedral, square planar, and octahedral arrangements. These structural features are not only important for classical inorganic complexes but are also the foundation of metal-organic frameworks. In MOFs, metal ions or clusters act as nodes, while organic ligands function as linkers, producing extended crystalline networks. The same principles of bonding, geometry, and stability discussed in the review are therefore directly relevant to the design of advanced porous solids.

3 .Stability and Reactivity

The review also emphasizes the factors that determine complex stability, including ligand basicity, chelation, ring size, steric effects, and the nature of the donor atom. These are crucial for understanding why certain compounds are kinetically inert while others are highly reactive. In modern materials science, these concepts are essential for building frameworks that can survive under realistic conditions such as heat, humidity, and chemical exposure. A material may have excellent porosity, but without sufficient chemical stability, it cannot be used in practical applications. For this reason, the classical ideas of coordination stability are now central to the development of durable metal-organic materials. The review's discussion of substitution reactions, magnetic behavior, and geometrical preferences provides a strong platform for understanding these more advanced applications.

4 .Importance in Energy

The importance of metal-organic compounds in energy-related technologies is one of the most active areas in current research. Metal-organic frameworks have shown exceptional promise in hydrogen storage, methane storage, carbon dioxide capture, and selective gas separation. Their high surface area, tunable pore size, and chemically customizable interior make them superior to many traditional porous materials. In addition, MOFs and coordination polymers are being explored as electrode materials, catalysts, and precursors for derived nanostructures in batteries and supercapacitors. These applications are especially important in the context of the global transition to cleaner and more efficient energy systems. The ability to fine-tune metal nodes and ligands gives researchers a molecular-level tool for engineering performance.

5 .Importance in Materials

Beyond energy, metal-organic compounds have a major role in advanced materials science. They provide a versatile platform for designing functional solids with controlled optical, magnetic, electronic, and catalytic properties. Coordination compounds are used in sensors, luminescent devices, drug delivery systems, separation membranes, and catalytic platforms. MOFs in particular have opened a new era in materials design because they combine crystallinity with porosity and modularity. This makes them ideal for applications that require selectivity and structural precision. The reviewed paper's explanation of ligand field theory, crystal field splitting, and coordination geometry helps clarify why these compounds can be engineered for different functions. In short, coordination chemistry has evolved from a structural discipline into a materials strategy.

6 .Why Yaghi Matters

The Nobel Prize awarded to Omar Yaghi, together with Susumu Kitagawa and Richard Robson, brought global recognition to the field of metal-organic frameworks and reticular chemistry. Their work demonstrated that extended coordination networks can be deliberately built from molecular building blocks to create materials with extraordinary porosity and functionality. This was a landmark moment because it confirmed that coordination chemistry can drive innovation far beyond classical inorganic compounds. Yaghi's contributions made MOFs a defining class of materials for gas storage, capture, catalysis, and water harvesting. The Nobel recognition also signals a broader shift in chemistry toward rational materials design, where structure can be programmed to deliver specific properties. This is exactly the kind of scientific direction that links the reviewed article to contemporary research.

7 .Conclusion

Coordination chemistry has evolved far beyond the study of isolated metal complexes and is now a foundational platform for designing advanced functional materials. The principles of metal–ligand bonding, coordination geometry, chelation, and stability directly enable the construction of metal-organic frameworks and related architectures with tunable porosity, high surface area, and controllable reactivity. These features have made metal-organic materials highly relevant to modern energy challenges, including gas storage, carbon capture, catalysis, electrochemical energy conversion, and sustainable separation technologies. The recognition of Omar Yaghi's work with the Nobel Prize further underscores the transformative value of reticular chemistry and the importance of rational molecular-to-material design. Taken together, the field demonstrates how classical coordination chemistry has become a powerful engine for next-generation materials discovery. For this reason, metal-organic compounds should be regarded not only as important chemical entities, but also as strategic building blocks for the future of energy and advanced materials research.

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