Green Chemistry; Sustainability an Innovative Approach

(Green Chemistry and Sustainability)

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***Abstract*: Green chemistry is an approach to the design, manufacture and use of chemical products to intentionally reduce or eliminate chemical hazards. It focuses on the reduction, recycling/ elimination of the use of toxic and hazardous chemicals in production processes by finding creative, alternative routes for making the desired products that minimize the impact on the environment. Sustainable economic growth requires safe, sustainable resources for industrial production. This article describes an introductory account of the basic tanets on which the concept of the Green Chemistry is based.**

Keywords: Green chemistry, environmental chemistry, feedstock, analytical chemistry, sustainability, metathesis

INTRODUCTION

Green chemistry is a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances.1The goal of green chemistry is to create better, safer chemicals while choosing the safest, most efficient ways to synthesize them, to reduce wastes and to eliminate hazards right at the design stage. The practice of eliminating hazards from the beginning of the chemical design process has benefits for our health and the environment. A typical chemical process generates products and wastes from raw materials such as substrates, solvents and reagents. If most of the reagents and the solvent can be recycled, the mass flow looks quite different. Thus, the prevention of waste can be achieved if most of the reagents and the solvent are recyclable.

MATERIALS AND METHODS

PRINCIPLES OF GREEN CHEMISTRY

1. Prevention

It is better to prevent waste than to treat or clean up waste after it has been created.

2. Atom Economy

Synthetic methods should be designed in such a way to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Syntheses

Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals

Chemical products should be designed to affect their desired function while minimizing toxicity.

5. Safer Solvents and Auxiliaries

The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6. Design for Energy Efficiency

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feed stocks

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8. Reduce Derivatives

Unnecessary derivatization (use of blocking groups, protection/deprotection, and temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9. Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

11. Real-time analysis for Pollution Prevention

Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

RESEARCH AND DEVELOPMENT IN THE FIELD OF GREEN CHEMISTRY

Alternative feed stocks

Green chemistry promotes the development of innovative technologies to utilize the potential of renewable resources. Historically, many of the materials used to make products often were toxic or depleted limited resources such as petroleum, but green chemistry research is developing ways to make products from renewable and nonhazardous substances, such as plants and agriculture wastes. For example cellulose and hemicellulose, which constitute up to eighty percent of biomass, can be broken down to sugars, then fermented to chemical commodities such as ethanol, organic acids, glycols, and aldehydes. Converting biomass to ethanol has become economically and technically viable due to a new class of genetically modified bacteria capable of breaking down the different sugars in hemicellulose.

Benign manufacturing

The methods used to make chemical materials, called synthetic methods. These methods have generated large quantities of hazardous wastes. Green chemistry research is developing new ways to make these synthetic methods more efficient and to minimize the unnecessary derivatization via ; use of blocking groups, temporary modification of physical/ chemical process and metathesis play an important role to achieve this goal.

METATHESIS IN GREEN CHEMISTRY

Metathesis represents a great step towards “Green chemistry”. It is an example of how important basic science has been applied for the benefit of man, society and the environment.

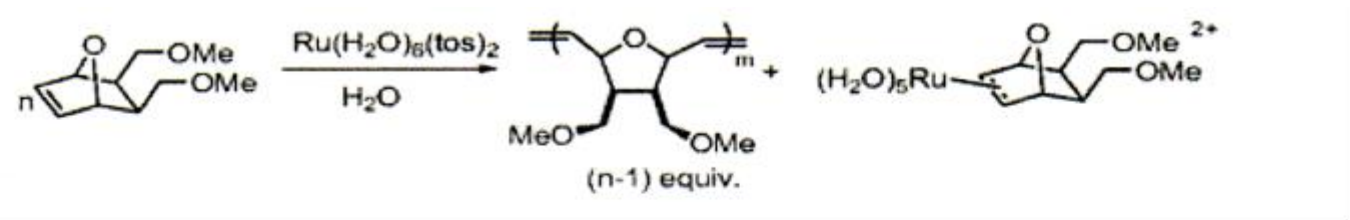
The word “Metathesis” means change places. In metathesis reactions, double bonds are broken and made between carbon atoms in ways that cause atom groups to change places.

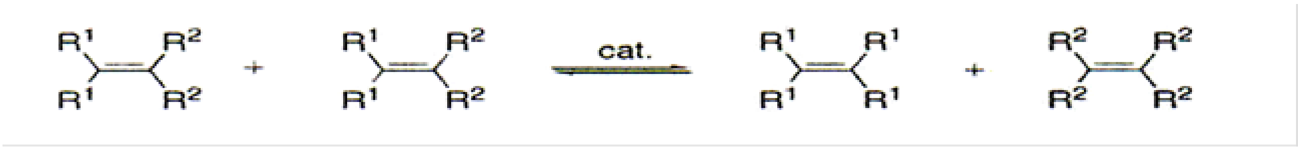
$$A\text{-}B + C\text{-}D \longrightarrow A\text{-}C + B\text{-}D$$

It involves the synthesis methods that are (i) more efficient(fewer reaction steps, fewer resources required, less wastage) (ii) simpler to use (stable in air, at normal temperatures and pressures)and (iii) environmentally friendlier (non-injurious solvents, less hazardous waste products)..Olefin metathesis was first observed[2]. The metal catalyzed olefin metathesis reaction will be used to demonstrate principles of green chemistry.

IMPLEMENTATIONS IN GREEN CHEMISTRY FIELD

Ring-opening metathesis polymerization.

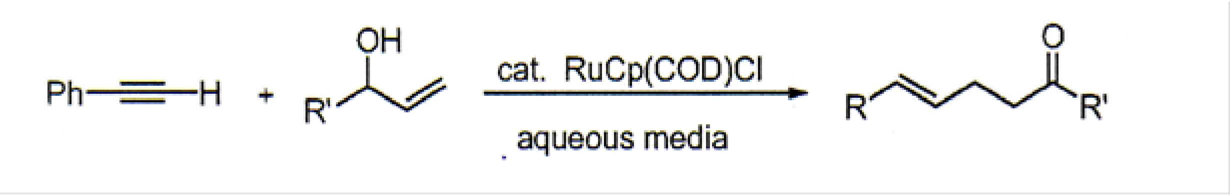




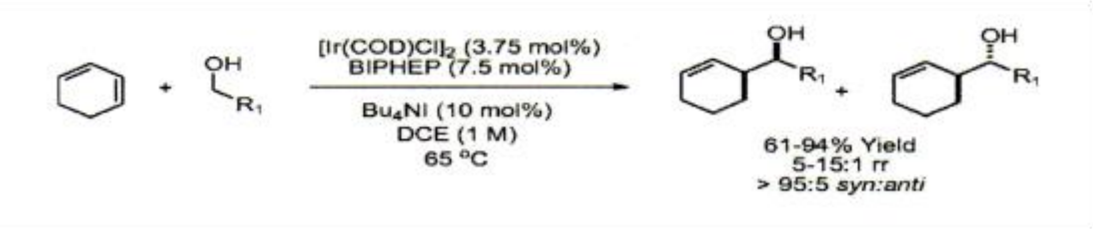
The living ring-opening metathesis polymerization developed by Grubbs and coworkers represents another type of isomerization and has been used to make a variety of materials, such as those used in dentistry.[3]

Addition reactions.

The processes of adding alkyl alcohol to alkynes to form γ,δ-unstaturated ketones and aldehydes in aqueous media were developed.[4,5]

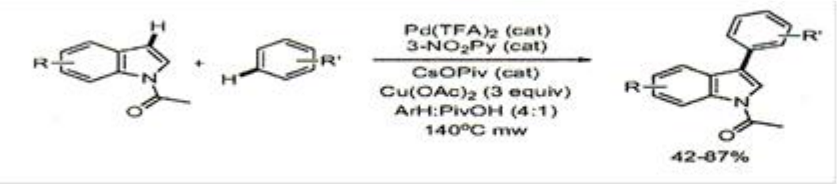


Another elegant example in which primary alcohols were added stereoselectively to alkenes, which provides an atom-economic version of the classical reaction where a Grignard reagent is added to an aldehyde.[6]

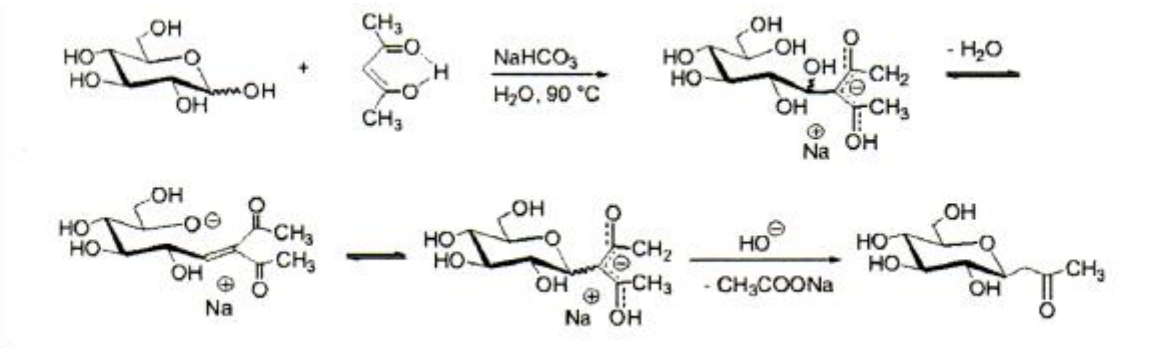


Direct Conversion of C–H Bonds.

Direct transformation of the C–H bonds of organic molecules into desired structures without extra chemical transformations represents another class of major desirable reactions (5-6). Recently, an elegant cross-coupling of two aryl C–H bonds to form arene–arene coupling products was reported ..[7,8,9,10]



Recently, an elegant cross-coupling of two aryl C–H bonds to form arene–arene coupling products was reported.[11,12]



Synthesis Without Protections.

Because of the nature of classical chemical reactivity, organic synthesis extensively utilizes protection–deprotection of functional groups, which increases the number of steps in synthesizing the desired target compounds. Novel chemistry is needed to perform organic synthesis without protection and deprotection. The Knoevenagel condensation of the β-diketone with hemiacetalic sugar gave β-*C*-glucosidic ketone in water directly.[13]

Solvents

Solvents are auxiliary materials used in chemical synthesis. The development of Green Chemistry redefines the role of a solvent: An ideal solvent facilitates the mass transfer but does not dissolve! In addition, a desirable green solvent should be natural, nontoxic, cheap, and readily available.

Water The only natural solvent on earth is water. Life requires the construction of chemical bonds in an aqueous environment. It is obvious that water is the most inexpensive and environmentally benign solvent. One challenge of using water as a solvent is the regeneration of pure water that contains only minor impurities. In this respect, newer purification technologies such as ultra filtration or natural evaporation (if the impurity is not vaporizable) help. Another challenge of using water is separating water-soluble products from water. In addition, many organic compounds are not soluble in water. Although "on-water" techniques have provided excellent solutions for some situations, there will be cases where completely soluble in water is desired.

CO_2. In some cases, water is undesirable. Although some chemical processes may be modified to use water, green solvents with different properties than water are nevertheless needed. One such solvent is liquid and supercritical CO2. It is also a natural solvent, although some energy (pressure) is consumed in its production. In addition, CO_2 is renewable, nonflammable, and readily evaporating. Other excellent features of CO_2 include its fast drying time, better ability to dissolve organic compounds, and better flow ability because of its low viscosity compared with other solvents including water. These properties are complementary to water and provide supplementary needs.[14,15]

One special feature of liquid and supercritical CO_2 is its high mixibility with gases, which offers high efficiency (and often higher selectivity) in reactions such as hydrogenations with hydrogen gas and oxidations with air.[16]

CONCLUSION

My future challenges in resource, environmental, economical, and societal sustainability demand more efficient and benign scientific technologies for working with chemical processes and products. Green chemistry addresses such challenges by inventing novel reactions that can maximize the desired products and minimize by-products, designing new synthetic schemes and apparati that can simplify operations in chemical productions, and seeking greener solvents that are inherently environmentally and ecologically benign. Together, such fundamental innovations in chemical sciences will lead us to a new generation of chemical syntheses.

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