

Green Chemistry and Catalysis

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ABSTRACT

The development of chemical goods and procedures that lessen or do away with the use and production of hazardous materials is known as green chemistry, often referred to as sustainable chemistry. Only environmentally safe chemicals and chemical processes are employed. It is based on twelve principles that can be used to build or copy molecules, materials, reactions, and processes that are more beneficial to human health and the environment. Green chemistry lessens the impact of chemical processes and technology on the environment, as this article explains.

The goal of this review is to gain a better understanding of how catalysts work in green chemical synthesis and how they might contribute to the development of a more sustainable future. The ecologically friendly synthesis of both new and old compounds depends on catalysis. Catalyzed processes appear to be more efficient because they require less energy and produce fewer byproducts, coproducts, and other waste products. It is possible to create ecologically friendly catalysts. There are many different types and sizes of catalysts, and some of them are useful in the chemical industry.

Keywords: AI Strategy, Green Chemical Synthesis

I. INTRODUCTION

Green Chemistry: -

The main definition of "green chemistry" is the reduction of environmental damage brought on by the production of materials and the ethical disposal of wastes generated during various chemical processes. "Green chemistry" is also described as "a new approach committed to the synthesis, processing, and

use of chemical materials in such a way as to reduce risks to people and the environment." [15]

New chemistry is required to increase the efficiency of chemical production and to better protect the environment. The concept of "green chemistry" is a technology that appeals to chemical specialists, researchers, and entrepreneurs for cutting-edge study and implementation.[1] The development of environmentally friendly starting materials or the

Careful planning of novel synthesis routes that minimize the use and production of toxic substances using modern energy sources are therefore essential for improving synthetic and engineering chemistry. [11]

Green Chemistry Theory and Practise, a 1998 book by Paul Anastasi and John Warner of the EPA, outlined twelve green chemistry principles and described how to put them into use. According to the tenets of "green chemistry," it is essential to reduce or entirely stop using substances that are harmful to the environment and human health while creating, manufacturing, and using chemical goods.[2] The two concepts are "Reducing Risk" and "Minimising the Environmental Footprint." Historically, several chemical enterprises have been viewed as dangerous. Synthetic chemical products received a "bad name" due to associations with potentially dangerous compounds for humans and environmental pollution. Numerous factors, such as energy use, climate change, disasters, and the depletion of natural resources, have an impact on the environmental footprint.

1. Protection

Atom Economy

Less Dangerous Chemical Syntheses

Creating Safer Chemicals

Safer Solvents and Auxiliaries

Create with energy efficiency in mind

Use of Renewable Feedstock

Lessen the Use of Derivatives

Catalysis

Design for Degradation

Real-time analysis for pollution prevention

Inherently Safer Chemistry for Accident Prevention.[2]

3. The principles of green chemistry:

The "better to prevent than to cure" principle

Instead than subsequently processing and cleaning up garbage, it is advantageous to avoid waste creation up front.

The "atom economy" principle

Planning synthetic production pathways must maximize the inclusion of all the synthesis-related chemicals into the final product.

The "less precarious chemical syntheses" principle

Wherever possible, such synthetic processes that use and produce substances with little to no toxicity to the environment and human health must be pursued.

The "designing safer chemicals" principle

Chemicals should be created in a way that achieves the functionality they are intended to have while also significantly minimising their toxicity.

The "safer solvents and safer auxiliaries" principle

Expenditure of auxiliary substances, such as solvents, separation agents, and others, should be avoided wherever possible; if not possible, harmless auxiliaries should be used.

The "design for energy efficiency" principle

The environmental and economic impact of energy demands for chemical processes should be analyzed in terms of followed by optimizing the required energy input. Wherever practicable, chemical synthesis should be carried out under mild process conditions, hence, at ambient temperature and pressure.

The "renewable feed stocks" principle

Whenever feasible in technological and economic terms, synthetic processes should resort to such raw materials and feed stocks, which are renewable rather than limited.

The "derivative reduction" principle

Redundant derivation, e.g., protection/ DE protection, the use of blocking groups, or temporary modification of physical/chemical processes, requires additional reagents and often contributes to additional waste generation. Therefore, wherever possible, they should be avoided or reduced to a minimum

The "catalysis" principle

Generally, catalytic reagents are intrinsically superior to stoichiometric reagents; these catalysts should be as selective as possible

The "degradation" principle

Chemical products have to be designed in such a way that, at the end of their life span, they do not resist in

the biosphere, but disintegrate into nontoxic degradation product.

The “real-time analysis for pollution prevention” principle

Advanced analytical methods have to be developed, which permit the real-time, in-line process monitoring and control well before hazardous substances are generated

The “accident prevention by inherently safer chemistry” principle

Compounds and the compound’s formula applied in a chemical process should be chosen in a way minimizing the risk of chemical accidents, encompassing the release of chemicals, detonations, formation.[15]

Green chemistry for pharmaceuticals: The chemical industry's pharmaceutical sector is the most dynamic. It is at the forefront of significant changes toward "greener" feedstock, cleaner solvents, other techniques, and novel ideas [1]. All of these steps will raise the pharmaceutical industry's environmental standing while bringing down costs and requirements for raw materials used in production, opening the road for long-term sustainability.

For chemists, green chemistry is a Hippocratic oath, and a new generation of scientists and technologists is emerging to analyze the production and development processes and materials effectively in order to safeguard the environment and natural resources [11]. There is no risk if hazardous chemicals are not utilized or produced, thus there is no need to worry about getting rid of them or restricting exposure. As the saying goes, "green chemistry is about decreasing waste, raw materials, hazards, energy, environmental effect, and cost." Scientific Fields for Green Chemistry's Applied Applications the areas under green chemistry that are suggested for special study. [1]

4. Chemistry Benefits of Green:

Benefits in human:

Cleaner air: Less release of hazardous chemicals to air leading to less damage to lungs

Cleaner water: less harmful chemical waste being released into water will result in cleaner drinking and recreational water. increased protection of chemical sector employees; less usage of harmful materials reduced need for personal protective equipment, lower risk of mishaps (such as fires or explosions) safer consumer goods across the board

New, safer items will be put on the market, some (like medications) will be produced with less waste, and others (like pesticides and cleaning supplies) will take the place of less safe ones. Safer pesticides that are poisonous exclusively to certain pests and breakdown quickly after usage will result in safer food by eliminating persistent toxic compounds that can infiltrate the food chain. less exposure to endocrine disruptors and other hazardous substances.[14]

Benefits to Environment:

Many chemicals end up in the environment by intentional release during use (e.g., pesticides), by unintended releases (including emissions during manufacturing), or by disposal.

Green chemicals either degrade to innocuous products or are recovered for further use

Plants and animals suffer less harm from toxic chemicals in the environment

Lower potential for global warming, ozone depletion, and smog formation

Less chemical disruption of ecosystems

Less use of landfills, especially hazardous waste landfills Economy and business

Higher yields for chemical reactions, consuming smaller amounts of feedstock to obtain the same amount of product

Fewer synthetic steps, often allowing faster manufacturing of products, increasing plant capacity, and saving energy and water

Reduced waste, eliminating costly remediation, hazardous waste disposal, and end-of the-pipe treatments

Allow replacement of a purchased feedstock by a waste product better performance so that less product is needed to achieve the same function

Reduced use of petroleum products, slowing their depletion and avoiding their hazards and price fluctuations

Reduced manufacturing plant size or footprint through increased throughput

Increased consumer sales by earning and displaying a safer-product label (e.g., Safer Choice labeling)

Improved competitiveness of chemical manufacturers and their customers.[1]

5. Green Chemistry's Latest Trends:

The green program's core goals are achieved through many prominent trends in the design, development, and use of chemical products and processes that decrease or eliminate the use or production of substances that are dangerous to human health and the environment".

Catalytic and biocatalytic reaction research in order to obtain highly

Searching for new raw materials that are both harmless and renewable, such as biomass;

Developing and evaluating new non-toxic, renewable reaction media, such as water, ionic liquids, and supercritical fluids.

Developing and evaluating new reaction conditions, such as microwave, ultrasound, and light reaction. [14]

Green chemistry is the utilization of a set of principles that will help reduce the use and generation of hazardous substances during the manufacture and application of chemical products. Green chemistry aims to protect the environment not by cleaning up, but by inventing new chemical processes that do not pollute. It is a rapidly developing and an important area in the chemical sciences. Principles of green chemistry, developments in this field and some industrial applications are discussed. The terms 'Environmental Chemistry' and 'Green Chemistry' are two different aspects of environmental pollution studies. Green chemistry seeks to reduce pollution at source, whereas environmental chemistry focuses on the study of pollutant chemicals and their effect on nature. [3]

6. Catalysis:

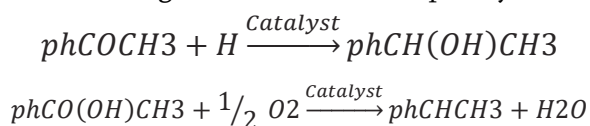
1. Role of Catalysis:

The study of chemicals and processes that are beneficial to the environment is the main goal of the field of chemistry known as "green chemistry." In green chemistry, catalysis is a crucial element. Reduces toxicity through the use of green chemistry, sometimes referred to as ecologically friendly or sustainable chemistry. Its goal is to develop and implement pollution prevention plans that do not include waste management but instead decrease waste, conserve energy, and stop the depletion of natural resources. Due to its alleged ability to lower pollutants and carbon emissions, green chemistry is seen as being ecologically benign. [1] Environmental pollution has decreased thanks to catalysis. By removing and controlling NOx emissions, lowering the use of volatile organic compounds (VOCs), developing alternative catalytic technology to replace the use of chlorine or chlorine-based intermediate in chemical synthesis and waste minimization, and more, catalysts have been used to improve air quality. Catalysis enables more effective and selective reactions, eliminating enormous amounts of by-products and other waste compounds. [3]

Inorganic salts make up the majority of the waste produced during the production of organic compounds, as was already mentioned. [1] This is a direct result of using stoichiometric inorganic reagents throughout the organic synthesis process. Particularly, outdated "stoichiometric" manufacturing techniques are widely used in the production of delicate chemicals and medicines. Stoichiometric reductions with metals (Na, Mg, Zn, Fe) and metal hydride reagents (LiAlH₄, Phloroglucinol from TNT.NaBH₄), as well as oxidations with permanganate, manganese dioxide, and chromium (VI) reagents, are a few examples that immediately come to mind (AlCl₃, ZnCl₂, BF₃). [3]

The obvious solution is to replace traditional stoichiometric methods with more environmentally friendly catalytic ones. The development of procedures based on H₂, O₂, H₂O₂, CO, CO₂, and

NH₃ as the direct source of H, O, C, and N is, in reality, a significant problem in the synthesis of (fine) chemicals. methods using salt and catalytic hydrogenation. Similar to how Lewis acids and stoichiometric bases like NaOH and KOH may be replaced with recyclable solid acids and bases, ideally in catalytic proportions, the production of huge volumes of inorganic salts can be completely avoided.



For instance, the production processes for many substituted aromatic compounds have not altered in more than a century and are therefore ready to be replaced by catalytic, low-salt alternatives. The production of hydroquinone offers a useful illustration. Historically, benzoquinone was created by oxidising aniline with stoichiometric quantities of manganese dioxide to form benzoquinone, which was then reduced with iron and hydrochloric acid (Be champ reduction). Nitration and be champ reduction were used to create aniline from benzene. In all, the procedure produced nearly 10 kg of inorganic salts (MnSO₄, FeCl₂, NaCl, and Na₂SO₄) for every kilogram of hydroquinone. This outdated method has been replaced by a more contemporary one that involves autoxidating p-diisopropyl benzene (produced by Friedel-Crafts alkylation of benzene), followed by an acid-catalyzed rearrangement of the bis-hydroperoxide, which results in the production of about 1 kg of inorganic salts per kg of hydroquinone. As an alternative, phenol is hydroxylated with aqueous hydrogen peroxide and hydroquinone is formed (together with catechol) (see later). Because functional group protection and deprotection are frequently not necessary, biocatalysts offers several benefits in the context of green chemistry, such as gentle reaction conditions and frequently fewer steps than traditional chemical processes. As a result, in the fine chemicals business, cleaner biocatalytic substitutes are progressively replacing traditional chemical processes. [3]

The study of environmentally friendly substances and procedures is the main goal of the field of chemistry known as "green chemistry." Green chemistry relies heavily on catalysis. Green chemistry, sometimes referred to as ecologically safe or sustainable chemistry, reduces toxicity. [2]

2. Catalysis by Solid Acids and Bases:-

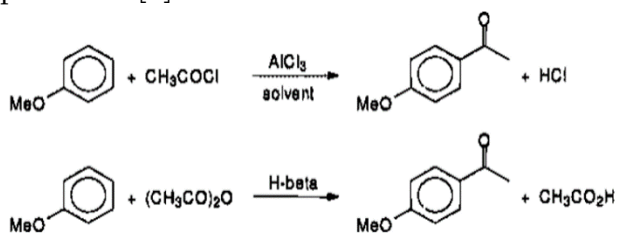
As mentioned above, the extensive use of liquid mineral acids (HF, H₂SO₄) and other Lewis's acids is a significant source of waste in the (fine) chemicals industry. They are difficult to recycle and typically result in waste streams with significant inorganic salt content after hydrolytic processing.[1] A significant decrease in waste might be achieved by replacing them on a large scale with recyclable solid acids. Solid acids with many benefits in this regard include zeolites, acidic clays, and similar substances.[8] They are frequently really catalytic and may be easily regenerated by separating them from liquid reaction mixtures without the need of hydrolytic work-up. Solid acids are also less dangerous to handle and less corrosive than mineral acids like H₂SO₄ or HF.[1]

Solid acid catalysts are, in principle, suited to a variety of acid-promoted reactions in organic synthesis. These include different electrophilic aromatic replacements, e.g. nitrations, and Friedel-Crafts alkylation's and acylations, and several rearrangement processes such as the Beckmann and Fries rearrangements.[12]

Friedel-Crafts acylation, which is frequently used in the fine chemicals sector, is a notable example. Friedel-Crafts acylation's typically require more than one equivalent of, for instance, AlCl₃ or BF₃, unlike the comparable alkylation's, which are really catalytic reactions. This is because the ketone product strongly complexes the Lewis acid. One example in this field is Rhone-(now Poulenc's Rhodia) commercialization of the first Friedel Crafts acylation mediated by zeolite. In a fixed-bed process, p-methoxy acetophenone is produced by acetylating anisole with acetic anhydride using zeolite beta as a catalyst. In the original

procedure, acetyl chloride was combined with $AlCl_3$ equivalents in a chlorinated hydrocarbon solvent, and 4.5 kg of aqueous effluent including $AlCl_3$, HCl, solvent remnants, and acetic acid was produced for every kilogram of product. In sharp contrast, the catalytic approach avoids the creation of HCl in both the acylation and the synthesis of acetyl chloride. It uses no solvent and produces 0.035 kg of watery effluent, which is more than 100 times less. This waste is made up of 99% water, 0.8% acetic acid, and 0.2% other organics. In addition, a product of better purity is produced in a higher yield (>95% vs. 85-95%), the catalyst is recyclable, and there are only two unit operations rather than twelve. As a result, the Rhodia method has better economics than the conventional approach and is also more ecologically friendly. This is a crucial finding; green, catalytic chemistry is more desirable economically in addition to having clear environmental advantages. [13]

Another illustration of this is the production of caprolactam, a chemical used as a raw ingredient to make Nylon 6. In the standard procedure, cyclohexanone reacts with hydroxylamine sulphate (or another salt) to produce cyclohexanone oxime, which is then exposed to the Beckmann rearrangement in the presence of stoichiometric quantities of sulfuric acid or oleum. In all, the two phases of the process produce around 4.5 kg of ammonium sulphate for every kilogram of caprolactam. [3]



The manufacturing of a variety of specialty chemicals, including pharmaceuticals, agrochemicals, flavours, and fragrances, as well as the oil refining and petrochemical industries, depend on acid and base catalyzed reactions. Many of these procedures necessitate the use of traditional Bronsted acids (H_2SO_4 , HF, HCl, p-toluene-Sulfonic acid) or Lewis's

acids in liquid-phase homogeneous systems or on inorganic supports in vapour phase systems ($AlCl_3$, $ZnCl_2$, BF_3). Similar to this, common bases include NaOH, KOH, and KOB. The production of inorganic salts that eventually make their way into aqueous streams as a result of their subsequent neutralization. [3]

Additional advantages of using solid acids and bases as catalysts include :

- Easier separation and recycling lead to a quicker process and cheaper manufacturing costs.
- Solid acids, such H_2SO_4 and HF, are safer and more manageable than their liquid counterparts. very corrosive, requiring the use of pricey building materials.
- Compared to their liquid counterparts, granular compounds are safer and simpler to use.[3]

3.Catalytic Reduction:

Using a catalyst, selective catalytic reduction (SCR) transforms nitrogen oxides, generally known as NO_x , into water and diatomic nitrogen (N_2) (H_2O). A stream of flue or exhaust gas is mixed with a reductant, commonly anhydrous ammonia (NH_3), aqueous ammonia (NH_4OH), or a solution of urea ($CO(NH_2)_2$), and is then reacted onto a catalyst. Nitrogen (N_2) and carbon dioxide (CO_2) are created as the reaction progresses toward completion when urea is used. In 1957, the Engelhard Corporation received a patent for selective catalytic reduction of NO_x utilizing ammonia as the reducing agent. Early 1960s research focused on less costly and more long-lasting catalyst agents while SCR technology development progressed in Japan and the US. In 1978, the IHI Corporation installed the first significant SCR. Large utility boilers, industrial boilers, and municipal solid waste boilers are frequently equipped with commercial selective catalytic reduction systems, which have been demonstrated to reduce NO_x by 70–95%. [1]

Catalytic hydrogenation, which has a lengthy history extending back to the days of Sabatier, who won the 1912 Nobel Prize in Chemistry for his ground

breaking work in this field, is without a doubt the workhorse of catalytic organic synthesis. It is often employed in the production of fine and speciality chemicals, and a recent special issue of the journal *Advanced Synthesis and Catalysis* was devoted to this significant subject. In the synthesis of vitamins at Hoffmann-La Roche in 1996, 10%–20% of all reaction steps (and even 30% for vitamin E) were catalytic hydrogenations, according to Roessler. [13]

The manufacture of a precursor for the Roche HIV protease inhibitor Saquinavir serves as an example. While avoiding racemization at the stereogenic centre present in the substrate, it includes the chemo- and diastereo-selective hydrogenation of an aromatic. [1] Manufacturing of fine compounds frequently runs into the issue of chemo specific hydrogenation of one functional group when other reactive groups are present. The chemo selective hydrogenation of an aromatic nitro group in the presence of an olefinic double bond and a chlorine substitute in the aromatic ring is a beautiful illustration of the level of accuracy that may be attained. Despite the fact that commercial organic synthesis utilises catalytic hydrogenation on a large scale as a mature technique, new uses for the process are constantly being discovered, sometimes in unexpected areas.[3]

4. Catalytic Oxidation:

It is probably true to say that the process in which green catalytic alternatives are most required for the creation of fine chemicals is oxidation reactions. To a greater extent than reductions, oxidations still include the use of stoichiometric inorganic (or organic) oxidants such permanganate, manganese dioxide, periodate, and chromium (VI) reagents. Without a doubt, catalytic alternatives utilising pure primary oxidants like oxygen or hydrogen peroxide are required. O₂ catalytic oxidation is extensively used in the bulk petrochemical manufacturing process. [3] However, applying them to fine compounds is often more difficult due to the multifunctional nature of the interest molecules. However, in some circumstances, these techniques have been utilised successfully to

create fine compounds. A perfect illustration is the BASF process for making citral, which serves as a crucial bridge between essential oils and vitamins A and E. The critical step is a catalytic vapour phase oxidation over a supported silver catalyst, which is essentially the same method used to create formaldehyde from methanol. This atom-efficient, low-salt approach, which featured, among other things, a stoichiometric oxidation using MnO₂, has supplanted the old approach, starting with α -pinene. [1] The selective oxidation of alcohols to the appropriate carbonyl compounds is an important step in the synthesis of organic molecules. Greener conversion methods are urgently needed, ideally employing O₂ or H₂O₂ as safe oxidants that are compatible with a range of substrates, as was previously noted. [13]

5. Catalytic C–C Bond Formation :

The creation of C-C bonds is a crucial transition in organic synthesis, and carbonylation is a significant catalytic mechanism for doing so. It is employed in the field of bulk chemicals, for instance, in the rhodium- catalyzed carbonylation of methanol to produce acetic acid. Such reactions are increasingly used in the production of fine compounds because they are 100% atom efficient. The Hoechst-Celanese method, which produces several thousand tonnes of the painkiller ibuprofen annually, is a beautiful illustration of this. In this method, *p*-isobutylacetophenone is converted to ibuprofen in two catalytic stages (hydrogenation and carbonylation) with 100% atom efficiency. This method took the place of a more traditional one that required more stages and had a significantly higher E factor. [3] Palladium-catalysed amide carbonylation of 2,5-dichloropyridine in a procedure created by Hoffmann-La Roche for the anti-Parkinsonian medication lazabemide superseded an initial synthesis that required eight stages and started with 2-methyl-5-ethylpyridine and had an overall yield of 8%. Lazabemide hydrochloride may be produced using the

amidocarbonylation method in a single step with a 65% yield and 100% atom efficiency. [12]

Hydrolysis: -

The standard loss rate for every chemical in an aqueous environment is provided by hydrolytic reactions. Although only the reactant species that water provides H⁺, OH⁻, and H₂O—account for significant value in various hydrolytic pathways, the full picture also includes analogous reactions and the equivalent effects of other chemical species found in the immediate environment, such as SH⁻ in anaerobic bogs, Cl in sea water, and various ions in laboratory buffer solutions. Since the first edition of the Lyman Handbook, methods to forecast the hydrolysis rates of organic compounds for application in the environmental evaluation of contaminants have not greatly improved (Lyman et al., 1982). To estimate hydrolytic rate constants for application in environmental systems, two methods have been employed extensively.[12] Applying quantitative structure/activity connections is the first, and presumably more accurate, way (QSARs). A database of chemical descriptors linked to the substituents on the reactant molecule and a set of rate constants for a number of compounds with systematic structural changes are required in order to create such prediction techniques. A less precise estimate of the rate constant can be obtained by comparing the target chemical with an analogous compound or compounds that contain comparable functional groups and structure, which is the second and more popular technique.[3] When evaluating hydrolysis for straightforward one-step processes where the product distribution is known, predictive approaches can be used. However, routes are often only recognized for simple compounds. In environmental studies, the researcher is frequently interested in the parent component as well as its intermediates and derivatives. As a result, estimate techniques can be needed for a number of reaction pathways. [11]

Renewable Raw Materials:

The use of renewable raw materials, i.e., those obtained from biomass, rather than fossil fuels, is another crucial objective of green chemistry. Again, in this case, the conversion procedures for the renewable feedstocks primarily carbs, but also triglycerides and terpenes should create little waste, ideally by catalytic means. A biocatalyst, which can be complete microbial cells or an isolated enzyme, is utilized in the processes outlined in the previous section to speed up the transformation of a specific substrate, which typically takes place in a single step. It is referred to as a precursor fermentation when growing microbial cells are involved.[3] As an alternative, de novo fermentation may be used to create compounds straight from biomass. In contrast to red biotechnology (biopharmaceuticals) and green biotechnology, this is now referred to as white biotechnology (genetically modified crops). White biotechnology is now receiving a lot of interest and is seen to be the key to creating a chemical industry that is sustainable.[13] Utilizing metabolic pathway engineering, the generation of the desired product may be optimized dependent on the amount of substrate (often obtained from biomass) utilized. De novo fermentation has more recently replaced multistep chemical syntheses, such as those used to produce vitamin B2 (riboflavin) and vitamin C. more current achievements of white. [12]

Process Integration and Catalytic Cascades:

The conventional barriers between the subdisciplines of homogeneous and heterogeneous catalysis and biocatalysis are gradually dissolving as a consequence of the extensive use of chemo- and biocatalytic techniques in the production of fine compounds. [3]

7. Microwave Assisted Synthesis:

The study of using microwave radiation in chemical reactions is known as microwave chemistry. An important development in synthetic chemistry methodology, microwave synthesis marks a significant shift in how chemical synthesis is carried out. Conventional heating has long been acknowledged to be ineffective and time-consuming,

but it has also been found to be artistically constricting. Chemists have extra time thanks to microwave synthesis to exercise their creativity, try out new hypotheses, and create new procedures. [6] Chemists may now carry out the identical process in a matter of minutes rather than spending hours or even days synthesizing a single chemical. By conducting processes without a solvent under microwave irradiation, the issue with solvent waste disposal has been solved. Under solvent-free circumstances, combining microwave irradiation with mineral-supported catalyzed reactions results in clean chemical processes that have the advantages of faster reaction rates, higher yields, improved selectivity, and easier manipulation. As a result, microwave synthesis may be used as a technique in green chemistry. [9]

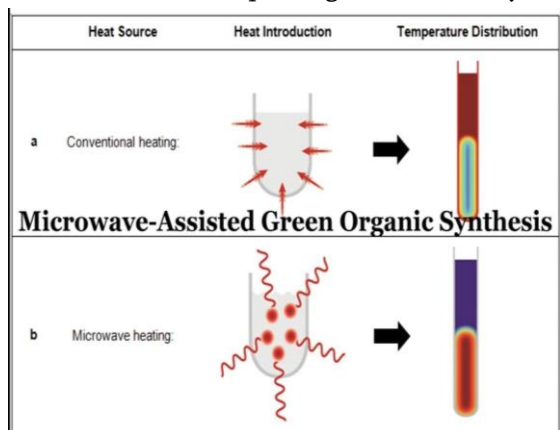


Fig - Microwave assisted Synthesis

Microwave-accelerated metal catalysis: In the expanding, heterogeneous area of microwave aided chemistry, palladiumcatalysed reactions in particular and organometallic catalysis in general, have become the success stories. There are various causes for this, but few other branches of chemistry have responded to the unique requirements of high-temperature microwave reactions as quickly as these.[7]

Many methods have been created that benefit from the practicality and unique properties of microwave chemistry. Results have been reported in many instances that are superior to those typical of conventional heating methods.[6] Reaction rates are typically very high, and yields are frequently

increased because competing side reactions can often be reduced in the short periods of time required for focused, in situ heating, which is typical of this new method of superheating.[11] Because less solvent quantities are required in many processes, gentler and less toxic chemicals may be utilized, and less energy is consumed, microwave aided chemistry has also been viewed as an ecologically benign alternative to traditional heating procedures. The unique needs of microwave flash heated organic chemistry, which first restricted its usage, have recently led to a number of advancements in the area.[2]

Microwave-assisted reductions: In synthesis, reductions of organic functional groups are crucial. However, due to the severe conditions required, their use is frequently constrained and is incompatible with the synthesis of delicate goods. High temperature and protracted reaction periods are typical in organic chemistry, and several processes are hampered by the creation of byproducts.[11] Thus, it is anticipated that microwave irradiation will enhance functional group reductions in a similar manner. The utilization of gases under high pressure is necessary for a variety of reductions in organic chemistry, such as catalytic hydrogenation reactions using hydrogen.[2]

Solvent-free reactions are significant in microwave-enhanced chemistry, and the development of "dry" reactions on mineral supports in combination with microwave irradiation has particularly had a significant impact on the development of safe and effective reduction schemes.[2]

Reduction of carbon-carbon multiple bonds:

Solvent-free reactions play an important role in microwave-enhanced chemistry, and the development of "dry" reactions on mineral supports in conjunction with microwave irradiation has notably had a considerable impact on the development of secure and efficient reduction strategies.[2]

Reduction of carbonyl groups:

By reducing carbonyl molecules like aldehydes, ketones, or derivatives of carboxylic acids, alcohols

are readily available.[10] There have been no instances of using microwave technology to reduce nitriles or amides, despite the fact that aldehydes, ketones, and esters have regularly been reduced with the use of microwaves.[2]

Reduction of nitrogen functional groups:

In chemistry, the family of molecules known as amino acids is crucial. Their synthesis may be done easily by reducing the relevant nitrogen functional groups, such as imines, nitro groups, or hydrazones.[7] Although azides have been employed in cycloaddition processes without any substantial risks being identified, it is surprising that no microwave-assisted reduction of azides has been recorded in the literature. Additionally, to our knowledge, microwave-assisted reductions have not yet been used with additional nitrogen-containing functional groups, such as nitroso compounds, oximes, or hydroxylamine's. [6] It is also possible to reduce carbonyl compounds to their equivalent alkyl compounds indirectly by reducing hydrazones. Additionally, the reductive synthesis of aldehydes has utilized hydrazides. [9]

Hydro dehalogenation: Ring or allows for the isotopic labelling of certain aromatic compounds.[6]

Detoxifying chlorinated organic Dehalogenation of aromatic compounds has grown in importance as an organic chemistry technique because it enables the employment of halogens as a kind of protective group for reactive sites in the aromatic molecules or converting them into products with additional value is another possible use.[7] Even though in these instances the actual dehalogenations with hydrogen gas were carried out in a flow reactor under thermal conditions, microwave heating was nonetheless effectively employed to prepare more effective catalysts for hydro dehalogenation processes.[11]

Microwave-assisted multi-component reactions: Drug development needed the optimisation of lead structures that were most likely derived from biological sources through a multi-step approach of serial synthesis and screening. This process is highly

costly since a synthetic chemist must synthesise each component independently.[2] Pharmaceutical firms are turning to combinatorial chemistry to provide more affordable drug development procedures. [11] The basic premise of combinatorial chemistry is that there is a higher probability that one of the many, different compounds would be suitable for the creation of a new drug. [7]

Integrating microwave-assisted synthesis and solid-supported reagents:

Since its introduction as an alternate heating technique for organic processes in the late 1980s, microwave-assisted chemical processing has drawn a lot of attention as a potential future technology. [7] Despite the extensive use of this technique, we still lack a thorough understanding of many of the fundamental characteristics of microwave heating and how they affect the supported chemistries. Significant research has to be done in order to further our understanding because the field is still very much in the exploratory stage. [9] Significant research has to be done in order to further our understanding because the field is still very much in the exploratory stage.[2]

Microwave-assisted solid-phase synthesis: Combinatorial chemistry, the art and science of swiftly synthesising and assessing potential lead compounds for any desired quality, is one of the most promising approaches for discovering novel medications. With the great advancements in molecular biology, biochemistry, and genomic sciences, a large number of physiologically important target proteins are now easily accessible for screening.[2] Large libraries of novel compounds that are being screened using the appropriate screening methods in order to ascertain their biological characteristics are thus becoming more and more necessary.[7] Along with the discovery of new target molecules, modern high throughput screening (HTS) technologies, such as miniaturized formats, were created. These formats allow for the daily testing of thousands of novel compounds. Conventional methods of organic synthesis are much too sluggish to

keep up with the growing demand for these molecules.[3] The fundamental principle underlying combinatorial synthesis is the ability to swiftly create a large number of chemical molecules.[2]

Sonochemistry:

Sonochemistry is the study of how ultrasound affects the formation of acoustic cavitation in liquids, which leads to the beginning or intensification of chemical activity in the solution. The wavelengths of sound waves travelling through a liquid at ultrasonic frequencies are several times greater than the size of a molecule or the length of an atom's bond. [11] As a result, the sound wave cannot directly alter the bond's vibrational energy and cannot therefore raise a molecule's internal energy. Sonochemistry, on the other hand, results from acoustic cavitation, which is the development, expansion, and implosive collapse of bubbles in a liquid. As a result of the huge energy buildup inside the bubble caused by the virtually adiabatic way in which these bubbles burst, a minuscule area of the sonicated liquid experiences extraordinarily high temperatures and pressures. [4] Any stuff inside or very close to the bubble is chemically excited as it rapidly implodes due to the high temperatures and pressures.[6] Sonoluminescence, increased chemical activity in the solution as a result of primary and secondary radical reactions, and increased chemical activity as a result of the formation of new, relatively stable chemical species that can diffuse further into the solution to produce chemical effects are just a few of the many outcomes that can come about from acoustic cavitation (for example, the formation of hydrogen peroxide from the combination of two hydroxyl radicals following the dissociation of water vapour within collapsing bubbles when water is exposed to ultrasound).[11]

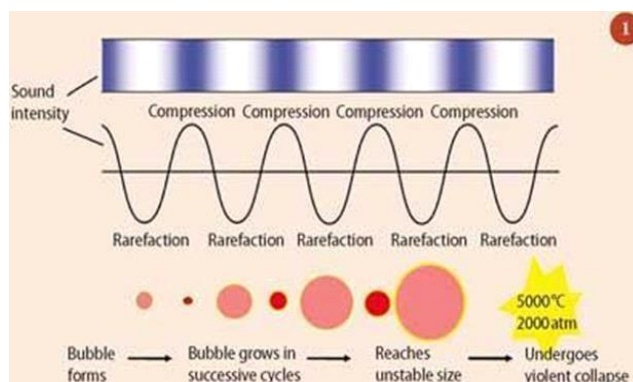


Fig- Principles of Sonochemistry

Homogeneous sonochemistry of liquids, heterogeneous sonochemistry of liquid-liquid or solid-liquid systems, and sonocatalysis, which combines the aforementioned two types of sonochemical reactions by catalysing or speeding up the chemical reaction with ultrasound, are the three different types of sonochemical reactions. Sonoluminescence results from the same cavitation processes that produce homogeneous sonochemistry.[5] The chemical amplification of processes by ultrasound has been investigated in mixed phase synthesis, materials chemistry, and biological applications. Because cavitation can only occur in liquids, chemical reactions cannot be seen when solids or solid-gas systems are subjected to ultrasonic radiation. In the field of chemical kinetics, for instance, it has been discovered that ultrasound may successfully activate heterogeneous catalysts by considerably increasing chemical reactivity by up to a million-fold in a variety of systems. Furthermore, ultrasonic waves break apart solid particles that are reacting at liquid-solid interfaces, exposing nearby cavitation collapse and solid fragmentation. As a result, the solid reactant has more surfaces on which the reaction may occur, increasing the rate of reaction that is seen. [4]

A 2007 article in the journal Nature described the use of ultrasound to focus on a specific cyclobutene ring-opening mechanism, despite the fact that its application commonly yields combinations of compounds. In a study by Atul Kumar, a multi-component Hantzsch ester was synthesized in

aqueous micelles using ultrasound. Certain water pollutants, notably chlorinated organic compounds, can be removed sonochemically.

A number of methods that are regarded to be environmentally safe have benefited from sonochemistry, or the use of ultrasonic irradiation to trigger chemical reactions. [11] Ultrasonic waves are often used to start synthetic processes, and the typical results are quicker reaction times, higher yields, and higher selectivity's, or cleaner products. Sonochemistry will be helpful in the field to synthesize compounds using green chemistry methods. sonochemistry will be useful in the field of sustainable or green synthesis. [4]

9. Conclusion: -

Knowing the value of green chemistry, which is necessary in the modern pharmaceutical industry. The plan will help avoid the usage of dangerous chemicals, which might lead to a range of risks specific to the business. These traditional methods may easily be replaced by the use of procedures that are safe and helpful to the environment for the synthesis of the same. Modern methods that don't employ dangerous chemicals or catalysts, including microwave aided synthesis and sonochemistry, have taken the place of older ones. The technique will undoubtedly help with the synthesis by keeping a secure environment.

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