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An overview of Green Chemistry and its applications

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Abstract: Green chemistry is the implementation of innovative chemical technologies that prevent pollution in scientifically sound and cost effective manner. Green chemistry accentuates how important it is to building the future. In this paper an overview on applicability of 12 Principles of green chemistry, applicability is covered, along with their developments and some applications are discussed.

Key words: Green Chemistry, Green Principle, Green Synthesis and Green Solvents

Introduction

Green Chemistry has spent the last two decades. It is a way of thinking about present and emerging tools, knowledge, and chemistry design in order to contribute to society's economy while protecting the environment and human health. Green chemistry is a trend that will persist. "Green chemistry efficiently uses raw resources (ideally renewable ones), reduces waste, and forgoes the use of hazardous and/or toxic reagents and solvents in the production and use of chemical products. The design of eco-friendly products and processes (benign by design), as established by Paul Anastas and John Warner, serves as the guiding concept. The Twelve Principles of Green chemistry are as represent step by steps [1, 2] i) Prevention, ii) Atom Economy, iii) Less Hazardous Chemical Syntheses, iv) Designing Safer Chemicals, v) Safer Solvents and Auxiliaries, vi) Design for Energy Efficiency, vii) Use of Renewable Feedstocks, viii) Reduce Derivatives, ix) Catalysis, x) Design for Degradation, xi) Real-time analysis for Pollution Prevention, xii) Inherently Safer Chemistry for Accident Prevention.

These guidelines offer a comprehensive framework for scientists, engineers, and researchers to create novel solutions that not only satisfy the needs of contemporary society but also drastically lessen the environmental impact of chemical processes.

The Renowned 12 Principles of Green chemistry

Green chemistry examines how chemical products and the methods used to make them affect the environment. The objective is to create a green process to produce the product, which is a given. Green chemistry is a fundamental form of pollution prevention rather than waste remediation since it eliminates waste at the source. The primary tenet of green chemistry is that prevention is preferable to cure. Sustainable Technologies is a different word that is currently preferred by the chemical industry. Green chemistry is the means to achieving sustainability, according to some. For better understanding of the principles of green chemistry [2-5] and some examples of their applications to basic and applied research are illustrated below:

1. Prevention

One of the most well-known rules for process optimization refers to scientists' ability to rework chemical reactions to reduce the production of hazardous waste as a crucial step in the avoidance of pollution. The risks connected with garbage storage, transportation, and treatment could be reduced by minimizing waste generation. This idea is simple to comprehend and straightforward to put into practice, and examples from both business and academics have demonstrated its importance, applicability, and viability. This tenet of green chemistry is still true, but we need to think about it differently, moving away from a narrow definition of waste based on its quantity and toward a more inclusive strategy: (i) we need to consider the multidimensionality of trash. (ii) The "amount of waste per quantity of product" paradigm needs to give way to one that addresses the "quantity of waste generated per function given by the product." In this way, we must strive to improve both product quality and functionality. (iii) When considering a product's whole life cycle, we must take into account the fact that waste is produced not only during the production process but also after the product has

been used up or reached its end of life. This is known as "end-of-life waste." This includes both their ability to be recycled and the transformation of materials that were previously deemed garbage into useful items. In general, modernizing industrial processes through clean production methods is included in the movement toward "zero-waste production" and "waste prevention." These methods were typically created to help safeguard the climate and environment and are aimed at reducing gaseous emissions, effluents, solid residues, and noise generation. Fundamentally, its seeks to advance zero-waste technologies (ZWT). Waste product in chemical synthesis should be zero or at a minimal. Additionally, it uses trash from one system as the starting point for developing other systems. As an illustration, thermal power plant bottom ash can be utilized as a raw material for the cement and brick industries, and effluent from the cleaning of machinery parts can be used as the coolant water in thermal power plants and by making the polymers susceptible to biodegradation by proactively transitioning to the biodegradable plastic in place of highly resistant petrochemical plastics [2, 3, 4].

2. Atom Economy

Atom economy also termed as a "Atom Efficiency". The methodology should be designed so as to maximize the incorporations of starting materials into the desired final product during the synthesis of chemical product. Therefore, it requires minimizing by- product formation. To avoid the use and formation to toxic materials when possible, poisonous and environmentally dangerous compounds should not be used in synthetic techniques. The second principle of green chemistry can be simply stated as the atom economy of a reaction. Barry Trost's concept of atom economics asks, "What atoms of the reactants are absorbed into the ultimate intended product(s) and what atoms are wasted?" Atom Economy is the mass of desired product divided by the total mass of all reagents, times 100 and can be calculated by following formula:

$$\text{Percent Atom Economy} = \frac{\text{Mass of Desired Product}}{\text{Total Mass of all Reagents}} \times 100$$

Green techniques or methodology involve self-regulating thermal systems. It focuses on maximizing the assimilation of components from raw materials or reagents into the finished product. Essentially, it is molecular pollution prevention. For instance, a chemist who uses the atom economy could prefer to synthesize a desired product by putting basic building blocks together rather than disassembling a much larger starting material and discarding the majority of it as trash. In atom economy the rearrangement reactions entail reorganization of the atoms of the molecules. Because neither elimination substitution nor addition of atoms is not taking place so the molecule undergoes the rearrangement reactions, the green solvent is also emerging concern to maximizes the atom's efficiency. For example benzene can be replaced by the toluene; cyclohexane instead of carbon tetrachloride can be replaced. Now a day Microwaves are more environmentally friendly than traditional solvent-free organic synthesis processes. Recently, the scope of microwave chemistry has been expanded to include several elements of organic synthesis. Similarly, Sonochemistry has a high yield in chemical synthesis without the use of solvents and includes low energy use, no solvents, and less trash[6,7]. So, the atom economics is concerned with waste minimization at the molecular level, whereas chemists have typically focused on boosting yield, lowering the number of procedures, or generating a completely unique molecule. For example ethylene reacting with oxygen in presence of catalyst forms the ethylene oxide. The % atom economy can be calculated by the percent atom economy formula. The formula weight of the reactants is 44 and atoms utilized are also 44. So, the % atom economy is 100%.

Green chemistry and atom economics inject a new objective into reaction chemistry, which is to design reactions so that the atoms contained in the starting materials end up in the result rather than in the waste stream. This notion gives a framework for analyzing various chemistries, as well as a goal to strive towards in new reaction chemistry. [8, 9, 10,]

3. Less Hazardous Chemical Syntheses

Synthetic methods should be developed wherever possible to use and make chemicals that are secure for both the environment and people**.** When you think about it, the first two words, "whenever practicable," separate this rule into two halves. This is, if you will, the get out of jail free card that chemists use to try to avoid applying this concept to their work. By using those two phrases, it implies that it may not be practicable or possible to avoid employing compounds that are dangerous. Let's face it, scientists frequently use poisonous substances because reactive compounds enable favorable kinetic and thermodynamic processes. Inherently harmful materials will still be employed unless—and until—replacement compounds and new synthetic methods are created. However, it is simpler to dismiss it as impractical and ignore any consideration of the chemistry used.

Regarding the concepts of green chemistry, what matters in synthetic organic chemistry is achieving a successful chemical transformation in a novel manner, with a novel molecule, or in a novel order. Numerous studies have unequivocally shown the connection between toxicity and the dangers and risks linked to chemical reactions and the substance present in the reaction vessel. In general, the chemistry underlying a process and the transformations contributing to a chemical synthesis chain have a significant impact on the holistic toxicity spectrum of products or processes, as well as most other sustainability and green chemistry criteria. An exception is noted in situations where a molecule is created on purpose and is intended to exhibit biological activity or toxicity. For example, this scenario is found in the case of various molecules synthesized for pharmaceutical or agricultural applications, such compounds exhibit toxicity and/or impact living organisms. A crucial step in the creation of a process is choosing the compounds and materials that will be utilized to enhance the efficacy of chemical transformations; scientists should pay more attention to the choice of materials to be placed in reaction vessels. It is easy to ignore the other components and concentrate all of your efforts on the chemosynthetic process, which gives us the desired outcome. However, ignoring all other factors involved in a production process has a cost that must be paid in the end, thus we must finally do away with this situation.[10]

4. Designing Safer Chemicals

This principle is dedicated to the design of compounds that are inherently safer in their nature because chemists do occasionally create dangerous molecules. Chemical products should work well yet with minimal impact on the environment if they are to be employed in a variety of activities. One of the most difficult parts of building safer products and processes may be minimizing toxicity while

retaining function and performance. To accomplish this, one must comprehend not only the fundamentals of chemistry but also those of toxicology and environmental science. Chemists frequently use highly reactive compounds to create products because of how valuable it is for them to influence molecular changes. They are more prone to react with unanticipated biological targets, including human and ecological ones, which can have undesirable negative impacts. Even the most expert molecular magician starts the challenge without a full toolset if they don't understand the basic structure hazard relationship. Toxicology requires novel approaches to chemical characterization that assert that risk is a design error and needs to be addressed at the outset of molecular design in order to master the art and science of toxicology. A systems-based approach to chemical design must characterize, assess, and manage the intrinsic danger of elements and molecules, which is a fundamental chemical feature.

The time is right for toxicologists and chemists to work together to create a complete programmed that will prepare the next generation of scientists to create safer chemicals in a truly holistic and cross-disciplinary way. Toxicology is a fast developing subject that uses advances in molecular biology to understand the processes of toxicity. Elucidation of these pathways serve as the starting point for articulating design rules that are required by chemists to guide their choices in a quest to make safer chemicals. We are at the dawn of a new sunrise, poised to illuminate the path forward to a safer, healthier and more sustainable world. Not only are the waste products but also the raw materials highly dangerous for the environment and the workforce in many chemical businesses. Adipic acid, for instance, is frequently utilized in the polymer industry. Adipic acid is produced using benzene as a starting material, but benzene is carcinogenic and a VOC, which pollutes the air [10-12].

5. Safer solvents and auxiliaries

The usage of auxiliary materials, such as solvents, separating agents, etc., should be minimized during chemical synthesis. If used, these should be environmentally beneficial. Green solvent or bio solvents, are environmental friendly beneficial solvents that come from the processing of agriculture commodities. The majority of chemical processes rely on the uses of petrochemical solvents, although doing so has serious environmental consciences.

Solvents and mass separation agents of all kinds matter a lot to the chemistry not to mention the chemical process and the overall "greenness" of the reaction. Many reactions would not be possible without the use of solvents and/or mass separation agents. To assert they don't matter, or that only chemistry matters, is not only a logical mistake, but also scientifically inaccurate. Solvents and separation agents allow for mass and energy transfer, which is essential for many processes. The Green solvent [13-15] usually are used in the enzyme assisted extraction methodology, the least toxic solvents such as acetone, ethanol, methanol, 2- propanol, ethyl acetate, isopropyl acetate, methyl ethyl ketone, 1- butanol, and tert-butanol and dichloromethane are the example of some commonly-used solvent, with a safer alternative and water is a safe benign cheapest solvent, Likewise supercriticalCO_2 [16-18] in place of volatile halogenated organic solvents for chemical synthesis and other purposes. Furthermore, Methylene chloride, as a solvent that certainly needs to be replaced, is primarily used for formulations such as paint strippers, adhesives, and aerosols. It has also been demonstrated that solvents account for 50 - 80 % of the mass in a typical batch chemical procedure, depending on whether water is included or not. Furthermore, solvents account for about 75% of the total life cycle environmental consequences of a typical batch chemical process. The Solvents and mass separation agents also use the majority of the energy in a process. Consider that for a moment. Solvents are heated, distilled, cooled, pumped, blended, vacuum-distilled, filtered, and so on. And that's before they're recycled or not. They are frequently burnt if they are not recycled. Solvents are also significant contributors to the overall toxicity profile and, as a result, constitute the bulk of the materials of concern connected with a process. Because they are flammable, volatile, or explosive under certain situations, they pose the most worry for process safety problems. They also often require employees to wear some form of personal protection equipment. Solvents will always be required, and as with many other aspects of chemical processes, it is a matter of impact trading. When you optimize a solvent based on one green measure, there are always three others that don't seem so nice. The goal is to select solvents that make chemical sense, decrease energy needs, have the least toxicity, have the fewest life cycle environmental consequences, and have no serious safety implication espite what one or more well-known synthetic organic chemists may believe, solvents and separation agents do matter. Better choices are conceivable, and the implementation of this concept should encourage them. [19-25]

6. Design for Energy Efficiency

Energy and energy consumption during the synthesis of a chemical product should be reduced to make the process more and more cost-effective. The synthetic procedures should ideally be performed at room temperature and pressure. Energy is a critical concern for the twenty-first century. The majority of energy generated is and will continue to be dependent on fossil fuels. And the majority of the energy delivered to the place of consumption is wasted during conversion and transmission. This implies that if you look at the energy production life cycle and how much energy is truly accessible for meaningful labour at the moment of demand, it is less than 1% or 2% of the energy that was previously available in the fossil fuel. It is also true that the majority of fossil fuel energy is utilized for transportation services of some type or another, with space heating and cooling coming in second. There are several chances for chemists to improve their energy usage profile, but, relatively few chemists consider themselves to be a part of transportation or the built environment. When it comes to energy, most chemists, and especially chemical engineers, are taught around H in the Gibbs free energy equation. We consider temperatures of formation, heats of vaporization, enthalpy, exothermic processes, and so on.

There's a lot more to energy and engaging chemists in energy thinking than asking them to conduct reactions at room temperature and pressure. The bulk of energy is required in solvent removal to prepare for the next reaction, or to remove one solvent and replace it with another, or to isolate the desired product, or to eliminate contaminants. Apart from hydrogenations and oxygen or moisture sensitive reactions, most reactions take place at atmospheric pressure. This is not to say that energy isn't vital; it's simply that most chemists aren't focused on it.

Again, considering more than one aspect of the reaction or process during the creation of a novel molecule is crucial not just from an energy standpoint, but also from a variety of other perspectives. Energy is merely another design parameter, much as thinking about how to structure a synthesis to have the fewest number of steps, use the cheapest starting materials, or any other element of interest to

the synthetic or process chemist or improving energy efficiency in the chemical industry. Historically, it has not been seen as such, but we can no longer afford to build new molecules in the absence of a thorough examination of how energy will be utilized.

electrons flowing in currents generated from renewable energies (RE) solar, wind, hydro- or geothermal power to mention the most often cited ones. The intermittence and/or the geographic uneven distribution of these renewable energies are among the biggest challenges connected with their integration in the current infrastructure. Chemistry connected to how to produce them (one by one in a valence band of a semiconductor or industrially through a wind turbine), distribute them (in an academic photoelectric cell or in an urban electric (smart grid), store them and recover them back from the storing location (be it a battery or in a chemical bond) has definitely become green chemistry too. Furthermore, since the production, distribution, storage and utilization of electrons embrace chemical reactions (such as the CO_2 reductions just to name one possible family of reactions) materials (electrodes, membranes, conducting organic-based composites, and semiconductors) and reactors (as in photo-bioreactors, solid oxide electrolyzers or dye-sensitized solar cells), green chemistry is to be understood in its broad sense of relating to chemical sciences, advancements in molecular, heterogeneous and bio-chemistry, process engineering, material science. That is all the various facets which make chemistry a platform science in the energy challenge.

Photogenrated electrons or green electron, renewable forms of energy and combined heat and power (CHP), will complement Re-power generation. Necessary scientific advancements connected with materials, process and, in the broad sense, chemistry, are undoubtedly targets of the field. Synthetic techniques should require more and more moderate settings to save energy, and the ambient pressure and temperature are the ideal options. It requires the right catalysts to speed up the reaction even at low temperatures. The biocatalysts can operate in normal environmental conditions [19- 25]

7. Use of Renewable Feedstocks

In the event that it is both technically and financially feasible, the renewable if technically and economically feasible, raw materials or feedstock should be made from renewable resources (like biomass) rather than non-renewable resources like crude oil. The concept of manufacturing all of our future fuels, chemicals, and materials from infinite Feedstocks is appealing, but it looks unrealistic at first glance. Mankind today harvests minerals and fossil fuels, such as coal, oil, and natural gas, for profit from the ground until they are exhausted. With expected worldwide population growth and expanding energy-intensive economies on several continents, our fossil fuels for carbon-based chemistry and materials are rapidly decreasing in a predictable manner. The implications for human health and the environment are dire, offering huge challenges to our scientists and leaders over the next 50 years.

We can address these global concerns with green chemistry principle -7 as if by magic, we will obtain our feedstock from "thin air," and it will be renewable. Carbon dioxide and methane are two forms of carbon in the atmosphere that are extracted by photosynthetic processes powered by the sun to produce plants, trees, crops, algae, and other creatures known together as "biomass."

Every year, nature creates around 170 billion tones of plant biomass, of which people presently utilize approximately 3.5 percent for human needs. It is estimated that 40 billion tones of biomass, or around 25% of annual production, will be required to completely build a bio-based economy. The technical challenge in using such renewable feed stocks is to develop low-energy, non-toxic pathways to convert biomass to useful chemicals without generating more carbon than is removed from "thin air"; the carbon footprint C is the difference between C(in) from the air and C(out) from the energy used. When using Principle -7, all carbon footprints should be designed to be positive, so that C(in) > C(out)). This naturally leads to a reduction in the global warming gases that are causing our present climate change.

We must also ensure that new chemicals and materials created from renewable resources are neither poisonous nor harmful to human health or the environment.[24-25]

Vegetal oils are important renewable raw materials of the chemical industry, due to their main applications as surfactants, lubricants, and coatings. According to the United States Department of Agriculture, the annual production of major vegetable oils was 188×10^6 t in 2016/2017, which included, in order of importance: palm, soybean, rapeseed, sunflower seed, kernel, peanut, cottonseed, coconut, and olive oils. The main structural components of these oils are triglycerides, triesters of glycerol with fatty acids, classified as saturated, monounsaturated, and polyunsaturated depending on the number of alkenes functionalities they contain Historically, triglycerides have been used directly to make materials. For example, linoleum, a resin used in flooring, is traditionally made from linseed oil by cross linking Diels-Alder reactions at high temperature. Starch is the most common annually renewable raw material and is mainly extracted from cereals and tubers. Commercial water-resistant, starch-based bioplastics are produced by using blends of biodegradable petroleum-derived polymers and starch. These materials are made with gelatinized starch (60–85%) and hydrophilic (e.g., EVOH) or hydrophobic petroleum-derived biodegradable polymers (e.g., polycaprolactone) and compatibility agents. The polyesters form the continuous phase leading to materials having relative water resistance and acceptable barrier and mechanical properties. Glycerol (also a major by-product of the biodiesel industry) can be used as a cross linking agent in resin production, or as a raw material for the production of monomers such as epichlorohydrin. The main route for biosynthesis of itaconic acid is through glycolysis and tricarboxylic acid (TCA) cycle, and itaconic acid is enzymatically produced by the subsequent of *cis*-aconitate decarboxylate (CAD) .A great example of the use of enzymes to avoid protecting groups and clean up processes is the industrial synthesis of semi-synthetic antibiotics such as ampicillin and amoxicillin. In the past 10 years, significant advances have been made in the development of fuels, chemicals and materials from renewable feedstock. These for example, have included biodiesel from plant oils and algae, bioethanol and butanol from sugars and lignocelluloses, plastics, foams and thermosets from lignin and plant oils, and even electronic materials from chicken feathers. On the other hand, using sustainable or renewable resources, such as agricultural or biological products, assures that present and future generations will be able to share resources. Additionally, this approach typically has little impact on the environment. Most of the items and garbage are biodegradable. Numerous examples of this principle in action include the production of bioplastics and biopolymers, biodiesel, CO_2 feedstock for the production of polycarbonate, and a more environmentally friendly method of producing furfural from biomass [26-28]. The production of aromatic amines which are halide free by reacting benzene with chlorine with the help of nitrogen and then replacing the chlorine with the new

group through nucleophillic substitution. Aniline is used to treat nitrobenzene while tetra methyl ammonium hydroxides are present to give tetra methyl –ammonium salts.

8. Reduce Derivatives

As much as feasible, during the synthesis of a chemical product, the steps blocking groups, production/reproduction of the group, temporary change of physical and chemical processes, etc., should be avoided. A desired product should therefore be synthesized in a minimum number of stages. Reduced usage of derivatives and protecting groups in the synthesis of target molecules is one of the main concepts of green chemistry. Derivatization demands the consumption of additional energy and reagents, as well as the formation of additional waste during the synthesis. It also involves the application of protective or deprotecting substances, as well as any short-term changes to the physical and chemical process. The selection of the protective group is a critical aspect in the effective implementation of a synthetic process. The choice of the protective group has a significant impact on the overall efficiency and length of the synthetic process. Selectivity in the reaction will be induced by derivatizing the desired reactive site to make it more receptive to the reacting species. Using derivatives as little as possible in chemical synthesis can be achieved by avoiding the use of protecting groups which will result in an increase of atom economy on the reaction. [29-30]

A prominent example is the manufacturing of penicillin-based antibiotics or the substitution of traditional chemical enzymatic techniques in which 6-aminopenicillic acid is produced by interacting with the catalyzed immobilized enzyme penicillin amide. This resulted in the substitution of many chemical processes by an enzymatic reaction, which no longer required a low temperature (-60°C), organic solvents, and completely improper conditions, which increased and complicated production in the case of chemical synthesis.

In this manner another newer technique involving greener route to produce ethanol commercially can be prepared by oxidation of ethene, in the presence of an ionic catalyst in an aqueous medium. This is also greener method and gives 90% of yield. Likewise, Tetrachloroethene was used as a solvent for dry cleaning purposes. It is a suspected carcinogen and groundwater contaminant. It is replaced by greener solvent like supercritical CO_2 [31]. The synthetic methods should avoid using or generating substances toxic to humans and/or the environment. Hence less hazardous chemical synthesis is an important principle. Photochemical reaction occurs when light energy gets absorbed by a substances' molecule. It is a green route as no by product will be formed. Vitamin D3 synthesis is assisted by a photochemical reaction [32]. We were bleaching the paper, by using chlorine gas because it has excellent oxidizing characteristics. Now H_2O_2 with a proper catalyst is being utilized for bleaching since it does not pollute groundwater. Halogenated solvents contaminate groundwater. Whereas liquefied CO_2 leaves a lower amount of residue. It is also a non-toxic and attractive solvent for temperature-sensitive materials. Hydrogen peroxide can easily breakdown into water and oxygen. It is a good oxidizing agent and a strong bleaching agent. Use of H_2O_2 gives better results and makes use of a lesser amount of water. When compared to conventional solvents, liquefied CO_2 leaves a lower amount of residue. It is also a non-toxic and attractive solvent for temperature-sensitive materials [35-36]. Thus these all are excellent example of green chemistry making a genuine difference.

9. Catalysis

Catalysis is a major pillar of green chemistry, which involves the development of chemical products and processes that decrease or eliminate the usage and manufacture of harmful compounds. The development and implementation of novel catalysts and catalytic systems achieves the dual objectives of environmental conservation and economic advantage. Catalysis is the most pervasive topic in contemporary chemistry. With escalating economic demands for greater efficiency and productivity in R&D, combinatorial catalysis is increasingly being used to bring more catalysts to market per unit time. High-throughput automated synthesis and improved screening methods are increasingly being used to find more efficient homogeneous and heterogeneous catalysts and materials. By establishing an integrated workflow of rapid parallel or combinatorial synthesis of large numbers of catalytic materials, subsequent high-throughput assaying of these compounds, and large-scale data analysis, the combinatorial process enables the exploration of large and diverse compositional and parameter spaces. The number of tests that may be screened has increased by orders of magnitude, increasing the likelihood of identifying novel catalysts or materials. The reduction, if not elimination, of waste in the synthesis of chemicals and related products is a fundamental objective of green chemistry: "prevention is better than cure." This needs a paradigm change in the idea of efficiency in organic synthesis, from the chemical yield to one that places a premium on waste reduction. What is the origin of waste? The key is found in the atom economy concept: "synthetic processes should be developed to optimize the assimilation of all elements employed in the process into the end output." In the reaction scheme we compare, for example the use of sodium borohydride or molecular hydrogen as a reductant to convert a ketone to the equivalent secondary alcohol .The former has an atom economy of 81%, but the latter has a 100% atom economy, indicating that everything ends up in the product and there is no waste.

Unfortunately, under typical circumstances, hydrogen does not react with ketones at all. This requires a catalyst, such as palladium-on-charcoal. A catalyst is described as "a material that affects the rate of a reaction without changing itself in the process." It reduces the activation energy of the reaction but does not use it. This implies that, in theory; it may be used in little quantities and regenerated endlessly, resulting in no waste. Fluoride silica alumina, has replaced HF as the catalyst used in the manufacture of linear alkyl benzenes. The production of oxime, by titanium(IV)-silicate (TS-1) catalyst, the dehydration of organic molecules, etc., and the usage of TiO_2 as a photocatalyst in the removal of water contaminants are other examples of greener catalysts. Furthermore, because molecular hydrogen is the least costly reductant, catalytic hydrogenations are commonly used in the petrochemical sector, while other reductants are often not economically viable. Catalysis, however, has only been widely used in the pharmaceutical and fine chemical industries in the last two decades, following the rise of green chemistry, with the objective of eliminating the large amounts of waste created by the use of stoichiometric inorganic chemicals. This necessitates the employment of all types of catalysis, including heterogeneous, homogeneous, organocatalysts, Enantioselective catalysis, Main group chemistry and catalysis, Natural product synthesis, Reaction mechanism , Supramolecules chemistry and, more recently, Nature's own superb catalysts, biocatalysts could be generated in bacteria that have been genetically engineered enzymes. These latter are particularly good in catalyzing highly selective

reactions with complicated substrates under moderate circumstances, and as a result, they are finding widespread use in the pharmaceutical and allied sectors[33- 43].

10. Design for Degradation.

After serving their purpose, chemical goods should decay quickly into harmless byproducts. In other words, they shouldn't linger in the environment. The best example is DDT. Although it is a powerful insecticide, its stability in the natural environment poses a number of environmental risks. Green chemistry practitioners aspire to optimize the commercial function of a chemical while minimizing its hazard and risk. Hazard, or the ability to inflict harm, is an intrinsic property of a chemical that arises, like function, from its stereochemistry (the content and arrangement of atoms). Breakthroughs in mechanistic understandings relating molecular characteristics to risks and degradability will allow for a more complete use of green chemistry to manage hazard and risk. Effective cross-disciplinary communication is also required to supply designers with knowledge that they can incorporate into the intricacies of product design. Many product design choices must be made early due to regulatory and business limitations. Predictive decision-making systems must give certainty regarding hazard and risk in a way that is consistent with the timeliness and scale of development choices, and most critically, while the freedom to change a molecular design or product formulation is still available. Some examples of this principle in action are the compostable utensils and biodegradable soap/detergents. Compostable cutlery is most commonly made up of poly-lactic acid chains that derived from a biomolecule, lactic acid. Due to this, when the polymer degrades into its biomolecule monomers, no toxic products are formed which allow us to lower our impact on the environment instead of using plastics that will stay in our landfills and oceans for hundreds of years. Biodegradable soaps are very common now, but it was through the design of a soap that could degrade using 10th principle here that we were able to produce a soap that could be more easily broken down. The molecules below are of two common detergents with the difference between the two is the left is the branched sodium dodecyl benzene sulfonate, where the right is the linear version of sodium dodecyl benzene sulfonate. The branched version is less toxic than the linear version, but is unable to be readily broken down and would accumulate in the environment. The linear version is much more easily broken down and is, therefore, the detergent that is used [36].

11.Real-time analysis for Pollution Prevention

In order to enable continuous monitoring of the production and processing units, analytical procedures should be created or adjusted. For nuclear reactors and the chemical industry, this is crucial. To prevent the accident, this effective monitoring is very important. Principles 11 are focused with prior to the production of hazardous substances during the synthesis of chemical products, analytical approaches should be further improved to enable real-time process monitoring and control. This means that before hazardous chemicals are created, analytical processes must be enhanced to allow for real-time, in-process monitoring and control. To decrease the likelihood of chemical accidents such as leaks, explosions, and fires, substances and material forms used in a chemical process should be carefully selected. Green chemists constantly strive to maximize a chemical's economic function while minimizing its hazard and risk Hazard, or the ability to do injury, is an inherent characteristic aspect of a chemical that, like function, originates from its stereochemistry i.e., the content and arrangement of atoms [44-46].

12.Inherently Safer Chemistry for Accident Prevention

In order to reduce the likelihood of chemical mishaps, explosions, fires, and emissions, the compounds to be employed in chemical reactions should be chosen carefully. To put it another way, the substance should not be dangerous. Avoiding highly reactive compounds that can result in accidents during the reaction is of the utmost importance. In order to reduce the possibility of chemical accidents, such as the release of toxins, explosions, and fire creation, material and the form of a substance employed in a chemical process should be chosen carefully. A tank carrying methyl isocyanate gas, for instance, may unexpectedly explode if water, the most prevalent solution medium, spilled into it, releasing a significant amount of methyl isocyanate into the vicinity. Alkali metals are found with other well-known substances that react with water in ways that frequently have devastating results. The risk of explosion, even one that resulted in death, would have been reduced if an alternate reaction without this reagent had been created.

Intrinsically safe chemistry can also be performed in flow mode with tubular microreactors that have extremely small-diameter reaction channels. Such flow chemistry methods significantly reduce the need for catalyst, reaction time, and volume, intensify the processes by increasing space/time yield, open new process windows for the application of extremely high temperatures and pressures, and even enable the safe conduct of extremely risky reactions [47-50]. Additionally, the use of flow chemistry in microreactors demonstrates a method to get around some of the more traditional constraints of microwave-driven processes, like the limited depth to which microwaves may penetrate absorbing medium [51-57].

Applications and Impacts:

The principles of green chemistry have found applications across a wide range of industries, leading to numerous positive environmental and economic impacts. Some key areas of application include Pharmaceuticals, Materials Science, Agrochemicals, Energy Production, Waste Management, Water Treatment for these research holds immense significance in addressing critical global challenges like

1. Human Health and Safety:

Safer Products: Research in green chemistry leads to the creation of safer chemical products, reducing the health risks posed by toxic substances.

Reduced Exposure: Developing methods that minimize exposure to hazardous chemicals in manufacturing and daily life improves public health.

2. Economic Viability:

Cost Reduction: Green chemistry often results in cost savings through improved process efficiency and reduced waste, making it economically attractive.

Market Competitiveness: Companies that embrace green chemistry principles gain a competitive edge by responding to consumer demand for sustainable products.

3.Global Regulatory Compliance:

Compliance with Regulations: Research in green chemistry assists industries in adhering to increasingly stringent environmental regulations.

International Agreements: Green chemistry aligns with global initiatives, such as the Paris Agreement and Sustainable Development Goals, making it a key driver for international cooperation.

4. Innovation and Technological Advancements:

Catalysis and Materials: Green chemistry research leads to innovations in catalysis and materials, advancing fields like nanotechnology, renewable energy, and healthcare.

Cross-Disciplinary Collaboration: Collaborations between chemists, engineers, biologists, and other experts foster innovation and enable the development of sustainable solutions.

5. Education and Outreach:

Knowledge Dissemination: Ongoing research in green chemistry contributes to educating future generations of scientists and the public about the importance of sustainability.

Institutional Integration: Incorporating green chemistry principles into curricula and institutionalPractices enhance sustainability awareness.

Result and Discussion:

Green Technologies plays important role in sustainable methods to recover resources. A lot of attention is being paid to the high-tech and Research in this innovative field covers all aspects of catalysis and synthesis across a broad range of scales. Interests range from manipulating single chemical bonds for the preparation of specific molecules, through to manipulation of nanoparticles and supramolecular compounds, to the preparation of multi-layered materials. aims range from making bonds and materials in entirely new ways to making larger scale processes more efficient.

Much of this activity relies upon an in-depth understanding of how molecules behave, also study the physical, spectroscopic, and chemical properties of molecules as well as understanding reaction mechanisms and kinetics and provides efficient industrial processes that minimize energy, waste and harmful by-products, and follow green principles. It has revolutionized the way the products we depend on as a society are made, impacting on healthcare (pharmaceuticals, imaging), food security (herbicides, pesticides), and energy conversion and harvesting (materials, catalysts). [3, 58-66]

Conclusion:

Consequently, we can say that in green chemistry, recently, there has been an increase in the use of green chemicals in biomedical research, medicinal delivery, the food industry, and agriculture. And as a result, numerous methods for producing eco-friendly chemicals have been developed. In this A few limitations include high costs, excessive energy use, and environmental risks. Therefore, the creation of alternate tactics is required.

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