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Green Chemistry : A Tool for Sustainable Development

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Abstract: Green chemistry which was initiated about three decades has attracted lot of attention. It is a multidisciplinary field which cover's areas such as synthesis, solvemts, catalysis, raw materials, products, efficient methods and many more. In the current globalized world green chemistry is becoming the most potent tool, the strength towards the sustainable and overall development. It is environmentally benign chemistry which reduces or eliminates the use and generation of hazardous chemicals and substances. The basic principle of green chemistry on which it works is the minimization of risks, hazards and pollution and maximising the efficiency by maintaining the cost and potential exposure. It includes all parts of chemistry and other disciplines that aims to minimize the negative effects and maximize the efficiency .There are many innovations in green chemistry such as synthesis, renewable products, catalysts, disposal of wastes, design of nontoxic chemicals and components, new formulations and many more. Therefore it is imperative to acknowledge the importance and values of this branch of chemistry to future generations. This paper addresses the importance, innovation and application of green chemistry for a sustainable development.

Keywords: Green Chemistry, Multidisciplinary, Sustainable Development, Design of Safer Chemicals, High Efficiency

I. INTRODUCTION

In the last few decades trends such as climate change, population explosion, high degree of urbanisation, toxicity, scarcity of resources, energy and water have led to the initiation of sustainable practices in various sector's including industry, education and society. The ambition to improve standard of living and pure atmosphere the need for performance materials are required so that the gap between developed and developing nations get more narrower. These conditions has accelerated the development of materials based on green chemistry. The green chemistry is described as the movement towards more environment friendly chemical processes and synthesis. Nowadays green chemistry is regarded as a vital tool for the practice of chemistry and other branches of science to attain the sustainable development, by maintaining the balance with the environment. The concept of green chemistry was coined in 90's by the US Environmental Protection Agency (USEPA). Since then lot of research has been done in this field by developed nation's to achieve the optimum level of this branch. This fast moving concept is governed by some basic set of principles which move processes and products towards an economy based on renewable feedstock's which prevents chances of toxicity at the atomic or molecular levels. The chemical synthesis and products are designed and formulated so that to minimize the waste and side effects. The present era of globalization demands emphasis on safer and efficient products which can only be possible with the technology called as the green chemistry. There can be numerous applications of green chemistry in industries such as plastics, textile, pharmaceutical, renewable energy, pesticides, solvents, water purification, etc. It is believed that in the coming timegreen chemistry will change the face of science as a whole towards an economy based on renewable energy, green processes and bio based productions.

Green chemistry is commonly based on a set of 12basic principles proposed by Anastas and Warner. The principles includes instructions for chemist's and professionals to implement new chemical methods and novel ways of synthesis. The 12 principles are-

1. Prevention
2. Atom economy
3. Less hazardous chemical synthesis
4. Designing safer chemicals

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5. Safer solvents and auxiliaries
6. Design for energy efficiency
7. Use of renewable feed stocks
8. Reduce derivatives
9. Catalysis
10. Design for degradation
11. Real time analysis for pollution prevention
12. Inherently safer chemistry for accident prevention

Table 1. Examples of implementation of green chemistry principles into practise.

Nr	Principle	Examples:
1	Prevention	Use of solvent-less sample preparation techniques [2]
2	Atom Economy	Hydrogenation of carboxylic acid to aldehydes using solid catalysts
3	Less Hazardous Chemical Syntheses	Adipic acid synthesis by oxidation of cyclohexene using hydrogen peroxide [3]
4	Designing Safer Chemicals	New, less hazardous pesticide (e.g. Spinosad) [4]
5	Safer Solvents and Auxiliaries	Supercritical fluid extraction, synthesis in ionic liquids [5]
6	Design for Energy Efficiency	Polyolefins – polimer alternative to PWC (polimerization may be carried with lower energy consumption) [6]
7	Use of Renewable Feedstocks	Production of surfactants [7]
8	Reduce Derivatives	On-fiber derivatization vs derivatization in solution in sample preparation [8]
9	Catalysis	Efficient Au(III)-catalyzed synthesis of b-enaminones from 1,3-dicarbonyl compds. and amines [9]
10	Design for Degradation	Synthesis of biodegradable polymers [10]
11	Real-time analysis for Pollution Prevention	Use of in-line analyzers for wastewater monitoring
12	Inherently Safer Chemistry for Accident Prevention	Di-Me carbonate (DMC) is an environmentally friendly substitute for di-Me sulfate and Me halides in methylation reactions [11].

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Thus the basic idea of green chemistry is to accomplish both transmateriliazation and dematerialization; through it's rational approach and metrics of principles. However to achieve the full potential of green chemistry a coordinated approach of factors like social, political, technological is required.

II. Implementation of Green Chemistry Principles

In different chemical processes the waste products and the reagents used for synthesis, causes a severe threat to the environment. The exposure to hazardous chemicals can be minimize in a simpler way by applying safe raw materials and intoxic procedure during the preparation. For example adipic acid is used for the production of polymers like nylon, Polyurethanes, lubricants, plasticizers, etc. This adipic acid is formed by benzene which is a potent carcinogen. However recently chemists have developed a method for the green synthesis of adipic acid by using raw materials like glucose which on action with genetically modified bacteria gets converted to adipic acid. Green chemistry emphasizes the use of renewable sources as raw materials and starting reactants. The production of biodiesel oil, is a perfect example of this. As the name indicates, biodiesel oil is produced from cultivated plants like soya beans and fats embedded in plants oil by extracting the glycerine from it. The advantage of using this nontoxic oil is obvious as on combustion it doesn't generates sulphur and nitrogen compounds which are serious threat for the environment.

Another threat to the environment are the organic solvents which are used during the synthesis of different compounds. They are released in the atmosphere by volatilization process especially in the case of volatile organic compounds (VOCs) .This problem can be minimized by using super critical fluids (SCFs) in chemical processes and synthesis which are harmless for humans and the environment. The use of SCFs is becoming very common to run the chemical reactions. The term SCF comprises the liquids and gases at their critical temperature (Tc) critical pressure (Pc). Above the critical point the liquid- vapour phase boundary disappears, while the present phase shows both the properties of liquid and the vapour. Due to this, the SCFs are able to dissolve many compounds with different polarity and molar masses. Some of the important fluids which have been in common use are the scCO2 and scH2O. CO2 as a SCF is frequently used as the solvent or medium for reactions, as it is inflammable, easily available and cheaper in cost. Room temperature ionic liquids are also considered to be environment friendly reaction media. However the lack of technology for the removal of products from the ionic fluid has limited their applications. But recently it has been found that CO2 can be used to extract non volatile organic compounds, from room temperature ionic liquids. The researches have shown that ionic liquids (using 1-butyl-3-methylimidazolium hexafluorophosphate) and CO2 shows very attractive phase behaviour. The solubility of CO2 in ionic liquids is substantial, reaching mole fraction as high as 0.5 at 10MPa. Inspite of this the two phase do not become completely miscible, so CO2 can be frequently used to extract compounds from the ionic liquids.

Green chemistry can also play a substantial role in analytical chemistry. Development of environmental monitoring techniques can lead to better knowledge of the state of environment and the processes that takes place in it. Due to the introduction of green analysis and evaluation new measuring techniques can be used to study the concentration of trace and micro trace components in samples. The novel techniques can also be used to study the acidic behavior of components in the environment, the ozone depletion phenomenon, change in the composition of air, increase in the concentration of persistent organic pollutants (POPs), etc. Thus the introduction of green tool into chemical laboratories and techniques can drastically reduce the instrumental costs and also the adverse effects on the environment which is caused by the liberation of chemicals and fumes. Nowadays many techniques have been used which are based on the rules of green chemistry. Some of them are.

- X-ray fluorescence (XRF)
- Solid phase extraction (SPE)
- Surface acoustic wave (SAW)
- Super critical fluid extraction (SCFE)
- Mass spectroscopy with membrane interface (MIMS)
- Green solvents
- In-line analyzers
- Out- line analyzers

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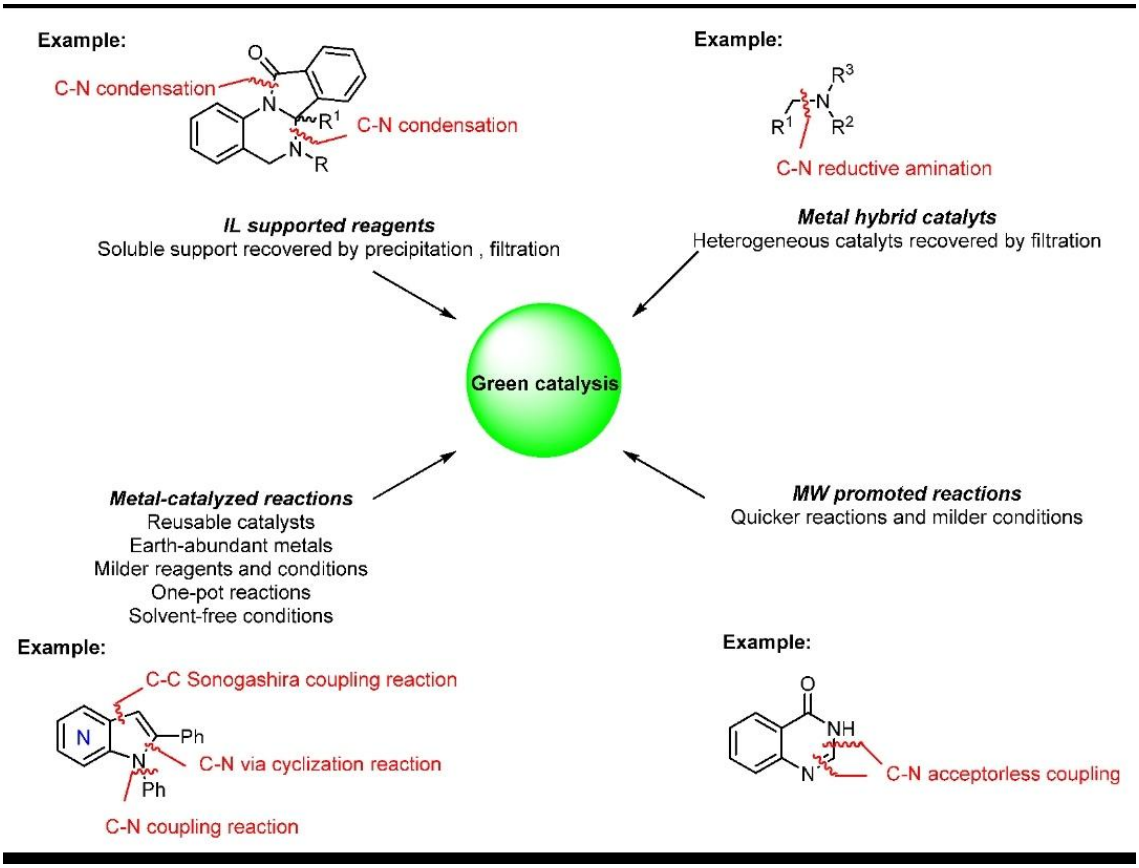
2.1 Green Nanotechnology

Nanotechnology is a potent tool of the present era and has varied applications in almost every sector. Hence there is a general perception that nanotechnology will have a significant impact on the development of green and clean technologies with numerous environmental benefits. Nanotechnology with green approach is playing a vital role in purification of water, separation of different solvents, energy sector, manufacturing units, etc. As a matter of fact renewable energy applications are the areas where nanotechnology is ready to play a crucial role and probably it will be a large scale breakthrough across the globe. Nanotechnology applications could provide decisive technological momentum in the energy sector and will enhance the generation of sustainable energy support that will shift the equilibrium away from the fossil fuels which are the major cause of pollution. Although these transitions require a political will and funding. The technological foundation is there, all it takes thecorrect approach and proper laboratory facilities to make it happen. Thus nanotechnology can provide the required thrust to accelerate the energy supply with greener means.

2.2 Green Catalysis

Greener catalysis means moving away from stoichiometric processes to homogenous and heterogeneous catalytic reactions using organic, organometallic, inorganic and biological catalysts.

Lots of research work has been going on to provide a path or mechanism for the greener synthesis routesby using the catalyts which are nontoxic, efficient and degradable. Olefin metathesis is an example of a very atom economical reactions with potential to eliminate the waste associated with alternate multistage synthesis. A versatile method for forming the carbon-carbon bond in polar and nonpolar solvents has been carried out in the presence of green catalyts like Fe-TAML, enzymes, highly acidic dysprosium(lll) triflate (trifluoromethanesulphonate), Molybdenum disulphide coated on alumina, Cativa catalyst, etc. These catalysts have also been used during polymerisation, to construct ring systems, synthesis of natural products and in cyclisation of Polypeptides.



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Olefin metathesis has also been very useful in obtaining useful products from renewable resources. Unsaturated fatty acid esters and natural oils can also be used to produce nontoxic feed stocks and many natural products. Hydrogenation using H2 gas is another example of atom economical reaction which has high degree of utility in designing green synthesis mechanism and different pathways in order to phase out hazardous and wasteful hydride and boran reagents. Now the time has arrived to increase the safety of chemical processes, providing alternative to toxic reagents and avoid the generation of harmful pollutants by the extensive use of green catalyst. One such catalyst is Fe-TAML which is an environment friendly oxidizing agent . It's use provides an alternative to polluting oxidizing agents like Cl and metal based oxidants. Fe-TAML activated oxidants can be used instead of dangerous ClO2 gas and metals like Zn, Cu, Ti, etc. for different processes like bleaching, oxidation and d

2.3 Need for Collaboration

There are many components and driver's of green chemistry. The promotion and commercial use of greener components, chemicals and techniques requires collaboration and communication between scientists, chemists, business leaders, politicians and common man. Designing different components and techniques requires lot of technicality and it can only be possible if there is an effective bonding between different branches of science. To implement green chemistry rules the market requires the inclusion of both the expertise and nontechnical manpower. Effective communication between different stakeholders is another criteria for the successful implementation of green technology as they use different technical terms and have different vested interests. However collaboration can be promoted with the creation of interdisciplinary research centres, which promotes fused action by including all the stake holders. The research centres can provide a common platform to discuss and identify key issues regarding the components of green chemistry. The components of green chemistry is actually the fusion of all the branches of science so constructive collaboration is needed among all these branches. As sustainable development has been accepted by the government, industries and the public, green chemistry has a very vital role in maintaining and improving the standard and quality of life, the competitiveness of the chemical industry and the natural environment. The challenges faced by the chemists and others are primarily concerned with social, economical and environmental benefits, where the concept of green chemistry has very important role to play. Although there are many challenges but the growing interest in this branch has made the things easier.

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III. CONCLUSION

Green chemistry is a tool which is being used to create a better, safer and efficient environment by minimizing the wastes and reducing the hazardous materials and chemicals. The future challenges in society, environment and resources needs the efficient and clean chemical process which can only be attained by the means of the green chemistry. It is a new smarter approach which can contribute towards the sustainable development of the society and the nation. The green chemistry rules are applied not only in synthesis, processing and manufacturing but are equally important innano, pharma, health and energy industries. The application of sample preparation techniques like SPME, SPE, ASE, etc. allows to obtain precise and accurate results. Green efforts are under going across the globe to design processes that initiates from non-polluting materials and requires no solvent to carry out the chemical reactions. Adoption of environmentally benign methods, new programs , government participation and funds are the important factors to replace the conventional methods by more greener and safer methods that forms the basis of green chemistry.

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