

# The Technology of Green Chemistry and Its Function in Redox Response and: Environmentally Friendly Technology for Sustainable Development: Assessment of Recent Findings

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## Abstract

Sustainability is the ability to nurture or support a process for a long time without compromising the needs of future generations. Rather, sustainable chemistry is a term that refers to the production of chemical products and processes that reduce or eliminate the use and production of hazardous substances. Green chemistry creates alternative technologies that are safer for human health and the environment to prevent further damage to human health and the environment, such as reducing the release of hazardous chemicals into the air, leading to reduced lung damage. Although sustainable and environmentally friendly technologies have evolved in other areas of science, their use in redox reactions and industry is still in its early stages. The current review aims to highlight the need for green chemistry as a sustainable chemistry and its principles and its application to produce environmentally friendly industrial products and to reduce or stop the production of harmful intermediates and products during its synthesis process.

## Keywords

Atom Economy, Green Chemistry, Green Technology, Oxidation, Reduction

## 1. Introduction

Green chemistry is also known as sustainable chemistry, pure chemistry or benign chemistry. Green as sustainable is a term associated with the production of

chemical products and processes that reduce or stop the use and production of hazardous substances [1]. Green chemistry can be described as the practice of chemical science and production in a way that is sustainable, safe and non-polluting, consuming small amounts of substances and energy while producing little or no waste. The practice of green chemistry begins with the locating that the production, processing, use and next disposal of chemical products also can purpose damage if now not achieved nicely. To reap their goals, inexperienced chemists and green chemists can remodel or completely remodel chemical merchandise and tactics to decrease waste and use or time for particular unsafe materials [2] [3].

Several researchers agree that green chemistry is a unique department of chemistry that includes the development of the latest gear, strategies and technology (1). It is beneficial for chemistry and chemical engineers in research, generally focused on developing and creating greener and extra green products, which can also have many financial advantages. It is a critical device in chemistry (2). Green chemistry has been defined because the formation of chemical products that reduce the use and manufacturing of unsafe substances [4] [5]. The motive is to design chemical compounds and chemical tactics that pose less threat to human health and the environment. Green chemistry protects the surroundings, not with the aid of cleaning, however by way of inventing new chemical methods that don't pollute [6] (Figure 1).

## 2. Study Methodology

### 2.1. Aim of the Review

The aim of this review is to introduce the topic of Green Chemistry, function of green chemistry in a redox reaction and key Green Chemistry principles that scientists and engineers can use to move towards sustainable development.

### 2.2. Objective of the Review

Understand and provide a detailed discussion of the importance of green chemistry

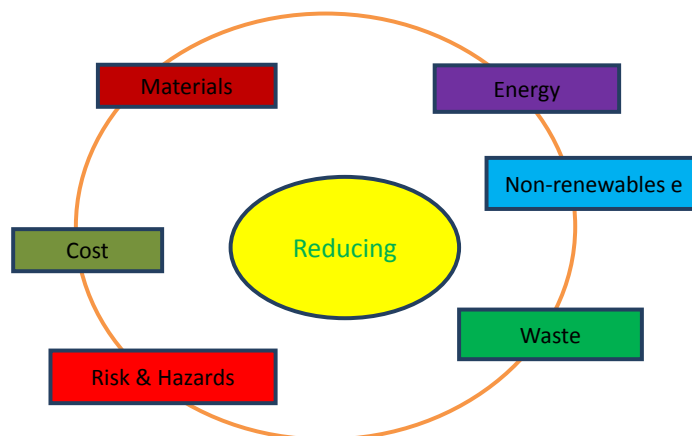


Figure 1. "Reducing": The heart of green chemistry.

and sustainable chemistry in redox reactions and environmentally friendly technologies for sustainable development.

## **2.3. Materials and Method**

### **2.3.1. Search Strategy**

To carry out this review we search out the articles from different databases. All papers that discussed about green chemistry, sustainable chemistry and application of green chemistry.

### **2.3.2. Study Selection Criteria**

Inclusion criteria: publication describing about green chemistry, its history and applications were included in the review.

## **3. Discussion of the Review**

### **3.1. Green Chemistry from Theory to Practice**

Environmental issues inside the past were considered as part of the economic system and the rapid exploitation of natural sources. It took a few years to take into account the established ways that materials have been used, the initial layout of chemical methods, the risky houses of merchandise, the power intake and different parameters worried in the manufacture of products (existence cycle, recycling). Green Chemistry turned into for many years an exceptionally summary concept with no fundamental concepts and definitions of practical applications. Now, the term green Chemistry has been described as “the invention, design and application of chemical products and procedures to reduce or to take away the use and era of unsafe materials for employees and consumers”. Some other component of the definition of green Chemistry is in the word “use and era of hazardous substances”. We need to suppose earlier if use of the product goes to be risky (workers, customers) or if it’s miles going to generate environmental pollutants via their use or after their realistic utility (as waste). Rather than focusing handiest on the ones unwanted materials that might be inadvertently produced in a system, green Chemistry also includes all materials which are part of the technique. Also, green Chemistry recognizes that there are tremendous results to using unsafe materials, starting from regulatory, handling and shipping, manufacturing of waste and legal responsibility troubles [4] [7].

The rapid development of new chemical technologies and the vast number of new chemical products in the last decades turned the attention of environmentalists to remedial actions for the negative impacts (monitoring environmental pollution, reduction of pollutants, recycling, etc). But the fact is that the most effective way to reduce the negative impacts is to design and innovation in the manufacturing processes, taking into account energy, materials, atom economy, use and generation of secondary materials which are dangerous and finally the life cycle of the products and their practical recycling into new materials [8].

### 3.2. Green Chemical Compounds

Chemical substances range in length a lot that they may be “green”. Dichlorodifluoromethane,  $\text{Cl}_2\text{CF}_2$ , the aforementioned chlorofluorocarbon, isn't actually green. This isn't because of the truth that it's miles toxic and it is one of the least poisonous synthetic compounds regarded—although due to the fact that it's far an awful lot stronger and greater resistant within the surroundings and can deliberately damage stratospheric ozone. Compounds that replace it, hydrofluorocarbons and hydrochlorofluorocarbons, are a good deal less experienced due to the fact they do now not final lengthy when released into the environment or do not contain chlorine dangerous to ozone [2].

#### Characteristics of Compounds That Meet the Criteria of Being Green

- ▶ Preparation from renewable or readily available resources by environmentally friendly processes.
- ▶ Low tendency to undergo sudden, violent, unpredictable reactions such as explosions that may cause damage, injure personnel, or cause release of chemicals and byproducts to the environment.
- ▶ Nonflammable or poorly flammable.
- ▶ Low toxicity.
- ▶ Absence of toxic or environmentally dangerous constituents, particularly heavy metals.
- ▶ Facile degradability, especially biodegradability, in the environment.
- ▶ Low tendency to undergo bioaccumulation in food chains in the environment.

### 3.3. Basic Principles of Green Chemistry

Green chemistry is commonly based totally on 12 concepts proposed by using Anastas and Warner. Today, these 12 fashions of inexperienced chemistry are taken into consideration to be the foundations contributing to sustainable development. The concepts encompass suggestions on the software of force to new chemical products, new syntheses and new techniques, as follows below [3] (Table 1 & Figure 2).

**Table 1.** The twelve principles of green chemistry.

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**Principles No. 1. Waste prevention:** it is higher to save you waste than to deal with or smooth waste after its generation. Measure of waste can be described by the following:

Environmental factor (E) =  $\frac{\text{kg waste}}{\text{kg product}}$ , E is the ratio of weight of waste with the weight of product produced during the synthesis process.

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**Principles No. 2. Atomic economics:** is the measurement of the number of atoms present in a final product after the completion of a chemical reaction or synthesis of the original material.

% atomic economy =  $\frac{\text{weight of the desired product}}{\text{Weight of all reactants}} \times 100$

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## Continued

**Principles No. 3 Less unsafe chemical synthesis:** wherein viable, synthetic techniques ought to be designed to use and bring materials with very little toxicity to human health and the environment, which includes opportunity reagents replacing phosgene in urethane synthesis.

**Principles No. 4 Layout more secures chemical substances:** chemical merchandise must be designed to affect their favored function whilst minimizing their toxicity.

**Principles No. 5. More secure solvents and excipients:** the use of excipients (e.g solvents, separators, etc.) has to be as needless and harmless as feasible at some stage in use, including the use of supercritical CO<sub>2</sub> as an innocent solvent.

**Principles No. 6. Strength efficiency concept:** the energy necessities of chemical methods ought to be recognized with reference to their environmental and economic effects and ought to be minimized.

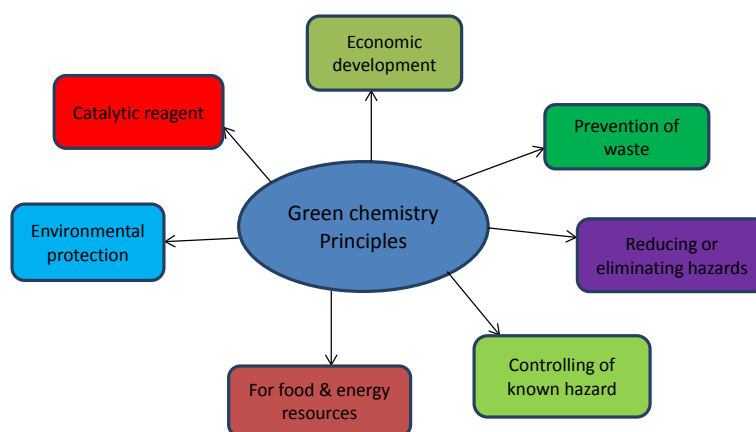
**Principles No. 7. Reduce derivatives:** unnecessary derivatization (use of blockading groups, protection/deprotection, and transient change of physical/chemical tactics) need to be minimized or averted, due to the fact such steps require additional reagents and can generate waste.

**Principles No. 8. Catalysis:** catalytic reagents (as selectively possible) are higher than stoichiometric reagents.

**Principles No. 9. Damage design:** chemical products must be designed in such a way that they decompose into a non-hazardous environment at the end of operation and do not remain in the environment.

**Principles No. 10. Naturally safer accident prevention chemicals:** substances and forms of substances used in a chemical process should be selected in such a way as to minimize the possibility of chemical accidents, including emissions, explosions and fires [1] [2] [4].

**Principles No. 11. Real-time pollution prevention analysis:** analytical methods need to be further developed to allow real-time monitoring and control of the process before hazardous substances are generated.



**Figure 2.** Graphical abstract of principles of green chemistry.

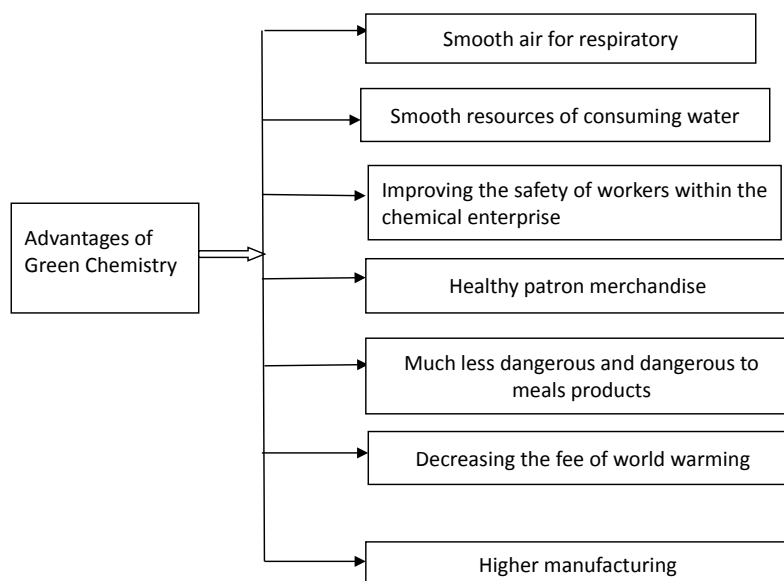
### 3.4. Raw Materials for Green Chemistry

Traditionally, chemicals are comprised of petroleum raw substances. Even though

chemical manufacturing for money is due to simplest 3% to 5% of oil consumption, oil sources account for extra than 98% of chemical raw substances. Chemists, chemical companies and consumers all see the benefits of the transition to sustainable raw substances. Chemists see the potential for brand new innovations and hazard losing nature's potential to paintings on greater selective chemistry. Chemical corporations see custom uncooked substances, which constitute a financially strong deliver of uncooked materials [7].

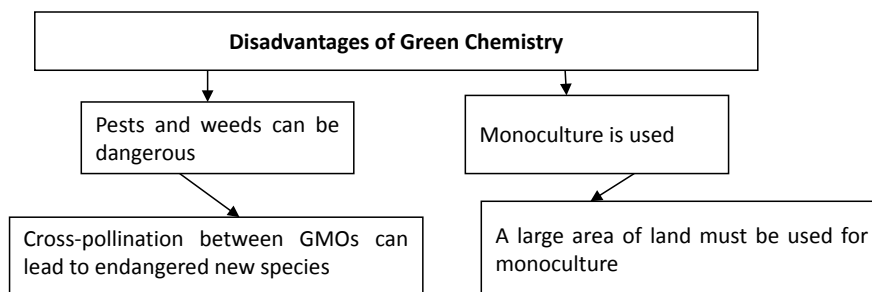
### 3.5. Advantages of Green Chemistry

Green Chemistry ensures minimum waste generation. Green chemistry is, in truth, a brand new manner of ensuring the protection of human fitness and the environment. It has lengthy been recognized that electricity savings and intake have a massive impact on the environment [8].



### 3.6. Disadvantages of Green Chemistry

The simple business of green chemistry is to design chemical products and methods that reduce or eliminate harmful substances. In particular, the conversion of an old traditional product into a new “green” product, the scheme of the new product and the method are now always less cumbersome and relatively expensive. Lack of integration with what is considered safe [9].



### 3.7. Applications of Green Chemistry

- ▶ It can be used as starting materials.
- ▶ It can be used as green reagents.
- ▶ It can be used as green chemical products in the making of alternative hydrides.
- ▶ Green chemistry can be used in the manufacture of better drugs that is used to cure deadly diseases.
- ▶ Green chemistry has a very wide application in agriculture sector. They can be used as biological control agents.
- ▶ It can be used in atomic economy and homogeneous catalysis.
- ▶ Green chemistry can be used in halide free synthesis of aromatic halides.
- ▶ Chemists have developed new methods of producing polymers from renewable source such as biomass.
- ▶ The manufacturing of computer chips requires large amount of chemicals, water and energy. The mass of the chemicals and fossil fuels which is used for making a computer chip is 630 times the weight of the chip.

## 4. Role of Green Chemistry in Oxidation Reactions

### 4.1. Oxidation Reactions

Oxidation-reduction reactions include electron recovery and loss and an alternative to the oxidation state of the molecules involved [10] [11]. Oxidation is a way in which the tremendous thing of a carbon atom binds extra electronegative factors to specific oxygen [12].

#### Uses of Green Chemistry in Oxidation Reactions

The enhancements which might be made in the effect at the surroundings because of the pharmaceutical and agricultural chemical industry have lagged in the back of and stalled the increase which is taken into consideration within the manufacturing of bulk commodity chemical compounds. Exceptional chemicals are organized via using reactions concerning many steps which make use of stoichiometric reagents and chiral auxiliaries. The atom financial machine of manufacturing these is terrible. The various biologically lively compounds which can be from the pharmaceutical and agricultural industries are noticeably oxygenated and are product of the a few type of the oxidation response. So there may be more demand for the greater selective oxidation catalysts [4].

### 4.2. Reduction Reactions

Reduction is a process in which a carbon atom gains bonds to less electronegative elements, especially hydrogen. Reducing Agents: Reducing agents add the equivalent of two hydrogen atoms to a molecule [10]. Most common reducing reagents are:

- 1) Lithium aluminum hydride ( $\text{LiAlH}_4$ ), a very strong reducing agent.
- 2) Nascent (atomic) hydrogen.

- 3) Hydrogen without or with a suitable catalyst e.g. a Lindlar catalyst.
- 4) Sodium amalgam (Na (Hg)).

### Role of Green Chemistry in Reduction Reactions

Reduction methods lessen the effect of chemical compounds on human fitness and on the surroundings by way of utilizing environment pleasant tactics and the reactions techniques.

The choice of the solvents and chemical substances which might be utilized for dissolve many of resources in the answer are of very plenty significance in green chemistry. They form a most critical source of waste in the business chemical production however careful willpower can be used to growth reaction expenses and lowering of reaction temperatures [4].

## 5. Green Chemistry and Sustainable Chemistry

Green Chemistry or Sustainable Chemistry needed to be invented and its inception in 1992 become once very timely. Scientists and mainly lookup chemists should start from the layout of chemical merchandise and techniques that minimizes or does away with the use and generation of unsafe substances. Green chemistry is sustainable chemistry [2]. There are several important respects in which green chemistry is sustainable (Figure 3):

- ▶ Economic
- ▶ Materials
- ▶ Waste

Sustainable chemistry is a systematic idea that seeks to develop an effective manner to use herbal properties to fulfill human desires inside the sale of chemicals and services. Sustainable chemistry entails the layout, manufacture and use of efficient, powerful, safe and more beneficial income of chemical substances and environmental tactics [13] (Table 2).



**Figure 3.** Green chemistry is a new “philosophy” of how to make chemical products in the chemical industry and for chemical research.



**Table 2.** Selected targets relevant for green and sustainable chemistry.

Sectors	Examples of opportunities for management and innovation
Agriculture and food	Scale up Integrated Pest Management (IPM) and agroecological approaches, including development and use of non-chemical alternatives and other beneficial agricultural practices
Health	Sound management of pharmaceuticals and disinfectants that contribute to antimicrobial resistance
Energy	improve technologies using resource-efficient, sustainable materials when de-carbonizing the energy sector
infrastructure	Reduce raw material use and waste generation via advanced materials without creating future legacies
Industry	Ensure that chemical-intensive industries rely on best available techniques and best environmental practices
Housing	Reduce indoor air pollution through safer insulation and replace building materials of concern (e.g. asbestos)
Transport	Advance clean mobility, for example based on sustainable chemistry solutions for batteries
Tourism	Adopt practices to reduce the chemical footprint of tourism services
Education	Mainstream green and sustainable chemistry into relevant curricula
Finance	Enhance use of green and sustainable chemistry metrics as criteria in investment
Mining	While foremost ensuring sound management of mine tailings, tailings are reused and returned to the economy to the greatest possible extent possible

### 5.1. Green Chemistry and Environmentally Friendly Technologies

Green chemistry may be done by using environmentally eco-friendly technologies—a few old and a few new. While green Chemistry has prolonged been identified as a critical breakthrough in the manner we work out chemistry and is crucial of sustainable improvement, its software is fragmented and represents best a small part of real chemistry [13] [14].

### 5.2. Green Technology

Green technology is where science is environmentally friendly and is created and used in a way that protects plant wealth and the environment. Green technological know-how is ecological technological know-how and easy technology. Green technological know-how is the subject of new, revolutionary ways of making changes in everyday life. This seamless technology is currently in its early stages of development [15].

#### 5.2.1. Goals of Green Technology

Green technologies are the future of this company. The main goal is to find ways to do science in a way that does not damage or deplete the Earth's plant re-

sources. In addition to not depleting natural resources, green technology is considered an alternative source of technology that reduces fossil fuels and has been shown to be less harmful to human, animal and plant health because it damages the environment. Green technological know-how is then used to reuse and recycle the products. The use of inexperienced science should reduce waste and air pollution from production and consumption [7] [15].

### 5.2.2. Environmentally Friendly Technologies

There is a group of applied sciences that have been most studied or used in research to capture the aspirations of green chemistry. The main “clean technologies” are summarized in **Figure 4**. They range from well-established and proven technologies to new and often unproven technologies. Catalysis is a well-established technology that has proven itself in the most sophisticated trade in chemical compounds [13].

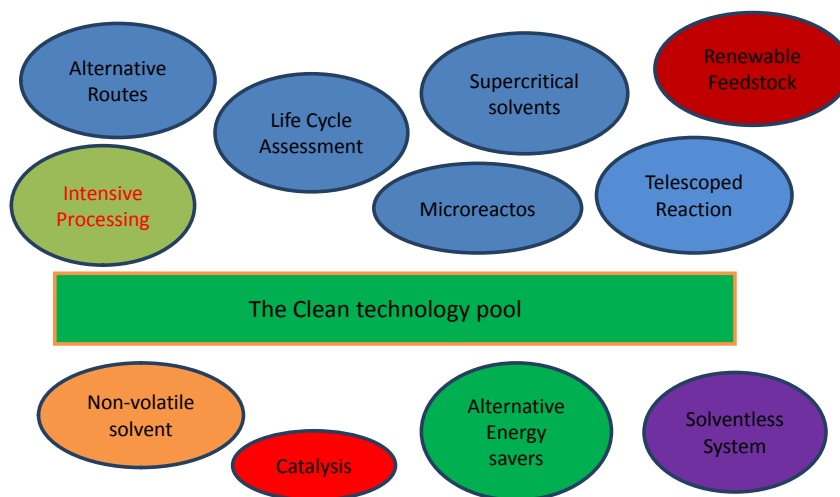
## 6. Basic Problems Faced by Green Chemistry and Chemical Technology

### 6.1. Green Design

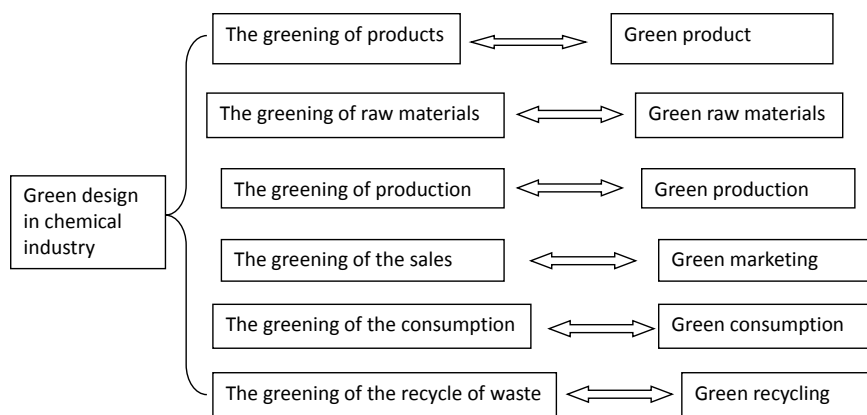
Green design makes people think about the relationship between the development of modern science and technology and the destruction of the ecological environment, and has become a hot topic in the field of industrial technology [5]. In industry, people’s awareness of environmental protection is growing and chemical product design is changing from a traditional desire to only increase economic interests to achieve environmental goals, standards and a comprehensive assessment of economic factors, social development and the ecological environment (**Figure 5**).

### 6.2. Green Production

The whole process of chemical production, *i.e.* the transformation of raw materials



**Figure 4.** The major clean technologies.



**Figure 5.** Content framework of green design in chemical industry.

into products, is a whole stage from the ideological level to the physical and technical means. The first form of a product is created by design, but no matter how good the design is, it must also be made through real production links before the products gain practical value, and the production process is also a necessary stage. Experience the green phase of chemical technology development. At this stage, the most important thing is to make sure that the raw materials are used harmless, specifically, it can be achieved in the following aspects: 1) ensuring the purity of the raw material. Raw materials must be fully utilized, because in some areas of technology, the raw materials themselves have higher requirements for purity, conversion ratio, etc., so inadequate application leads to unnecessary waste of resources. 2) Use as many sustainable raw materials as possible. The material consists mainly of paper, steel and other raw materials [7]. 3) If possible, use alternative raw materials. Some chemical manufacturing processes can cause contamination and release of toxic material. Therefore, some non-polluting alternative raw materials should be selected.

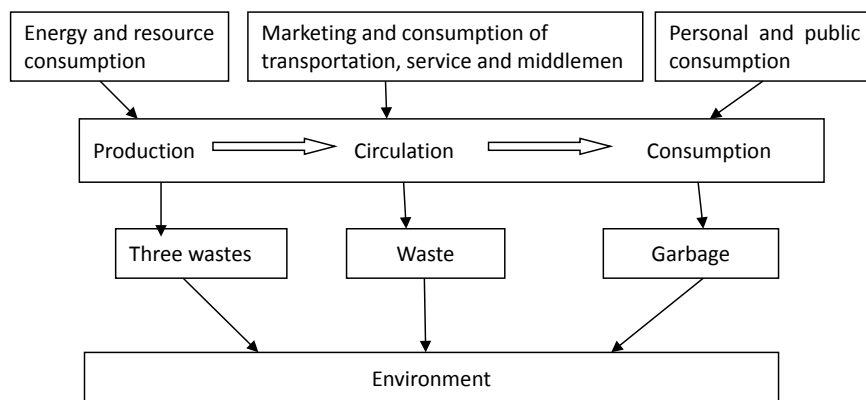
### 6.3. Green Consumption

Consumption plays an important role in human economic life and is directly linked to all aspects of social life and also has a major impact on the ecological environment. The impact of consumption on the environment is shown in **Figure 6**.

From the point of view of chemical products, the importance of green consumption can be summarized as follows: 1) the consumption process effectively reduces resource losses; 2) products used as green, chemical and chemical products; 3) the consequences of consumption are not harmful to them or to the environment and are characterized by lasting effects. Factors that affect the consumption of chemical products come from all aspects, first people need to have an idea of green consumption; the second aspect concerns differences in income levels.

### 6.4. Waste Treatment and Reuse

The sourcing of uncooked materials, the production and definitive use of chemical



**Figure 6.** Environmental impact of the consumer process.

products can cause a few pollution of the surroundings and likely waste water, waste residues and different wastes. The recycling of these waste products is the closing step inside the life cycle of a chemical product, and if this connection is lost, the waste that is launched directly into the natural surroundings will motivate not best pollutants, but additionally waste of assets. A variety of waste is useless in itself; it is able to also be just “bad resources”. Recyclable materials may be recycled with appropriate recycling and recycling technologies, and this is also a critical a part of green chemistry.

## 7. Future of Green Chemistry

Green chemistry and green technologies are still growing and are affecting scientists and engineers around the world. The growing international neighborhood now includes training and/or recruitment initiatives in more than 25 countries. New technical journals, numerous international conferences, and growing social networking sites for inexperienced chemistry have helped collaborators practice. Many of these collaborations are created to educate chemists about the incredible benefits of green chemistry. In order for chemistry to be inexperienced in the way substances are produced, the principles of sustainability must at some point be integrated into the academic system [7].

## 8. Conclusion

Green chemistry is an iterative process. Green chemistry aims to develop a new practice of chemistry with rules that will provide solutions to the problems people currently face, such as climate change. Green chemistry is a science that focuses on improving chemical methods and additives to protect the environment. It is important to understand the principles of green chemistry for future generations. Using different standards and principles of green chemistry can help identify better products, but there is always room for improvement. This does not mean green chemicals, just greener alternatives. Research and development of green chemistry is simply the key to an industrialized, technologically advanced, economically robust, less polluted and safer environment. The importance of

green chemistry and its applications in various industries is investigated.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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