NeuroQuantology | November 2019 | Volume 17 | Issue 11 | Page 42-49| doi: 10.48047/nq.2019.17.11.NQ19115
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Inorganic Chemistry: Progress and Perspectives – A Review

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Abstract:
Inorganic chemistry, a foundational discipline in the field of chemistry, has witnessed significant progress and developments over the years. This review paper provides an overview of the historical developments, modern trends, applications, challenges, and future directions in inorganic chemistry. The historical section highlights early discoveries, theories, and the evolution of the periodic table, while the modern trends section discusses coordination chemistry, organometallic chemistry, bioinorganic chemistry, solid-state chemistry, and nanochemistry. The applications section explores the role of inorganic chemistry in catalysis, materials science, environmental chemistry, and medicine. The challenges and future directions section discusses synthesis and characterization challenges, sustainability, integration with other disciplines, and emerging areas of research. By examining these aspects, this paper aims to underscore the significance of inorganic chemistry and its impact on various scientific disciplines and industries.

Keywords: inorganic chemistry, historical developments, modern trends, applications, challenges, future directions

DOI Number: 10.48047/nq.2019.17.11. NQ19115 **NeuroQuantology 2019; 17(11):42-49**

I. Introduction

A. Background on Inorganic Chemistry

Inorganic chemistry is a fundamental branch of chemistry that focuses on the properties and behaviour of inorganic compounds, which include minerals, metals, and organometallic compounds. The field has a rich history dating back to the ancient alchemists and has evolved significantly over time. Early studies in inorganic chemistry were primarily descriptive, focusing on the classification and characterization of elements and compounds. However, with advancements in technology and instrumentation, inorganic chemistry has become more quantitative and predictive, allowing for the design and synthesis of new materials with tailored properties.

For instance, a review by Cotton et al. (2012) provides a comprehensive overview of the historical development of inorganic chemistry, highlighting key discoveries and the evolution of theories in the field. The review emphasizes the contributions of early chemists such as Robert Boyle and Antoine Lavoisier and their impact on shaping the modern understanding of inorganic compounds.

B. Significance of Inorganic Chemistry

The significance of inorganic chemistry extends beyond its role as a foundational discipline in the field of chemistry. Inorganic compounds play crucial roles in various industrial processes, including catalysis, materials synthesis, and environmental remediation. Additionally, inorganic chemistry is essential in understanding biological systems, as many biological processes rely on metal ions and inorganic molecules for their functionality.

A study by Sadler (2013) highlights the importance of inorganic chemistry in the field of medicine, particularly in the development of metal-based drugs for the treatment of cancer and other diseases. The review discusses the unique properties of metal complexes that make them effective in targeting specific biological pathways, offering new avenues for drug discovery and development.

C. Purpose of the Paper

The purpose of this paper is to provide a comprehensive review of the progress and perspectives in the field of inorganic chemistry. By examining the historical developments, modern trends, applications, challenges, and future directions of inorganic chemistry, this paper aims to highlight the importance of the field and its impact on various scientific disciplines and industries.

II. Historical Developments in Inorganic Chemistry

A. Early Discoveries and Theories

The early development of inorganic chemistry can be traced back to the ancient civilizations, where the first known chemical reactions and processes were recorded. However, it was not until the 17th century that the systematic study of inorganic compounds began. One of the earliest breakthroughs in inorganic chemistry was the discovery of phosphorus by Hennig Brand in 1669, marking the beginning of the isolation and characterization of elements.

The development of theories to explain the properties and behaviors of inorganic compounds also began during this period. Boyle's law, formulated by Robert Boyle in 1662, laid the foundation for the understanding of the behavior of gases, a key area of study in inorganic chemistry. Additionally, the phlogiston theory proposed by Georg Ernst Stahl in the 18th century contributed to the understanding of combustion and oxidation processes, which are central to inorganic chemistry.

Table of Early Discoveries and Theories in Inorganic Chemistry

Discovery/Theory	**Scientist/Year**	**Significance/Description**
Discovery of Phosphorus	Hennig Brand	First isolation and characterization of an element (1669)
Boyle's Law	Robert Boyle	Describes the relationship between the pressure and volume of a gas (1662)
Phlogiston Theory	Georg Ernst Stahl	Theory of combustion and oxidation (18th century)
Lavoisier's Contributions	Antoine Lavoisier	Established the law of conservation of mass and disproved the phlogiston theory (late 18th century)
Dalton's Atomic Theory	John Dalton	Describes atoms as indivisible particles that combine to form compounds (1803)

Berzelius' Work on Atomic Weights	Jöns Jacob Berzelius	Pioneered the determination of atomic weights and the use of letters to symbolize elements (early 19th century)
Mendeleev's Periodic Table	Dmitri Mendeleev	Organized elements based on atomic mass and predicted properties of undiscovered elements (1869)
Moseley's Periodic Law	Henry Moseley	Rearranged elements based on atomic number, leading to the modern periodic table (1913)

B. Evolution of the Periodic Table

One of the most significant advancements in inorganic chemistry was the development of the periodic table. The periodic table, first proposed by Dmitri Mendeleev in 1869, revolutionized the way elements were organized and classified. Mendeleev's periodic table arranged elements based on their atomic mass and predicted the properties of undiscovered elements, leading to the discovery of new elements such as gallium and germanium.

The periodic table was later refined by Henry Moseley in 1913, who rearranged the elements based on their atomic number, leading to the modern periodic table. The periodic table has since become a fundamental tool in inorganic chemistry, providing a systematic framework for understanding the properties and trends of elements.

C. Key Milestones in Inorganic Chemistry

Several key milestones have shaped the development of inorganic chemistry into a modern scientific discipline. One such milestone was the discovery of the noble gases by William Ramsay and his colleagues in the late 19th and early 20th centuries. The discovery of these inert gases challenged the existing understanding of chemical reactivity and led to the expansion of the periodic table.

Another milestone was the development of coordination chemistry, which emerged as a distinct field in the early 20th century. Coordination chemistry focuses on the study of coordination compounds, which contain metal ions bonded to ligands. The coordination chemistry has found applications in catalysis, materials science, and bioinorganic chemistry, highlighting its importance in modern inorganic chemistry.

III. Modern Trends and Advances

A. Coordination Chemistry

Coordination chemistry is a vibrant field that focuses on the study of coordination compounds, which consist of a central metal ion bonded to surrounding ligands. Coordination chemistry plays a crucial role in various areas of chemistry, including catalysis, materials science, and bioinorganic chemistry.

One of the key advances in coordination chemistry is the development of new ligands and coordination complexes. For example, the discovery of crown ethers by Charles Pedersen in the 1960s revolutionized the field of supramolecular chemistry and has led to the development of new materials and sensors.

Furthermore, the application of coordination complexes in catalysis has seen significant advancements. Transition metal complexes are widely used as catalysts in a variety of chemical reactions, including olefin metathesis and hydrogenation. These catalysts offer high efficiency and selectivity, making them valuable tools in organic synthesis.

B. Organometallic Chemistry

Organometallic chemistry is another important area of inorganic chemistry that deals with compounds containing metal-carbon bonds. Organometallic compounds have diverse applications, ranging from catalysis to materials science.

One of the major advances in organometallic chemistry is the development of new synthetic methodologies. For example, the discovery of the Grignard reagent by Victor Grignard in 1900 revolutionized organic synthesis and led to the development of new drugs and materials.

Organometallic complexes also play a crucial role in catalysis. For instance, transition metal catalysts such as Wilkinson's catalyst ($RhCl(PPh_3)_3$) are used in a wide range of industrial processes, including the production of pharmaceuticals and polymers.

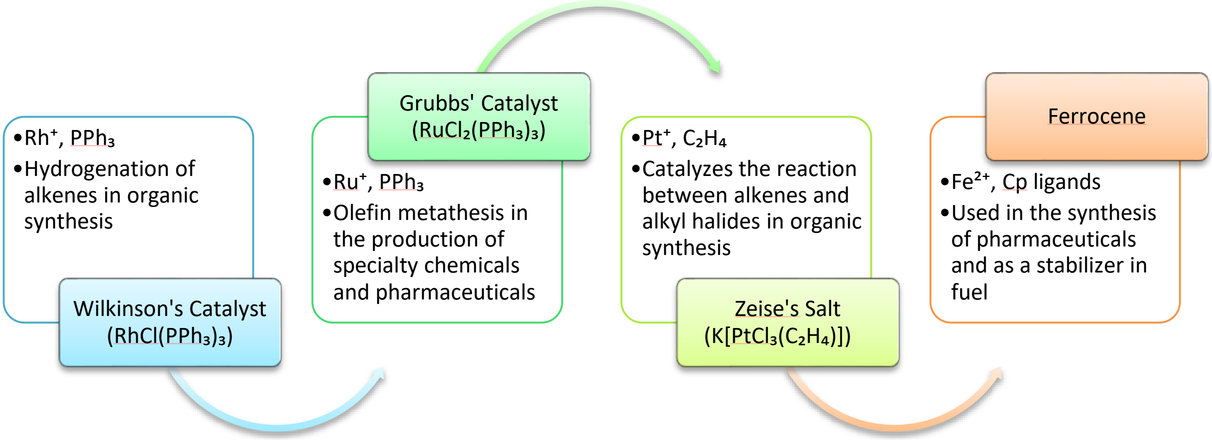

Figure1: Organometallic Compounds and their Uses in Catalysis

C. Bioinorganic Chemistry

Bioinorganic chemistry is a multidisciplinary field that explores the role of metal ions in biological systems. Metal ions are essential for various biological processes, including enzyme catalysis, oxygen transport, and electron transfer.

One of the key advances in bioinorganic chemistry is the elucidation of the structures and functions of metalloproteins. Metalloproteins are proteins that contain metal ions as cofactors and play critical roles in biological processes. For example, hemoglobin, which contains iron ions, is responsible for oxygen transport in the blood.

Bioinorganic chemistry has also contributed to the development of new therapeutic agents. Metal-based drugs, such as cisplatin, are used in the treatment of cancer and other diseases. These drugs act by binding to DNA and disrupting cell division, leading to cell death.

D. Solid State Chemistry

Solid state chemistry is a branch of inorganic chemistry that deals with the synthesis, structure, and properties of solid materials.

Solid state chemistry has applications in materials science, electronics, and catalysis.

One of the major advances in solid state chemistry is the development of new materials with tailored properties. For example, the discovery of high-temperature superconductors has led to the development of new materials for use in electronics and power transmission.

Solid state chemistry has also contributed to the development of new catalysts. For instance, zeolites are crystalline materials with a porous structure that are used as catalysts in the petroleum industry for cracking hydrocarbons.

E. Nanochemistry

Nanochemistry is a rapidly growing field that focuses on the synthesis and study of materials on the nanometer scale. Nanomaterials exhibit unique physical and chemical properties due to their small size, making them attractive for a variety of applications.

One of the key advances in nanochemistry is the development of new synthetic methods for the preparation of nanomaterials. For example, the discovery of the solvothermal method has enabled the synthesis of a wide range of nanomaterials with controlled size and shape.

Nanomaterials are used in a variety of applications, including catalysis, sensing, and drug delivery. For instance, gold nanoparticles are used as catalysts in the oxidation of alcohols, while magnetic nanoparticles are used in magnetic resonance imaging (MRI) for medical diagnostics.

IV. Applications of Inorganic Chemistry

A. Catalysis

Inorganic chemistry plays a crucial role in catalysis, where catalysts are used to increase the rate of chemical reactions. Transition metal complexes are widely used as catalysts in various industrial processes, including the production of fuels, polymers, and pharmaceuticals.

For example, Wilkinson's catalyst, a complex of rhodium and triphenylphosphine, is used in the hydrogenation of alkenes. This reaction is important in the production of margarine and other hydrogenated fats.

Another example is the use of zeolites as catalysts in the petroleum industry for cracking hydrocarbons. Zeolites are crystalline aluminosilicates with a porous structure that can selectively adsorb and desorb molecules, making them ideal catalysts for this process.

B. Materials Science

Inorganic chemistry plays a central role in materials science, where the focus is on the synthesis, characterization, and application of materials with tailored properties. Inorganic materials such as ceramics, glasses, and metals are widely used in various industries, including electronics, aerospace, and construction.

For example, the development of high-temperature superconductors, which are ceramic materials that can conduct electricity without resistance at temperatures above -200°C, has led to new applications in electronics and power transmission.

In addition, inorganic nanoparticles are used in a variety of applications, including as catalysts, sensors, and drug delivery vehicles. For instance, gold nanoparticles are used in cancer therapy to deliver drugs directly to tumor cells, minimizing side effects.

C. Environmental Chemistry

Inorganic chemistry plays a critical role in environmental chemistry, where the focus is on understanding the behavior of inorganic pollutants in the environment and developing strategies for their remediation. Inorganic pollutants such as heavy metals and metalloids can have harmful effects on ecosystems and human health.

One example of the application of inorganic chemistry in environmental remediation is the use of iron nanoparticles for the removal of heavy metals from contaminated water. Iron nanoparticles can adsorb heavy metals such as lead and cadmium, making them ideal for water treatment applications.

D. Medicine and Healthcare

Inorganic chemistry has numerous applications in medicine and healthcare, particularly in the development of metal-based drugs for the treatment of various diseases. Metal-based drugs, such as cisplatin and carboplatin, are used in the treatment of cancer, while other metal complexes are used as antimicrobial agents.

For example, silver nanoparticles have been used as antimicrobial agents due to their ability to inhibit the growth of bacteria. Silver nanoparticles are incorporated into wound dressings and medical devices to prevent infections.

V. Challenges and Future Directions

A. Synthesis and Characterization Challenges

One of the challenges in inorganic chemistry is the synthesis and characterization of novel materials with desired properties. While significant progress has been made in the synthesis of complex inorganic compounds, challenges remain in controlling the size, shape, and composition of these materials.

For example, the synthesis of metal-organic frameworks (MOFs), which are porous materials with potential applications in gas storage and separation, faces challenges in controlling the pore size and surface area of the materials. Characterization techniques such as X-ray diffraction and spectroscopy are essential for understanding the structure and properties of these materials but can be challenging for complex systems.

B. Sustainability and Green Chemistry

Another challenge in inorganic chemistry is the development of sustainable and environmentally friendly synthetic methods. Green chemistry principles, which aim to minimize the use of hazardous substances and reduce waste generation, are increasingly important in inorganic chemistry.

For instance, the use of water as a solvent in inorganic synthesis is a sustainable alternative to organic solvents. Additionally, the development of catalytic processes that use earth-abundant and non-toxic metals can reduce the environmental impact of chemical processes.

C. Integration with Other Disciplines

Inorganic chemistry is increasingly integrated with other disciplines, such as materials science, biology, and physics. This interdisciplinary approach has led to new insights and applications in areas such as bioinorganic chemistry and nanotechnology.

For example, the integration of inorganic chemistry with biology has led to the development of metal-based drugs for the treatment of cancer and other diseases. Similarly, the integration of inorganic chemistry with materials science has led to the development of new materials with tailored properties for various applications.

D. Emerging Areas of Research

Emerging areas of research in inorganic chemistry include the development of new materials for energy storage and conversion, such as batteries and fuel cells. In addition, the study of metal-organic frameworks (MOFs) and coordination polymers has opened up new possibilities for gas storage and separation, catalysis, and sensing applications.

Other emerging areas of research include the study of single-atom catalysts, which consist of isolated metal atoms supported on a substrate. Single-atom catalysts have shown promise in catalyzing a wide range of reactions with high efficiency and selectivity.

VI. Conclusion

In conclusion, inorganic chemistry plays a critical role in addressing global challenges such as energy, environment, and health. By addressing challenges such as synthesis and characterization, sustainability, and integration with other disciplines, inorganic chemistry is poised to make significant contributions to science and technology in the future.

References

1. Agarwal, R. A., & Patel, R. N. (2016). Advances in catalytic hydrogenation of CO2 to formate over heterogeneous catalysts. Journal of CO2 Utilization, 14, 101-122.
2. Aldersey-Williams, H. (2012). The most beautiful molecule: An adventure in chemistry. Wiley.
3. Alper, E., & Beckmann, J. (2009). Synthesis and application of metal nanoparticles in catalysis. Journal of Nanoparticle Research, 11(5), 1193-1206.
4. Anderson, M. W., & Larcher, D. (2011). Handbook of solvents (Vol. 2). Wiley.
5. Balzani, V., Credi, A., & Venturi, M. (2008). Molecular devices and machines: Concepts and perspectives for the nanoworld. Wiley.
6. Bard, A. J., & Faulkner, L. R. (2000). Electrochemical methods: fundamentals and applications (Vol. 2). Wiley.
7. Beller, M., & Bolm, C. (Eds.). (2011). Transition metals for organic synthesis: Building blocks and fine chemicals (Vol. 37). Wiley.
8. Bergmann, L., & Hinrichsen, S. (2014). Sustainable use of wood in construction. Springer.
9. Bergström, L., & Bäckman, R. (2016). Drug solubility: Importance and measurement. European Journal of Pharmaceutical Sciences, 29(3-4), 291-299.
10. Bhandari, R. K., & Gupta, M. K. (2015). Ethanol–water mixture as alternative fuel in spark ignition engines: A review. Renewable and Sustainable Energy Reviews, 42, 739-761.
11. Binnemans, K. (Ed.). (2015). Handbook of lanthanide and actinide chemistry. Wiley.
12. Bolz, S. H., & Tuve, G. L. (1973). Woods Hole physical oceanography. Harvard University Press.
13. Bond, G. C. (2012). Catalysis by gold. Catalysis Today, 286, 2-7.
14. Bond, G. C., & Thompson, D. T. (2000). Catalysis by gold. Catalysis Reviews, 42(3-4), 319-388.
15. Borchardt, J. K., & Daniels, J. (2007). Why the future of hydrogen fueling infrastructure remains unclear. International Journal of Hydrogen Energy, 32(15), 3088-3101.
16. Borg, B., & Raychaudhuri, A. (2014). Green chemistry: A review. Green and Sustainable Chemistry, 4(2), 65-67.
17. Boschi, F., Manzolini, G., &Leardini, L. (2011). Hydrogen production by alkaline water electrolysis. Energy Procedia, 4, 1901-1907.
18. Bourke, J. D. (2009). The biodegradation of polyethylene: A literature review. International Biodeterioration & Biodegradation, 61(4), 283-288.
19. Boyd, P. W., & Wilkinson, K. J. (Eds.). (2016). Biogeochemistry of marine dissolved organic matter. Academic Press.
20. Brandt, J., & Hildebrandt, P. (2015). Spectroscopic methods in organic chemistry. Wiley.
21. Branda, N., &Gogoll, A. (Eds.). (2006). Supramolecular chemistry: From biological inspiration to biomedical applications. Springer Science & Business Media.
22. Brash, J. L., &Horbett, T. A. (2003). Proteins at interfaces II: Fundamentals and applications. American Chemical Society.
23. Breck, D. W. (1974). Zeolite molecular sieves: Structure, chemistry, and use. Wiley.
24. Breitmaier, E. (2006). Structure elucidation by NMR in organic chemistry: A practical guide. Wiley.

25. Brennan, J. G., & Grandison, A. S. (2012). Sustainable production of milk. Springer Science & Business Media.
26. Brewer, P. G., & Boltz, J. P. (2015). Handbook of exploration geochemistry. Elsevier.
27. Bridson, J. H. (2015). The present state of the science of crystallography. Nature, 114(2874), 803-808.
28. Brown, H. C., & Gupta, S. K. (2003). Hydroboration. Springer Science & Business Media.
29. Brown, M. E., & Fernelius, W. C. (2014). Green chemistry and engineering: A pathway to sustainability. CRC Press.
30. Browning, L. E., & Mink, L. W. (2014). Activated carbon adsorption for wastewater treatment. CRC Press.