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Green Chemistry Techniques used in The synthesis of Organic and Biochemical Compounds

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Abstract

Green chemistry is closely related to "the design of chemical products and processes that specifically eliminate the use or generation of substances that are hazardous to humans, animals, plants, and the environment." Green chemistry contains 12 principles that guide how a chemical is produced and used in a green and sustainable way, reducing pollution. Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry involves the design, manufacture, and use of chemical products and processes that are efficient, effective, safe, and more environmentally benign. Chemical pollution is extremely dangerous, and the danger of chemicals is not limited to the waste resulting from their manufacture or the way they are disposed of, but rather to the entire manufacturing process and its products. Chemicals that have no equivalent in terms of their structure and the nature of their chemical bonds in the bodies of living organisms are considered highly toxic, such as organometallic materials that include one or more chemical bonds between a metal and an organic compound, in addition to many forms and types of compounds and materials that are produced and placed in the environment of our planet and its biosphere without taking into account the long-term effects of this. From a purely scientific point of view, the great development in chemical sciences has led to the production of materials that did not exist before, and this is an amazing human achievement, but this progress, which has been proven to be transformed into huge industries that produce huge amounts of waste and materials that lead to the slow destruction of our planet, must remain confined to laboratories and classrooms, and scientific and technological development must be used to direct scientific research towards solving the current problem, which is the destruction caused by chemical industries to the Earth's biosphere, whether through fertilizers or pesticides and herbicides that lead to the complete destruction of the biological system in the region for a limited economic goal related to increasing crops by a certain percentage in exchange for the loss of soil, or through the waste that factories dispose of in rivers or ponds so that it can find its way to groundwater and thus cause environmental pollution.

Keywords: *green chemistry, synthesis, organic, pollution, environment, photo.*

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INTRODUCTION

Over the past two decades, the branch of green chemistry, or sustainable chemistry, has been

slowly growing. It is a branch of chemistry concerned with making the process of synthesizing and manufacturing chemical compounds more environmentally friendly and more sustainable through a set of principles guiding scientific research, the first of which is avoiding waste [1,2], so that the process of synthesizing and manufacturing organic compounds is with the least possible amount of waste, or without waste, such as click chemistry, which provides a completely clean chemical reaction. Barry Sharpless [3], one of the most prominent scientists who contributed to its development, was awarded the Nobel Prize in Chemistry in 2022, along with Morten Meldahl and the pioneer of orthogonal chemistry, Caroline Bertozzi.

Atom economy is one of the foundations of green chemistry, and one of the principles that leads to the least amount of waste, so that the design of the chemical reaction includes using the largest number of atoms of the reactants in producing the final compound so that it produces the least amount of waste possible. This principle is considered one of the important indicators of the efficiency of the reaction and its economic feasibility, in addition to the principle of using renewable or sustainable materials instead of using chemicals whose manufacturing process also leads to more pollution and harm to the environment. The chemical industry, and chemical sciences in general, face a problem related to catalysts, as chemical reactions need catalysts to take place under standard conditions, or under physical conditions that can be achieved in the laboratory or factory. These catalysts are mostly organometallic materials, which include heavy elements and metals in addition to a chemical bond between the metal and other organic compounds, a bond that living organisms cannot deal with, and thus they are highly toxic and destructive to the environment, but they are essential for chemistry and related industries. Here, scientists interested in green chemistry set a set of principles, so that if it is necessary to use organometallic catalysts, their efficiency must be increased by conducting research that increases the number of reactions that a single molecule of the catalyst can produce, which leads to the use of smaller quantities of catalysts. The best situation is to seek to avoid using this type of catalyst and move towards using organic catalysts or enzymes, which Frances Arnold has made great strides in through directed evolution that leads to the production of enzymes that contribute to the catalyst of chemical reactions and has achieved a result for her efforts on the Nobel Prize in Chemistry in 2018 [4-6].

Among the obstacles facing the transition to green chemistry is the need for some important reactions to exceptional conditions such as high or low pressure, or very high or very low temperature, which means the need to consume energy. Here, the principles of green chemistry include striving to design a reaction that is more environmentally friendly, by evaluating the possibility of successfully using organic catalysts, or using organometallic catalysts with high efficiency, and conducting a risk assessment and which of these paths is less costly and harmful to the environment. Directing our thinking towards environmental solutions instead of thinking about profits, and studying environmental risks along with studying economic feasibility, leads to economic and environmental benefits. Twenty years ago, green chemistry was pure fantasy. Where can we find a chemical reaction that does not produce waste, does not consume energy, and does not require organometallic catalysts? Today, however, we are talking about scientific successes that have won Nobel Prizes, and scientific principles that intersect with economic goals in reducing costs. Reducing waste necessarily means reducing waste, and increasing the efficiency of the reaction means increasing the efficiency and returns on investment. Hence, the market economy is inseparable from the atomic economy [7-10].

Aims of Green Chemistry

Green chemistry aims to increase the efficiency of the chemical process and reduce the risks that threaten human health and the environment. Although there is no completely (green) reaction, the total negative effects of chemical research and industry can be reduced by following the twelve principles of green chemistry as much as possible. There is no doubt that human civilization has had a tremendous impact on the global environment, an impact that is often negative. Today, there is an urgent need to make efforts that bring about major changes in all types of human activities in order to slow down climate change, prevent pollution, and conserve depleting natural resources. The largest part of the burden of these changes falls on the chemical industries responsible for producing most of the materials that pollute the environment and deplete the largest share of natural resources. Therefore, companies working in this field seek to adopt new manufacturing

principles that are non-polluting and non-depleting of resources known as green chemistry principles. Green chemistry is a specialized field that advocates smarter and more sensitive production processes in industries that use chemicals on a large scale. Its goals are to increase the safety of final chemical products, reduce the production of hazardous waste, and limit the use of non-renewable resources required in chemical production processes. Green chemistry, also known as sustainable chemistry, is a scientific field that has been growing at a relatively slow pace for two decades [11-13].

Principles of Green Chemistry

The trend towards this new branch of chemistry was nothing more than a reaction to the many harms caused by traditional chemistry since the nineteenth century. The American marine biologist and science writer Rachel Carson (1907-1964) wrote her famous book "Silent Spring" in 1962, and explained the great damage caused by chemicals to local ecosystems. This book was a wake-up call addressed to the public, scientists and decision makers alike. However, the basic principles of green or sustainable chemistry did not crystallize until about four decades later, specifically in 1998, when the American chemists Paul Anastas and John Warner formulated the twelve principles of green chemistry known as the culmination of a scientific movement that swept the global chemistry community during the nineties of the last century. The twelve principles represent the main goals of green chemistry: making chemicals safer during the stages of production, use and disposal, and not creating hazardous waste if safe processes are available. And avoiding the use of limited resources in favor of renewable resources. In addition to scrutinizing chemical processes to ensure their safety and environmental impact, these principles are primarily aimed at professional chemists and chemical engineers and provide them with some general concepts such as the preference for reusable raw materials over non-renewable ones and very specific chemical practices, such as the use of selective catalysts instead of chemical reagents. In general, the most notable thing about the Twelve Principles is that they address the problem of hazardous chemicals and environmental damage at all levels [14-17]. They also introduce the concept of “atomic economy” to reduce waste production at the level of the individual chemical reaction. At the same time, these principles call for real-time monitoring of industrial chemical reactions to avoid their formation or release of hazardous or polluting substances. Green chemistry, as stated in the Hippocratic Oath of Chemists, "Begin, do no harm", is the true meaning of green chemistry, which not only defines green chemistry, but also includes the field in which it operates and the extent to which it will reach in the future. The early pioneers of this science established twelve principles on which it is based, and which clarify its future directions. However, in fact, the practice of green chemistry began in the United States in 1990 after the signing of the Pollution Prevention Act, which aimed to protect the environment by reducing harmful emissions from the same source. Under the law, the US government provided grants to develop chemical products through various institutes and universities to reduce the risks of these materials. The objectives of the grants provided have evolved to produce chemicals that neutralize harmful substances, reduce pollution, and develop alternatives to chemicals whose extraction processes pollute the environment. Green chemistry seeks to make chemistry an integrated science by reducing the pollution caused by chemical manufacturing, which is important for the pharmaceutical and pharmaceutical industries, petroleum and plastic industries, and other non-industrial chemical activities, by preventing this pollution from forming in the first place [18-20].

Green Chemistry and its Role in Reducing Pollution

The principles of green chemistry related to safety allow for the assessment and reduction of the impact of all stages of the chemical process on humans, wildlife and the environment. This also includes assessing the performance of products over longer periods of time. It is also crucial to design products with their future decomposition in mind when the product breaks down into smaller, simpler parts (decomposition). Decomposition can be physical (by breaking down into smaller parts) or chemical (by breaking down into

different molecules). Decomposition can occur naturally - such as composting - or with external assistance, such as dissolution, grinding or chemical reactions. Most importantly, the product and its decomposition products should be non-toxic and should not be resistant to degradation in the environment. Chemical or harmful substances that are resistant to degradation are described. Once produced, these substances are difficult to remove from the environment and can continue to cause harm for a long time. Ideally, all steps in the process - as well as raw materials, products and by-products - should be as safe and non-toxic as possible. If we take the safety implications of a process into account during its design, we can prevent harm to people and the environment [22-25]. Safety considerations also include the dangers of using high temperatures or high pressures during the reaction process. Green chemistry principles also include the use of renewable primary resources and reducing reliance on non-renewable resources such as oil, while ensuring that manufacturing processes are carried out at normal temperature and pressure to reduce energy consumption. Manufactured chemicals must also be easily degradable by natural factors into compounds that are harmless to the environment to prevent these manufactured materials from becoming environmental pollutants, as is the case with plastic products, the accumulation of which due to their slow decomposition has led to serious environmental damage that has not spared the oceans, and poses a threat to living organisms, the effects of which extend over decades [26-29]. Scientists must be able to compare and classify different chemicals and processes to understand their effects and benefits. It is important for them to understand how different chemicals affect the people who use them. Some chemicals may be harmful to humans or the environment. The information contained in chemical safety documents allows scientists [30] to determine which chemicals may be the most sustainable and safe option for use in their products, figure (1).

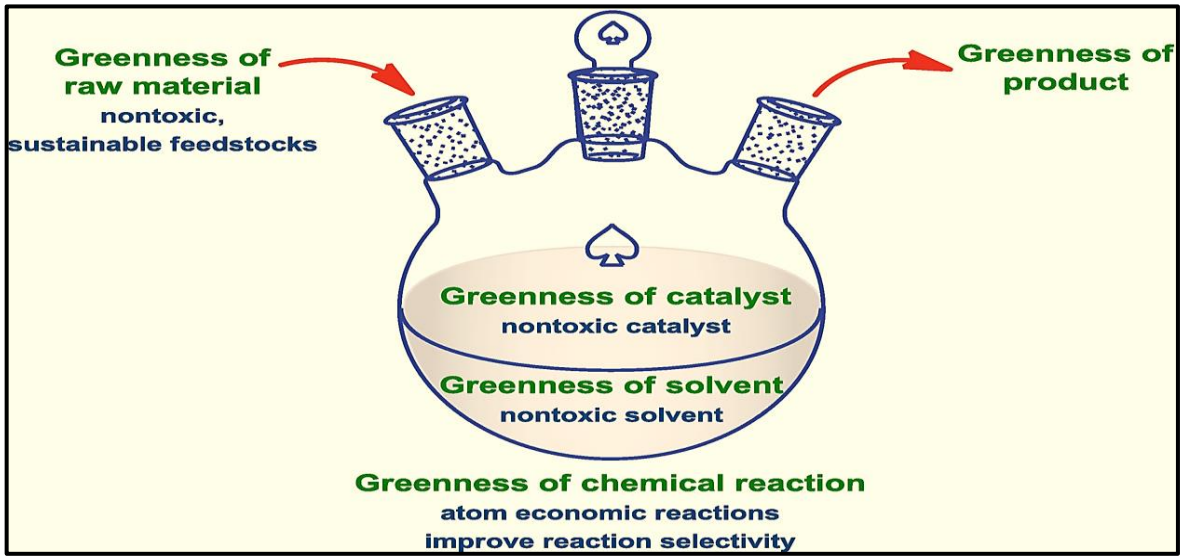

Fig. 1: Green Chemical Reactions

Applications of Green Chemistry in the Environment and Laboratory Fields

In application of the principles of green chemistry and with the aim of reducing waste production and depletion of natural resources and preserving a healthy environment, researchers have developed new manufacturing methods that meet these conditions. Including finding a natural alternative to polymers extracted from petroleum products that are widely used to produce materials that are harmful to the environment and human health, such as plastic bags [31]. These are polysaccharide polymers that can be extracted from potatoes, grains and many plants. These natural polymers will enable the manufacture of biodegradable materials without causing harm to the environment. To manufacture food coloring and flavoring materials, researchers have developed a new technology that relies on glucose extracted from starch to replace the currently widely used chemicals that are not without risks to human health, in addition to the fact that their manufacturing process generates many pollutants [32-34]. Green chemistry researchers have developed new techniques for conducting chemical reactions, including the use of ultrasound in chemical manufacturing. This technique works to achieve the principle of atomic economy and stimulates the reaction

to take place in a short time and has a high return compared to traditional methods [35, 36]. "Using carbon dioxide in a supercritical state in manufacturing increases the return of chemical reactions and reduces the quantities of chemicals and natural resources used in chemical industries." The technology of using carbon dioxide in a supercritical state - which is an intermediate state between liquids and gases - as a solvent is considered one of the promising technologies in the field of sustainable chemistry. This technology allows for increasing the return of reactions and reducing the quantities of chemicals used in chemical and textile industries, in addition to reducing the natural resources consumed in these industries [37].

Nike, the global shoe and clothing company, recently announced its reliance on carbon dioxide in a supercritical state as a solvent in fabric dyeing processes at one of its factories in Taiwan. According to the company, this technology will save large quantities of water estimated at 150 liters of water that were consumed to manufacture one shirt. Research centers, for their part, are working on developing new scientific techniques that help in manufacturing consumer products without harming the environment. In the past decade, many scientific journals specialized in the field of green chemistry have emerged to encourage researchers to produce scientifically in this field. However, the sometimes-high cost of some of these techniques remains the main obstacle to manufacturing alternative materials, at least at the present stage. However, the issue of preserving natural resources and maintaining a clean environment has become a matter of increasing interest for both peoples and governments and will push towards adopting these techniques in the future. Green chemistry has become a global trend, and many global environmental protection agencies and bodies have supported this trend. For example [38], the US Environmental Protection Agency, through its Office of Chemical Safety and Pollution Prevention, has supported this trend by giving the prestigious annual Green Chemistry Challenge Awards in partnership with the Green Chemistry Institute of the American Chemical Society and other trade associations and government academic institutions. During the 22 years of the awards program, EPA has presented awards to 114 winners. Since its inception in 1996, EPA has received more than 1,600 nominations. By recognizing pioneering scientific solutions to real-world environmental problems, the Green Chemistry Challenge has dramatically reduced the risks associated with the design, manufacture, and use of chemicals, figure (2).

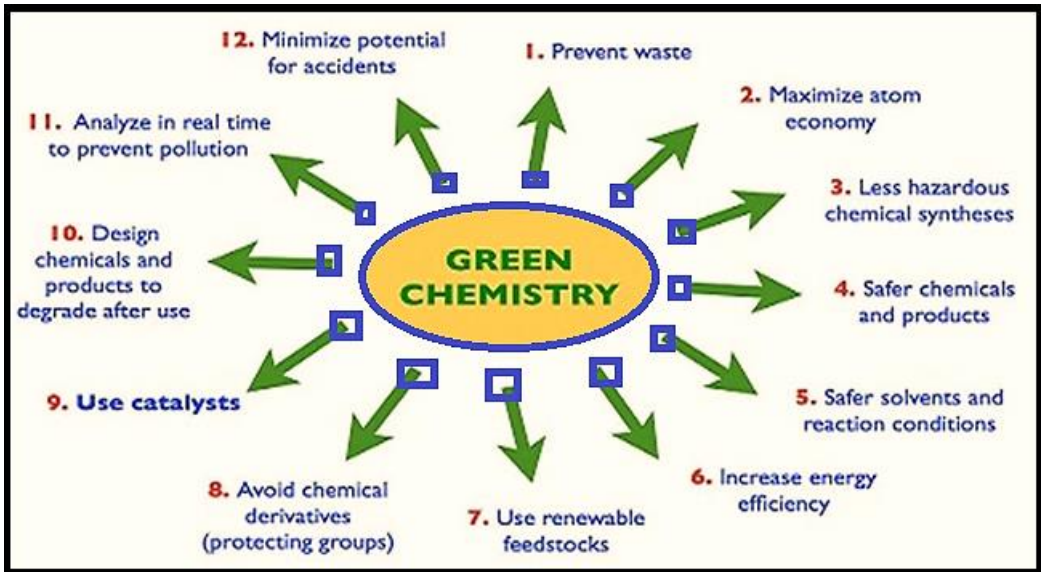

Fig.2 :Principles of Green Chemical Reactions

The importance of Green Chemistry for Environmental Reactions

The current exceptional circumstance of the world, which has caused the cessation of all human activities that cause environmental pollution, primarily industrial and transportation activities responsible for approximately

50% of air pollution causes, has seen in most regions of the world, especially industrial ones, how most of the environmental systems on land, sea and air in those regions have returned to the eye and most of the natural chains have reappeared and aerial photographs have proven a very large decline in air pollution for countries whose economies depend on industry, primarily China. As for the decline in the ozone hole at the poles of the Earth, it is an independent topic in itself, evidence that the decline in air pollution by nitrogen oxides resulting from industry and other greenhouse gases, i.e. (its return to the natural limit necessary to maintain the thermal balance of the Earth, which is its function by balancing what enters the Earth's atmosphere from sunlight and what is in excess of its need and which it reflects in the form of infrared rays) has given room for this wound of the Earth's atmosphere to heal [39]. In the midst of this abundance that nature took during the spread of the Covid-19 virus, which was caused by the cessation of human activities in general, God Almighty proves to us His saying in His Book "Dear in Surat Al-Rum, verse 41, in the name of God, the Most Gracious, the Most Merciful (Corruption has appeared on land and sea because of what the hands of people have earned so that He may let them taste some of what they have done that perhaps they will return) God Almighty's truth ,So, what the hands of people have earned and what they have extended to other components of the environment is great injustice. They are nations like us as God Almighty described them. Nature had no choice but to restore its balance that was disturbed by man by the command of God, and this virus was the means. It may be a result for all of the above, and God knows best. Every harm has a silver lining... In conclusion, I hope that the world after Corona has realized, even to a small extent, the responsibility for the results of its activities on the environment and what they have caused in disturbing its system, and that it emerges after this pandemic having returned to God and His guidance in a beautiful way, and that specialists realize the importance of applying the twelve previous safety and sustainability methods of green chemistry to protect and improve the environment in which we live. The first ideas and principles of green chemistry appeared in the early nineties of the last century; the term "green chemistry" did not appear in books and literature until twenty-two years ago. The "Pollution Prevention" conference held in the United States of America in 1990 is considered the starting point for green chemistry and its applications, where the most important problems raised were how to reduce pollution in its various forms. Among the results that researchers concluded was that: "The best way to eliminate pollution is to eliminate it during or after its formation in its first appearance before it is transferred to the environment; where it becomes difficult to eliminate it." This represents a prominent point of difference between environmental chemistry and green chemistry. In 1991, the green chemistry program and policies began to be adopted in the United States of America, while at the beginning of the first half of 1990, Italy and the United Kingdom launched their first programs, in addition to Japan, which joined the previous countries during the second half of the same decade. Green chemistry has been defined comprehensively by experts in this field as the development and design of chemical compounds and methods to reduce or prevent the use and production of hazardous materials [40,41].

The importance of Environmentally Friendly Reactions

Designing biodegradable chemicals where chemical products are designed to break down into harmless substances after use, so they do not accumulate in the environment. Reducing the likelihood of accidents by designing chemicals and their physical forms (solid, liquid, or gas) to reduce the likelihood of chemical accidents including explosions, fires, and releases into the environment. Analyzing the level of contamination by incorporating in-process and real-time monitoring and control during formulation processes to minimize or eliminate the formation of by-products. Designing safer chemicals Designing chemical products that are completely effective but have little or no toxicity. Using renewable feedstocks Use starting materials (also known as feedstocks) that are renewable. Renewable feedstocks are often sourced from agricultural products or other process waste. Green chemistry has made remarkable progress in recent years, as it has become possible to replace traditional organic solvents in manufacturing and chemical separation methods with environmentally friendly green solvents. Among the distinguished works in this field are:

Using carbon dioxide in a liquid state at supercritical temperatures in manufacturing and chemical separation. One of its most important features is that it does not oxidize under these conditions, which makes its use in

oxidation reactions of great value., Using plant waste to produce lignin, which is used in many chemical applications, thus making today's waste sources of safe raw materials for tomorrow's industries. We also add the efforts of chemists researching the development of clean chemical methods, such as microwave technology and ultrasound in chemical manufacturing. These technologies work to achieve the principle of atomic economy and atomic efficiency, and the reactions take place in a short time - or we can say in an imaginary period of one to ten minutes - and the reaction yield is great compared to traditional methods.
Establishing an educational policy to teach green chemistry in universities, introducing it into academic scientific research, and linking the latter with the economy and the requirements of industry and the market, in addition to finding environmentally friendly alternatives with high efficiency, which help in the final disposal of hazardous chemicals and take into account - at the same time - the economic aspect, all of which are among the most important challenges facing chemists in this field. Everything around us, such as the air we breathe, the water we drink, and all living organisms, are basically made of chemicals. In fact, the processes that occur inside our bodies without stopping are also chemical processes. We cannot imagine that we can ever do without chemistry under any circumstances [42, 43].
Over the course of nearly two centuries, chemical sciences have expanded continuously and increasingly, which has led to the production of many products that have contributed to the advancement of living and the facilitation of possibilities through the modern industrial renaissance, for example, but not limited to, medicines that have improved health and increased life expectancy, God willing, as well as fertilizers because of their role in increasing food production, and the semiconductor industry that has enabled the manufacture of computers and other electronics such as phones. Despite the benefits and industries that have had a positive role, there are some negatives and disadvantages behind these industries, including the release of toxic materials, whether liquid, gaseous, or solid, and non-degradable, and these are enough to destroy the planets and the environment in which we live and living organisms, including us humans [43].

CONCLUSIONS

To be considered green, chemistry must adopt manufacturing methods that do not produce highly toxic substances to humans and other living organisms and limit chemical waste, which in some conventional manufacturing processes exceeds hundreds of times the volume of the product itself.

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