



Importance Of Green Chemistry in Synthesis of Heterocyclic Compounds: An Overview

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ABSTRACT

The advent of "green chemistry" is regarded as a revolution in the effort to lessen the harm that synthetic materials cause to the environment and the risk they pose to human health, routes taken in making them. Utilizing green chemistry in research is the preferred method environmentally friendly, moderate, non-toxic, repeatable catalysts and effective solvents for chemical synthesis. In order to prevent further harm to human health and the environment, such as reducing the release of hazardous chemicals into the air, which reduces lung damage, it is imperative that those who apply chemistry to develop alternative technologies that are safer for both human health and the environment. Green chemistry is the synthesis of substances in a method that is proper, non-polluting, and protected, uses the fewest resources and least amount of energy, and produces little to no waste. In order to reduce the harm that anthropogenic materials and the processes used to produce them cause to the environment, green chemistry is necessary. Research on effluence responsiveness is shown to be emerging through green chemistry. There are 12 principles of green chemistry that aim to reduce or stop the usage or manufacturing of dangerous compounds. Recent developments in the green chemistry of the synthesis of heterocyclic compounds by using microwave irradiation, water as solvent, grinding methods, synthesis by green catalyst, synthesis without solvents is discussed in this review.

Key words: Green chemistry, green catalyst, microwave irradiation, grinding methods, nanoparticles, bio-based solvents.

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INTRODUCTION

It has been two decades since green chemistry has been started and making several changes in our world. Green chemistry is a process of synthesizing safe, protected, and uses a very little amount of energy with or without waste of materials. Green chemistry is needed because it protects our environment from anthropogenic substances and their generation process. By using green chemistry, the amount of chemical waste that is released to air, water and land has been decreased. Most industries are making use of toxic chemicals and extra difficult process that causes the production of a large amount of harmful substances. This substance has a bad effect on nature and its surroundings. The green chemistry is predicted as future of all chemistry by some industry reports. As per the information by EPA's Toxic Release Inventory (TRI) between 2004 and 2013 the chemical waste that has been released to water, land and air has decreased by 7%. As per the earlier update by pharmaceutical industry, the usage of harmful chemicals has been reduced by 50%.

Green chemistry gives environmentally beneficial ways to displace technologies and harmful solvents to stop pollution. The methods that induce green chemistry are Eco-friendly chemistry, clean chemistry, atom wealth, and benign design chemistry. Green chemistry plays a major role in synthesizing and replacing new chemicals in place of ones that have proven to be causing harm as per the reports by the U.S. National Research Council. The REACH authorization process is the main active aid in green chemistry and is a maintainable innovation, by encouraging the weed-out of harmful chemicals and substituting them with safer alternatives.

The pharma industries and research laboratories have given a great profit with design and synthesis of organic molecules. Green chemistry targets to terminate the release of any dangerous bi-products and increase the yield of the target compound without disturbing the environment. Paul Anastas and John C. Warner said that green chemistry is the usage of set of principles that decreases or stops the use of harmful

substances on the design of reaction mechanism, prohibition of waste; maximize the atom economy, use of safer solvents, reduction derivatization and design for energy efficiency [1-4].

Principles

The twelve principles in green chemistry which are introduced by Paul Anastas and John Warner in 1998 works as a base for the design of new chemical products and its methods, it includes the use of raw materials for process life cycle, the safety and benefit of the transformation, biodegradability and harmfulness of the products and the reagents used [1,5].

Principles

Prevention of waste: It is used to reduce the formation of waste rather than to clear it up after the fact. The establishment of this principle was justified, as evidenced by the fact that the United States yearly around 12 billion tonnes of waste which is so called hazardous waste that is harmful to human health and environment.

Atom economy (AE): It is also known as atom effectiveness which means mostly the use of raw materials. Barry Trost initiated the concept of synthetic efficacy in 1990. The most of the atoms are present in the final product from reactant. AE is the ratio of molecular weight of the product to the molecular weights of all reactants used in the reaction.

$$\text{Atom Economy} = \text{MW of Product} / \text{MW of reagents}$$

Safe solvents: Safer solvents advise that the synthesis process be minimized to the great extent possible and avoid using auxiliary chemicals. Energy efficient distillation has a connection to their recycling with significant losses.

Designing safer chemicals: Chemical products should be made with low toxicity while maintaining function and efficiency, and accomplishing the goal needs knowing the fundamentals of toxicology and environmental science in addition to chemistry. Risk is reduced to the absolute minimum.

Design for energy efficiency: The development of more energy-efficient practices and the hunt for renewable energies-non-depleting resources in a time period relevant to human scale-have were pushed by growing worries over the depletion of petroleum feed-stocks and the growth in energy demand.

Accident prevention: To reduce chemical accidents, chemical processes should be chosen carefully. Examples are the replacement of organic solvents with supercritical CO₂, which is non-toxic, non-explosive, and environmentally beneficial and the production of biodegradable plastics.

Chemical synthesis of less hazardous chemicals: When hazardous chemicals are replaced with biological enzymes, many industrial processes become more efficient and less expensive. For instance, a novel polycarbamate synthesis (PC) procedure that replaces dangerous carbonyl dichloride (COCl₂) with CO₂ is conceptually straightforward.

Catalysis: Bio-catalysis is an illustration of green chemistry. It often denotes both the usage of pure enzymes directly and the changes carried out by designed biological things. Enzymes have demonstrated greater chemical selectivity and stereochemistry. Additionally, biocatalysts offer a significant advantage over non-biological catalysts in terms of reaction rate, cost, and catalytic selectivity, but lack of heat sensitivity and poor ability.

Biodegradation: It is difficult to design biodegradable materials and chemicals. Branching chains, halogenated moieties, quaternary carbons, tertiary amines, and specific heterocyclic are among the chemical forms that are avoided because they may have increased persistence.

Analysis: The use of analytical techniques that generate less waste and are safer for the environment and people's health is known as "green analytical chemistry." Analytical apparatus manufacturing materials should be taken into account. When developing novel sensors, green chemists and engineers must be conscious of the material's toxicity and potential environmental issues. For instance, electrochemistry frequently uses mercury electrodes, by substituting them with carbon-based electrodes such nanotubes or nanofibers, the practical solution has been demonstrated.

The Green Chemistry Institute (GCI) was formed in 1997 and became a part of American Chemical Society (ACS) in 2001. These principles are design guidelines which help the chemist to achieve the intentional goal of sustainability [5-9].

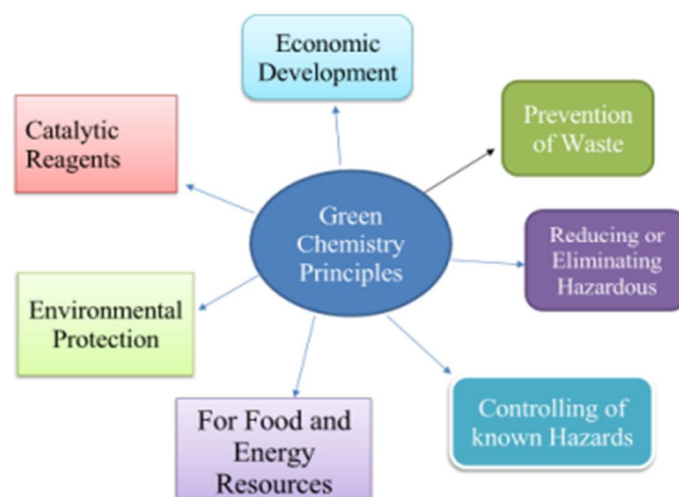


Figure 1: Green chemistry principles

Solvent free synthesis:

Benzimidazole and its derivatives: An expeditious one-pot solvent free synthesis of benzimidazole derivatives was prepared in 2008. Various biological activities like anti-viral, anti-cancer and anti-histaminic was shown by benzimidazole and its derivatives.

Coumarin: One-pot synthesis of coumarin was reported in 2009 by silica gel supported sulphuric acid under solvent free conditions. A green pathway for the synthesis of coumarin by avoiding toxic catalyst and solvents was provided by this method.

Coumarin derivatives: 8-Amino-4-methyl-2H-chromen-2-one coumarin derivative was synthesized by utilizing barium chloride (BaCl_2) through Pechmann condensation reaction without using the solvent. Some of the advantages this method has are short reaction time, excellent yield of product and solvent free conditions in agreement with green chemistry principles.

Chalcone derivatives: The synthesis of chalcone derivative (2E)-1,3-bis-(4-bromo phenyl) prop-2-en-1-one by cross aldol condensation of aryl methyl ketones using FeCl_3 /bentonite under solvent free conditions. This process provides a non-hazardous, easy work up, shorter reaction time and better yields.

Benzimidazole: Eco-friendly, easy and simple method for the synthesis of 2-aryl benzimidazole is formed by the reaction between arylidene malononitrile and 1,2-phenylene diamine.

Microwave synthesis:

Citric acid derivative:

Fenclofenac: It is non-steroidal anti-inflammatory in Nature. The Synthesis of fenclofenac by Microwave assisted was prepared in 2010. This Process takes place in 3 steps pathway for completion it takes 5 days. The final Yield is very low but the reaction takes small time that is approximately 1.5 h, good yield 52% and eco-friendly compared with conventional method.

Coumarin: The organic synthesis of coumarin and chalcone derivative using poly ethylene glycol (PEG) as a solvent. Under Suzuki-cross-coupling condition it is environmentally mild by microwave-assisted synthesis.

Azoles: Tetrahydro carbazole synthesis is a microwave assisted chemical synthesis. It is quick, safer, mild approach as compared to old traditional method.

Synthesis of fluorinated compounds: On PEG in the solid phase synthesized highly fluorinated molecules. Microwave assistance makes this reaction safe, and PEG, a soluble polymeric support for small molecule synthesis, makes process purification simple.

Triazine synthesis: Simple cost effective and sustainable method by using microwave assistant for synthesis of 6-aryl-2,4-diamino-1,3,5-triazine was occurred by using aryl nitrites and cyanoguanides.

Synthesis of benzothiazole compounds: Benzothiazole is crucial and provides a wide range of biological functions in the realm of medicinal chemistry, including anti-tuberculosis, anti-diabetic, anthelmintic, anti-cancer, anti-bacterial, anti-tuberculosis, anti-viral, anti-oxidant, anti-inflammatory, anti-glutamate, anti-tumor neuroprotective, anticonvulsant, muscle relaxant, anti-parkinsonian, inhibitors of many enzymes, etc. as a result it is has potent biological activity and show pharmacological effects. The fast synthesis of 2-aryl-benzothia/oxazoles by condensation of 2-aminothiophenol and various aryl aldehydes in the presence of *Acacia concinna* as a biocatalyst under microwave irradiation has been studied by Bhat and co-authors.

The microwave irradiation methodology has demonstrated a faster reaction time with higher yields of the desired compounds when compared to the conventional method. Furthermore, since no solvent is utilized during this process, the reaction course is highly environmentally benign.

Condensation of 2-amino thiophenol and aryl aldehydes under microwave irradiation:

Using green catalyst:

Activated fly ash: By using solid media, the organic synthesis was simplified by green chemistry approach. Taking fly ash, it is activated as Industrial waste which is systemic and effective Catalyst for some selected solvent free organic reactions under microwave irradiation.

Lemon Juice: Multi-component synthesis of substituted 2H-1,2,3-triazoles derivatives using lemon juice in ethanol by the reaction of 4-chloro-2-nitro aniline and 4-methoxy aldehyde with thiosemicarbazide in maximum yield. The basic principle of green chemistry is lemon juice plays a role of biocatalyst it provides a non-hazardous and mild condition.

Papain: The multicomponent synthesis from benzyl ammonium acetate and aromatic aldehyde in one pot was performed which is less cost effective, non-harmful biocatalyst. The tri substituent imidazoles by using papain (papaya latex).

Pectin: Using pectin as a green catalyst that is gentle on the environment, a mild and ecologically friendly synthesis of benzimidazole in outstanding yield.

Extract of lemon juice: These derivatives were created by reacting aldehydes 1,3-dicarbonyl compounds and urea at room temperature without the use of any solvents. This reaction, which uses multiple components in one pot, uses lemon juice as a green catalyst.

Biodegradable biocatalyst: The use of a productive, reusable, and biodegradable biocatalyst for the synthesis of 4H-pyrimido [2,1-b] benzothiazole derivatives. Here is a substitution-induced multicomponent reaction of aromatic aldehydes 2-amino benzothiazole/3-amino-1,2,4-dicarbonyl and triazole, urea, and thiourea in aqueous medium with 2% acetic acid chitosan as a green catalyst at a temperature of 60-65 °C.

Earthworm extract: By reacting several salicylaldehyde derivatives with various keto esters in the presence of unrefined earthworm extract, different coumarin derivatives were produced in yields in DMSO/water of 32–87%. The key benefits of crude earthworm extract are utilized as a catalyst in some environmentally friendly, safe, inexpensive, and simple steady and reachable.

Amberlite resin: For the preparation of (2E), 4-nitro phenyl-1-(4-ethoxy phenyl) prop chalcone derivative of 2-en-1-one via anion exchange with Amberlite resin.

Chalcones are well-known synthesis intermediates for numerous heterocyclic compounds. The product is simpler to recover, and the resin can be used repeatedly without losing its effectiveness.

Sodium formate: 4H-pyrans and 4H-pyran annulated heterocycles using sodium formate, a chemical that is non-toxic, inexpensive, and easy to get several green chemistry requirements are met by this pathway.

Sulphonated rice husk (RHA-SO₃H): By condensation of *o*-phenylene diamine with modified *o*-phenylene diamine, a green technique for the production of benzimidazoles and quinoxalines were introduced. Aldehydes in sulphonated rice husk (RHA-SO₃H) presence. This technique offers a catalyst and a rapid reaction time.

Amberlyst-15: In order to create coumarin derivatives, used naphthol and keto ester in the presence of Amberlyst-15, a recyclable and environmentally friendly catalyst. Additionally, they discovered that coumarin derivatives are significant in the industrial domains and have biological activity.

Protein directed solution: Using BSA as an effective and environmentally friendly biocatalyst, created pyrano 2,3-pyrazoles from a one-pot, four-component system. Five cycles of use of this catalyst were possible without loss of catalytic activity.

Using grinding method:

Esters: Simple and eco-friendly method by grinding technique with the use of Biginelli reaction introduced by Bose and his colleagues in 2004 for synthesis of ethyl-6-methyl-4-phenyl-2-thioxo-1,2,3,4-tetrahydro pyrimidine-5-carboxylate.

Pyrazole: As most of the pyrazole synthesis required many steps which require cost affective catalyst, inert environment condition, and they are time taking process. By using simple grinding methods given pyrazole synthesis methods and those are cost effective, reaction occurs in single step, without any catalyst.

Coumarin: Eco-friendly method like simple grinding technique is used for the synthesis of 7-hydroxy-4-methyl coumarin. By using Equimolar amount of ethyl acetoacetate and resorcinol were taken and then equimolar amount of TSOH were taken in a motor, pestle and grinded at room temperature.

Chalcones: It is an easy, cost effective, mild and sustainable when compare to traditional methods. This method involves synthesis of Chalcone (2E)-3-(4-hydroxy phenyl)-1-(4-methoxy phenyl)-prop-2-en-1-one by reacting substituted aldehyde and acetophenone with the help of grinding agent without using any solvent.

In the presence of anhydrates barium hydroxide using C-200 without any solvent. This technique is effective and mostly based on green synthesis.

Chalcone compound was obtained by reaction between *p*-chloro benzaldehyde and *p*-nitro acetone. This method does not require any catalyst, it is safe, non-toxic and it is a simple pathway and the product that synthesized by this process shows anti microwave activity.

This method involves preparation of charcoal by grinding method without use of solvent. This method estimated that chalcones have anti-oxidant activity. It is a simple process does not require much time and product yield is high.

Sustainable and eco-friendly method introduced for the synthesis of chalcone derivative without using any solvent. This method involves grinding different compounds like benzaldehyde, acetophenone and NaOH pellets at room temperature and to complete the process it requires 15 to 45 min.

Water as a solvent in the synthesis of heterocyclic compounds: Water replaces the usage of dangerous organic solvents, playing a major role as a solvent in the synthesis of several heterocycles. Water has several benefits as a reaction solvent for organic synthesis, but under normal circumstances, its usage is limited because many organic compounds are poorly soluble in it. But still its properties alter when it is utilized in high temperature and pressure environments. It is capable of serving as a strong solvent for a variety of chemical processes. As water has such great potential as a medium for heterocyclic synthesis, following are the moieties where the five-membered heterocyclic synthesis is carried in water.

Synthesis of nitrogen-containing heterocycles: The most prevalent and significant molecules in nature are nitrogen heterocycles. Many natural products, including vitamins, hormones, antibiotics, and alkaloids, as well as medications, herbicides, colours, and numerous other chemicals, contain their structural components.

Azines: A quick and easy method to create cyclo [3.2.2] azines using a three-component reaction in an aqueous solution with 2-picoline, α -bromo acetophenone, and alkyne under microwave illumination.

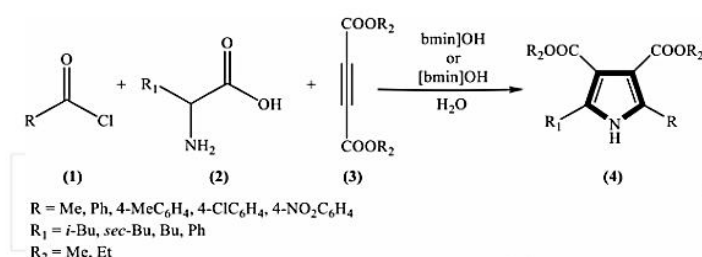


Figure 2: Synthesis of tetra substituted pyrroles



Figure 3: Synthesis of polysubstituted pyrroles using InCl₃ in presence of water as a solvent

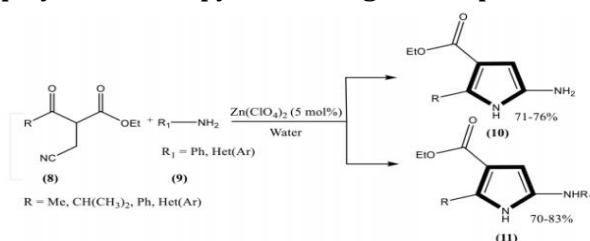


Figure 4: Zn(ClO₄)₂ catalyzed synthesis of pyrrole in water

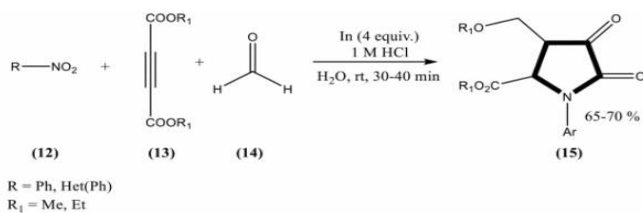


Figure 5: Synthesis of poly-substituted pyrrolidin-1,2-diones in water

Formation of the pyrrole ring: Since water is a cheap, non-flammable, and readily available resource, using it as a solvent in processes is a wise decision from both an economic and environmental stand point. Diels and Alder reported in 1931 that water was utilized as a solvent for the synthesis of heterocyclics in the cycloaddition reaction between furan and maleic anhydride. Later, Breslow provided a crucial example, demonstrating the hydrophobic effects which could significantly speed up a number of chemical reactions. Although water has several benefits as a reaction solvent for organic synthesis, its use is restricted under typical circumstances due to the low solubility of many organic compounds in water. But when exposed to extreme pressures and temperatures, it changes in composition and can develop into an effective organic synthesis solvent.

A successful technique to produce 6-substituted-6,6a-dihydro isoindolo-[2,1-a]-quinazoline-5,11-diones through the reaction of isatoic anhydride, amine, and 2-formyl benzoic acid. In this instance, the authors demonstrated that, as the multicomponent reaction is less efficient when β -CD (beta-cyclodextrin) is absent, the catalyst appears to be crucial in enhancing the reaction's efficiency, particularly by energizing the anhydride carbonyl group of 1 and augmenting the water solubility of all the reactants. β -CD also aided in the subsequent nucleophilic assault by amine 2 on the activated carbonyl carbon, which produced the 2-amino N-aryl benzamide intermediate. After that, this interacted with 2-formyl benzoic acid through intramolecular concurrent cyclization that involved the amide group and the carboxylic acid.

Polysubstituted pyrroles in water using 1,3-dicarbonyl chemicals and α -azido chalcones in good yields. According to their research, InCl_3 acted as a highly effective catalyst in this regioselective transformation. A three-component reaction-based direct technique for the synthesis of novel spiro[indoline-3,7,9-pyrrolo [1-c]imidazole]-6,9-carbonitrile derivatives was introduced. Using isatin, malononitrile, hydantoin or thiohydantoin in the presence of Et_3N , the reaction occurred in good yields as based.

5-(Alkyl aryl amino)-6-chloro pyrazine-2,3-dicarbonitriles with phenylacetylene to create pyrrolo [2-b] pyrazines. This coupling reaction/cyclization, which is a variation of the Larockindole synthesis, was carried out in water with sodium lauryl sulphate, K_2CO_3 , $\text{Pd}(\text{Ph}_3\text{P})_2\text{Cl}_2$ and CuI as the catalytic system for 24 h at 70 °C.

Greener synthesis of nitrogen-containing heterocycles in PEG and bio-based solvents: N-heterocycles are so important in medicinal chemistry, greener methods of synthesizing them are needed. In the chemical industry, solvents are vital, and one of the most essential aspects of their function is how well they work with reagents and products in chemical processes. The yield, selectivity, and chemical reactivity of the synthesis process will all be impacted by the solvent selection. Finding or creating new solvents to replace widely used ones is one strategy to attempt and reduce safety, toxicity, and emission issues. Water and polyethylene glycol are two viable suggestions for green solvents that have been reported in recent years due to their inexpensive costs and minimal acute toxicity. Recently, research teams have shown that the utilization of bio-based solvents. The best proof that the ideas of green chemistry have advanced significantly is seen in all these findings in the search for cleaner solvents.

PEG as solvent: Polyethylene glycols (PEGs) have garnered significant interest recently as environmentally friendly solvents for a range of chemical reactions. These inexpensive substances come in a variety of molecular weights. PEG 400 is described as a thick liquid that dissolves easily in a variety of organic solvents including water. Its benefits, which include being biodegradable, non-toxic, odourless, neutral, non-volatile, and non-irritating, have made it possible for a range of pharmaceuticals and therapies to contain it.

Bio-based solvents: Biologically based solvents and the need to discover substitutes for traditional organic solvents have received more attention recently due to growing concerns about sustainability. Due to initial obstacles such production costs, there is currently a limited supply of these solvents available for commercial application. As a result, their bio-based solvents' market price is not competitive. These challenges will be addressed soon, as research teams gradually increase the amount of money they devote to the investigation of substitute solvents. In this study, we discuss the physiologically based solvents

meqlumine, gluconic acid, ethyl lactate, and lactic acid, which have been reported to be viable substitutes in the production of N-heterocycles. Biodegradable Solvents, also known as bio-sourced solvents, are defined as mean solvents derived from renewable sources, including vegetable sources, which could include high-carb agricultural crops like corn, wheat, and beets, forestry, or aquatic goods. Usage of eucalyptol as the novel solvent for organic transformations was established for the first time by this study.

Synthesis of sulphur nanoparticles using plant leaf extract: For synthesis of sulphur nanoparticles, the sulphur powder was ground finely in mortar and pestle. The grinded sulphur powder was added into flask containing 50 ml of sodium sulphide (1 M). The reaction mixture was heated up to 100°C with continuous stirring to dissolve the sulphur powder. The change in colour of solution from light- yellow to reddish-orange indicated the formation of sodium polysulphide solution. The resulting sodium polysulphide solution was then mixed with each leaf extract in 1:4 proportion under continuous stirring followed by dropwise addition of concentrated H₂SO₄ for precipitation of sulphur nanoparticles. The suspended sulphur nanoparticles were obtained by centrifugation at 4000 rpm for 45 min and then repeatedly washed with sterile distilled water to remove any biological materials available. The obtained sulphur nanoparticles were dried in hot air oven at 80°C.

The treatment of leaves extract of *A. indica*, *C. roseus*, *M. indica*, and *P. longifolia* with sodium polysulphide and acidic solution (H₂SO₄) develop the yellowish precipitate in solution, which indicated the formation of sulphur nanoparticles. In this method of sulphur nanoparticles synthesis, as elemental sulphur, which is not soluble in water, was dissolved in sodium sulphide to get sodium polysulphide (Na₂S_x) and used as precursor source of sulphur. When sodium polysulphide (precursor) and concentrated sulphuric acid (H₂SO₄, precipitating agent) along with plant extract (reducing agent) were mixed together, resulting into appearance of yellow precipitate of sulphur nanoparticles. The following reaction occurs on mixing of leaf extract, sodium polysulphide solution, and concentrated H₂SO₄.

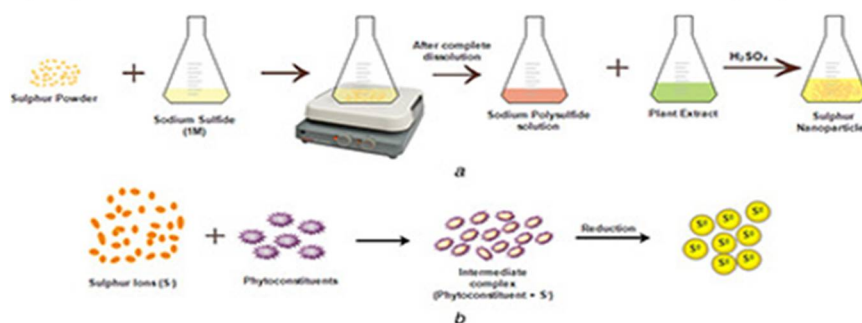
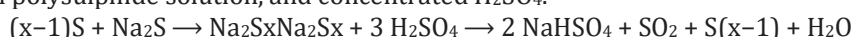


Figure 6: Schematic representation of (a) Method of synthesis of sulphur nanoparticles and (b) Mechanism involved in synthesis of sulphur nanoparticles

Careers: Green chemistry plays an important role in many careers;

- Biofuels plant engineers are entailed in the large-scale production of alternative, bio-based fuels, such as ethanol-added gasolines, biodiesel, and other new biofuels at biofuel production facilities.
- Biomolecular engineers can be a main part of green research team. Green chemistry engineers involve in projects such as cleaner smelting and refining processes, and how to convert crops or trees into sustainable fuels, biodegradable plastics and fabrics.
- Pharmaceutical chemists support drug industry in its ongoing efforts to manufacture the medicines having less harmful side-effects, utilizing processes that cause less toxic waste. Major part of the mass establishing a process stream in the chemical manufacture of active pharmaceutical ingredients generally stems from the solvent used; 80-90% if water is added. This indicates that the potential for the production improvements is huge.
- Recycling specialists do work with businesses and municipalities to support reusing and recycling chemicals and other wastes that is produced by industrial procedures. These specialists start and run their recycling programs.
- Regulatory specialists are those who work with governmental organizations and policymakers to execute and keep mechanisms in place to foster green chemistry research and education.
- Research chemists take up the research to develop more benign replacement to many thousands of hazardous chemicals utilized in modern refining and manufacturing processes [2,7,10-15].

Applications of chemistry

Environmentally safe laundering of clothes: Perchloroethylene (PERC) is cancer causing agent and is used for dry cleaning pollutes water resource. Joseph De Simons, Timothy Romark, and James they find solution that is they synthesized a micelle that is prepared by mixing liquid CO₂ and a surfactant for cleaning garments. Cleaning machines have now been produced making use of this procedure.

Mechanism for collecting rainwater: A rain collector system is a very basic mechanical device that connects to a gutter system or other rooftop water collecting network and collects rainwater to be used for irrigation, flushing toilets, and other non-potable purposes. These systems are quite affordable.

Photovoltaic cell: Solar cell is one of the best familiar examples of green technology. Photovoltaics is the process involved and decreases pollution and emission of green gas.

Reusable water bottle: The reusable water bottle is another straightforward product that can be categorized as green. Therefore, reusable water bottles that you can fill yourself are green, eco-friendly, and good for your health.

Using green technology when building: With the use of recycled materials, passive solar architecture, natural ventilation, and green roofing technology, construction companies may create buildings with a lot less carbon footprint than usual and these building techniques can also reduce the costs associated with construction and operation of a building. Green ventilation techniques involve open spaces and natural airflow, reducing the need for traditional air conditioning and preventing many of these problems.

Method to clear turbid water: Tamarind seed kernel powder, which is dumped as agricultural waste, works well as a clarifier for waste water in both urban and industrial settings. The current practice is to treat such water with Al-salt. Alum has been discovered to increase the amount of harmful ions in treated water, which can lead to disorders like Alzheimer's. On the other hand, kernel powder is not toxic, perishable, or very expensive. Four flocculants, namely tamarind seed kernel powder, a mixture of the powder and starch, and starch and alum, were utilized in the study. The study confirms the powder's potential as an economical flocculant with performance comparable to that of more developed flocculants such potash alum, K₂SO₄ Al₂(SO₄)₃.24 H₂O.

Wind turbine: A home wind generator's ability to produce power varies nearly as much as its original cost. Only 10-15% of your home's energy costs can be offset by several kit-based generators.

Insulation of house: Based on EPA estimates, 10% of household energy usage a year is due to energy loss from poor insulation. We will get an excellent return on investment from sealing our home to prevent energy escape.

Solar water heater: Solar water heating systems are more cost-effective and efficient than the substantial solar array needed to power a whole home [16-20].

CONCLUSION

The objective of green chemistry is to safeguard the environment. One way to do this is to prepare chemical compounds so that they degrade harmlessly into the environment after serving their purpose. The basic goal of green chemistry is to satisfy societal demands without harming or diminishing earth's natural resources. One of the main objectives of green chemistry is to reduce waste and pollution, hence actions are being conducted in this direction. Alternative technology development is essential to halting future harm to human health and the environment. Applying the twelve principles of green chemistry will finally assist to pave the road to a world where the grass is greener, but green chemistry alone cannot solve the urgent environmental challenges and influences on our modern period. Green chemistry is not a new branch of science. It is a new philosophical approach that through application and extension of the principles of green chemistry can contribute to sustainable development and the biggest challenge of green chemistry is to use its rules in practice.

Conflicts of interest

None.

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