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Review on the application of renewable energy in green chemistry

Shixun Zhu

Agincourt International Academy, Ontario, Canada, M1V 1Z6

zsx15652418969@sina.com

Abstract: Green chemistry, often referred to as environmentally friendly chemistry, or clean chemistry, aims to minimize or eliminate the utilization of harmful compounds and promote the development of chemicals and process designs that are environmentally sustainable. Renewable energy is a significant area of study within the realm of green chemistry. Given the phenomenon of global warming and the growing energy requirements, there is an increasingly pressing need for environmental consciousness and the promotion of sustainable development. This study will explore the application of renewable energy in green chemistry, along with the associated technologies for production and utilization. To effectively address the requirements of sustainable human development, it is crucial to prioritize the rational utilization of resources, maintain ecological equilibrium, and ensure environmental preservation. This will enable the achievement of a harmonious and coordinated relationship between mankind and the natural world.

Keywords: green chemistry, renewable resources, sustainable development

1. Introduction

Energy can be classified into two distinct categories: renewable energy and non-renewable energy. Renewable energy sources encompass several forms such as solar energy, hydroelectric power, wind energy, biomass energy, wave energy, tidal energy, ocean thermal energy, geothermal energy, and more. They are biodegradable. It is a perpetual source of energy that replenishes itself without human intervention and is a form of energy that contrasts with finite non-renewable energy sources. Prior to the emergence of coal in the mid-19th century, all energy utilized was derived from renewable sources. Aside from nuclear energy, tidal energy, and geothermal energy, the primary source of energy for human activities is predominantly sunshine. Fossil energy, including bioenergy as well as coal, oil, and natural gas, primarily originates from the assimilation of solar energy by plants via photosynthesis. Additional phenomena such as wind power, water power, and ocean currents are also consequences of solar radiation warming the Earth’s atmosphere and bodies of water [1].

Green chemistry, often referred to as environmentally sound chemistry, and clean chemistry, encompasses the development of chemicals and procedures that minimize or eliminate the utilization and generation of harmful compounds. Green chemistry encompasses several disciplines including organic synthesis, catalysis, biology, and analytical chemistry. The concept of “Green Chemistry” was introduced by American Chemistry and has gained significant traction in the present time. Green chemistry encompasses the utilization and creation of chemical techniques and processes that aim to minimize or eradicate the use of substances such as raw materials, catalysts, solvents, reagents, products, and by-products that pose risks to human health, community safety, and the natural environment. The optimal approach for green chemistry involves employing the "atomic economy" reaction, wherein every atom present in the initial raw material molecule is efficiently turned into a product. This process ensures the absence of any waste or by-products, hence achieving complete "zero emission" of trash. Green chemical technology is classified as a priority in the control of three types of waste. It represents a shift from passive to active measures in combating pollution, making it more significant than traditional "end treatment" methods [2].

This study will explore the application of renewable energy in the field of green chemistry, along with the associated technologies for its generation and utilization. The objective is to fulfill the requirements of sustainable human development by maximizing the rational utilization of resources, maintaining ecological equilibrium, and ensuring environmental preservation, thereby achieving a state of coordination and harmony between humanity and the natural world.

2. Application of renewable energy in green chemistry

2.1. Preparation and application of green catalyst

A green solvent is a type of solvent that is characterized by its mildness, low toxicity, and ability to biodegrade. Due to its distinctive features, it has witnessed a growing number of applications aimed at safeguarding the natural environment, preserving the air, water, and soil quality, and providing thermal insulation and support. Green solvents have diverse applications, ranging from transportation in the station area to their use in paint, cleaning agents, fine chemical wastewater treatment, and pesticide manufacture. In general, it can be utilized for administering drugs during the production of different products. Substituting conventional solvents with environmentally-friendly bath agents yields several benefits, including cost reduction, decreased air pollution, enhanced working conditions, improved paint manufacturing process stability, and enhanced paint quality. Furthermore, the highly hygroscopic green solvent can serve as a solvent in the pharmaceutical industry. In the pharmaceutical and manufacturing sectors, the utilization of green solvents for refining chemical products can significantly enhance product quality and stability. Additionally, green solvents can be employed for the purpose of cleaning surfaces, effectively eliminating pollutants and safeguarding the environment. The majority of catalysts consist of three distinct sorts of components: active components, carriers, and cocatalysts. The utilization of green catalysts has the potential to enhance reaction efficiency, decrease the energy demand, and fulfill environmental preservation standards. Consequently, their significance in the fields of oil, chemical, new energy, and environmental protection is progressively escalating. In general, China's catalyst sector has made significant advancements in its technical level via continual development. However, there still exists a noticeable disparity with the international advanced level. China's green catalyst industry research and development and innovation capabilities need ongoing improvement, given the growing stringency of environmental protection legislation and increasing demands for product quality [3].

In a recent development in China, coordination hydride materials were successfully utilized to catalyze the synthesis of ammonia. Additionally, a novel base (earth) ruthenium metal ternary hydride catalyst was created to enable the catalytic production of ammonia under gentle circumstances. The findings are officially disclosed in the scientific journal Nature Catalysis. Ammonia serves as a significant chemical feedstock and holds potential as an energy carrier. The traditional synthetic ammonia industry, which relies on fossil fuels, exhibits significant energy consumption and carbon emissions. Hence, achieving the effective synthesis of ammonia under moderate conditions holds immense scientific relevance and practical utility. The discovery of a highly efficient ammonia synthesis catalyst that operates at low temperatures and pressures is crucial in the production of "green" ammonia using renewable energy. The fundamental (earth) ruthenium metal ternary hydride catalyst material produced by the researchers may achieve the catalytic production of ammonia under mild circumstances. The catalyst material consists of an ionic compound of the coordination anion

$[RuH_6]^{4-}$ containing Ruthenium (Ru) and negative hydrogen, together with the base metal cation lithium ion (Li^+) or barium ion (Ba^{2+}). This catalyst has exceptional efficiency in synthesizing ammonia under conditions of low temperature and low pressure. The catalytic activity of the basic (earth) metal ruthenium ternary hydride catalyst remains detectable even at a reaction temperature as low as 100 degrees Celsius. The synthetic ammonia reaction using this particular terhydride catalyst was discovered to proceed through a hydrogen-assisted dissociation mechanism. All the components of the catalyst are involved in the reaction, with the coordination anion of electron-rich Ru serving as the activation site for nitrogen. Negative hydrogen acts as both an electron and proton carrier. The presence of Li^+ or Ba^{2+} ions reduces the energy barrier of the reaction by stabilizing intermediate species. This reaction is facilitated through multi-component collaborative catalysis. The conversion of nitrogen and hydrogen into ammonia occurs through a chemical pathway that exhibits superior energy efficiency [4].

2.2. Application of inorganic nanomaterials in the field of energy conversion

The increasing significance of inorganic nanoparticles in energy conversion is evident with the progress of renewable energy in China. Inorganic nanomaterials find extensive application across various disciplines including chemistry, electronics, and physics, particularly in the domains of solar cells and energy storage materials. Significant advancements have been achieved in the fundamental investigation and practical implementation of nanomaterials. The ability to regulate the preparation, modify the surface, add functionality, and create nanomaterials on a larger scale are essential for the practical use of nanomaterials. This approach emphasizes the manageable preparation and surface modification of nanomaterials with a one-dimensional structure. It also focuses on controlling the size, shape, and composition of nanomaterials, as well as developing composite technologies for these materials [4]. The ultimate goal is to enhance the potential applications of nanomaterials in the fields of energy and catalysis; create nanomaterials and technologies with practical uses in secondary batteries, such as lithium-ion, sodium-ion, and lithium-sulfur batteries, as well as coatings and automobile exhaust catalysts. We produced Cu_2O pentahedral micron-scale materials with well-defined crystal faces of high diffraction index by employing a mixed solvent of water and ethanol, and utilizing glucose as a reducing agent in alkaline circumstances. The study examined the effects of modifying the shape and dimensions of nano-micron Cu_2O polyhedra on their suitability as catalysts for CO oxidation and $C-N$ and $C-O$ cross-coupling reactions. Solar cells have consistently focused on enhancing the efficiency of converting light into electricity. In this pursuit, the investigation of inorganic nanomaterials, which possess exceptional electrical and photoelectric characteristics, has emerged as a prominent research area.

The dominant method for making lead halide perovskite solar cells in recent years has been strongly linked to inorganic nanocrystals. The core component of the solar cell is a photosensitive film made of lead halide perovskite, which incorporates nanocrystals and organic material that introduce iodide and bromine components. This combination significantly enhances the absorption of light and facilitates its conversion into electricity. Inorganic nanoparticles have the ability to enhance both the stability of lead halide perovskite and the efficiency of light conversion in solar cells, while also decreasing their cost. Furthermore, in the realm of flexible solar cells, inorganic nanomaterials also serve a vital function. Conventional silicon-based solar cells need fabrication on a costly and inflexible substrate, rendering them incapable of being folded or bent. Organic solar cells employ nano components that are directly printed onto a flexible polymer matrix, resulting in the production of thin film solar cells that are flexible in nature. This material is appropriate for installation on curved surfaces and can also be used for specialized applications such as space detectors. The use of inorganic nanoparticles in energy storage materials holds great potential, particularly with advancements in battery technology, which has garnered increasing focus towards energy storage technologies [5].

Inorganic nanoparticles serve as energy storage materials due to their ability to meet the demands of miniaturization and high efficiency. Consequently, they have gained significant importance in the realm of energy storage. Using inorganic nanoparticles can enhance the cycle performance, rate performance, and electrochemical reaction speed of lithium-ion batteries. When comparing nanocrystalline and micron-scale physical structures, the ion diffusion path is shorter during charge and discharge. This makes it easier to accomplish high capacity and extended cycle requirements, as well as increase battery efficiency and lifespan. Supercapacitors, along with lithium-ion batteries, are a significant domain where inorganic nanomaterials find crucial utility in the realm of energy storage. Supercapacitors possess high power density and extended cycle life, making them commonly employed as energy balancing components in energy storage systems. Utilizing inorganic nanoparticles can enhance the electrochemical efficiency of supercapacitors, reduce the time required for charging and discharging, and enhance their suitability for various energy storage requirements. China's rapidly growing economy and the escalating energy issues have led to the expanding use of inorganic nanomaterials in energy conversion. These materials exhibit exceptional performance and are expected to have even greater potential as technology advances [6].

3. Future development trend of renewable energy in green chemistry

During the 19th century, coal supplanted wood as the primary source of energy, marking the advent of the coal age. Since the 20th century, oil has progressively emerged as the primary source of energy and raw materials, marking the era in which humanity coexists with both oil and coal. In the middle and late 21st century, a forthcoming wave of energy and material transformations will emerge, leading human society to transition gradually from an industrial civilization to a low-carbon era. The progress of catalysis over the past century has primarily been propelled by the conversion of fossil resources, such as oil and coal, which is referred to as feedstock-driven catalysis. In the future, ecologically driven catalysis will involve utilizing sunshine, water, and carbon dioxide, alongside efficient catalytic conversion of fossil raw materials, to generate energy and compounds that fulfill the requirements of the economy and society. The utilization of energy and chemical catalysis is demonstrating an unavoidable shift from being driven by raw materials to being driven by ecological considerations [6].

When examining the primary obstacles and common advancements in the fields of energy and chemical catalysis: Firstly, it is crucial to further advance the development of novel and effective methods for utilizing feedstock in thermal catalysis processes. These processes include chemical petroleum refining, direct production of olefins from syngas, converting low carbon alkanes into olefins, recycling plastic, and converting biomass. Additionally, it is important to propose strategies for designing platform compounds that optimize the retention of functional groups; to expedite the advancement of effective and reliable electrocatalytic procedures, such as the production of hydrogen through electrolytic water and the reduction of carbon dioxide through electrocatalysis; additionally, to devise innovative and efficient photocatalytic procedures, such as the decomposition of water through photocatalysis and the coupling of $\mathrm{C-C}$ bonds through photocatalysis. Ultimately, the objective is to advance towards "precision catalysis", a process in which targeted $\mathrm{C-C/C-O}$ bonds are selectively transformed to achieve accurate synthesis of the desired product atom in a cost-effective manner. In the present petrochemical procedure, the conventional base compounds such olefins and aromatic groups are initially synthesized, and subsequently transformed into monomers or other types of products by the oxygen/nitrogen heterocyclic reaction. The platform chemicals undergo polymerization to get the intended synthetic substance. Additionally, in the case of certain biomass and molecular structures resembling platforms, the process of converting them into methanol necessitates the coupling of $\mathrm{C-C}$ bonds and the expansion of chains to achieve the desired end product or alternative resources. In the future, relevant approaches might involve developing function-oriented catalytic pathways to optimize the preservation of functional groups found in the initial substance. The crucial aspect of the strategy is to selectively activate certain $\mathrm{C-C/C-O}$ chemical bonds with greater precision. The design tactics suggested by these function-oriented answers in the biomass transition sector will also persist in influencing the design of responses in other related disciplines [6].

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4. Conclusion

Green chemistry extensively utilizes renewable energy sources. They are frequently employed to facilitate environmentally friendly chemical reactions and decrease dependence on conventional energy sources. Solar and wind power, which are renewable energy sources, are employed in the process of electrolyzing water to generate hydrogen for the production of environmentally friendly fuels. Furthermore, biomass energy can be utilized for the production of biobased compounds. These strategies aid in the reduction of carbon emissions and the advancement of sustainable development. Potential areas for future investigation encompass enhancing the efficacy and environmental viability of renewable energy within the realm of green chemistry. Researchers may prioritize the development of enhanced energy storage technologies to tackle the challenges presented by the unpredictability of renewable energy. Furthermore, a crucial focus lies in enhancing the incorporation of solar and wind energy into the chemical sector and augmenting its application in chemical manufacturing. Investigating novel catalysts and reaction routes to enhance the efficacy of sustainable energy in the chemical synthesis procedure while minimizing ecological consequences is also a crucial area of future investigation.

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