Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 10, October-2019, ISSN 2230-7540

Green Chemistry

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Abstract – Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances. It applies across the life cycle of a chemical product including its design, manufacture, use and ultimate disposal. It is also known as sustainable chemistry. To meet the demands of modern civilization, we need varieties types of chemical products and chemical industries. These very often lead to the formation of hazardous substances and sometimes we are also to use the hazardous substances. To prevent or minimize the formation and use of such hazardous substances, the chemists are required to develop the novel technologies. This need has inspired the generation of the new branch of chemistry called Green chemistry which follows the principle "Prevention is better than cure"

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Green Chemistry is defined as "it designs the chemical processes and products that reduce or eliminate the use and formation of hazardous substances. The main purposes of Green Chemistry are mentioned here.

a) **Eco-friendly Chemical Technology:-** Green chemistry aims to protect the environment and this is why it is also called as "Environmentally Benign chemistry".

b) **Replacement of Organic solvent and Minimise the Waste Product :** Green Chemistry aims to devise greener reaction conditions for the synthesis of chemicals so that waste products (Toxic waste) formation can be minimized. It needs the replacements of organic solvent by water or complete elimination of the use of solvent. It also minimize the formation of by products (the hazardous substances).

c) **Use of renewable feed stocks:-** Green chemistry aims to develop the greener Synthesis of the required chemical products by using the renewable resources. (eg. Biomass rather than petrochemical feed stocks).

d) **Minimize the energy consumption:** Green chemistry develop the greener conditions for the synthesis of chemical products so that energy consumption can be minimized. For many existing chemical technologies, drastic reaction conditions (eg. High Temperature, high pressure|) which are energy requiring are applied. Greener synthesis aims to develop the mild or modest reaction conditions.

e) **Use of more eco-friendly chemical products:** Green chemistry aims to design the new chemical products to replace the existing hazardous chemical products provided the new chemicals are having the same desirable properties of the existing ones (eg. development of new pesticides which is only toxic to the target species and at the same time it biodegrades easily to harmless products).

The Twelve principles of Green chemistry as the guidelines or blue prints for practicing green chemistry to save the environment. These principles are.

1) **Heart of Green chemistry to minimize the waste product formation:** It is better to prevent the formation of waste than to treat or clean up the waste after its formation.

Illustration of the 1st principle: The first principle aims to develop the zero waste technology (ZWT). In terms of ZWT in a chemical synthesis, waste product should be zero or minimum. It also aims to use the waste product of one system as the raw material for other systems. As for example, bottom ash of Thermal power station can be used as a raw material for cement and brick industry, effluent coming out from cleaning of machinery parts may be used as coolant water in Thermal Power station, municipal waste as a source of energy.

2) **Atom economy:** During the synthesis of a chemical product the methodology should be designed in a way to maximize the incorporation of starting materials into the desired final product. Thus it demands to minimize the formation of by product.

3) **To avoid the use and formation of Toxic materials:** If possible (both technically and economically) the synthetic methodologies should avoid the use and generation of Toxic and environmentally hazardous substances.

Illustration of the 3rd principle: This principle aims to develop the methodologies that will minimize the use and formation of Toxic and hazardous substances. In other words the synthetic methodologies should use and generate the ecofriendly substances that will show little or no toxicity to human health and environment.

4) **Use of mono Toxic chemical products:** Chemical products to be used in different activities should have the efficiency to function but with reduced toxicity.

Illustration of the 4th principle: In many chemical industries not only the waste product but the starting materials are also quite hazardous to the workers and environment. For example adipicacid is widely used in polymer industries (i.e. for manufacture of Nylon cloth). Benzene is the starting materials for the synthesis of adipicated but benzene is carcinogenic and benzene being a VOC pollutes air. In green technology adipic acid is synthesized from glucose.

5) **Minimum use of auxiliary substances:** If possible (both technically and economically) in a chemical synthesis. The use of auxiliary substances like solvents, separating agents should be avoided. If these are to be used, they should be eco-friendly.

Illustration of the 5th principle: This principle aims to use green solvents (eg: Water, supercritical CO_2) in place of volatile halogenated organic solvents eg. CH_2Cl_2, $CHCl_3$, C_2Cl_4 (perchloro ethylene), Cl4, fore chemical synthesis and other purposes. If possible solvent free synthesis is preferred. For eg. Claisen rearrangement can be carried out in solid phase.

6) **Minimum energy consumption:** In the synthesis of chemical product, the energy consumption should be minimized to make the process more and more economic. Ideally the synthetic methods should be carried out at ambient temperature and pressure.

Illustration of the 6th principle: To save energy, Synthetic methodologies should need more and more moderate conditions and the ambient temperature and pressure are the best choices. It needs suitable catalysts that will accelerate the reaction rate even at lower temperature. The biocatalysts (i.e. enzymes) can work at the ambient conditions energy save can be done in many other ways: refluxing conditions require less energy, waste heat may be used for heating the reactions and other things, improving the technology of heating system, preference for photochemical reactions (specially by using the Solar radiation) instead of thermo chemical reactions. These practices advocate the concept of green chemistry.

7) **Use of renewable sources:** If it is technically and economically possible, then the renewable resources (eg: biomass) rather than the nonrenewable resources (eg: crude oil) should be used as the raw material.

Illustration of the 7th principle: It encourages the use of starting material which should be renewable. In other words use of sustainable or renewable resources eg. Agricultural or biological product ensures the sharing of resources by future generation. Moreover, this practice generally does not put much burden on the environment. The products and wastes are generally biodegradable.

8) **Minimization of Steps:** If possible, the steps like blocking group, protection/deprotection of group, temporary modification of physical and chemical processes should be avoided as far as possible during the synthesis of a chemical product. Thus there should be a minimum number of steps to synthesis a target product.

Illustration of the 8th principle: Specially in organic synthesis we need very often protection of some functional groups. Finally we again need their deprotection. It is illustrated in the synthesis of m-hydroxy benzoic acid from m-hydroxy benzaldehyde. The Green chemistry principle aims to develop the methodology where unnecessary steps should be avoided.

9) **Use of Catalytic reagents :** Selective catalytic reagents are superior to stoichiometric reagents in a chemical synthesis. This will save the energy and reduce the burden of by-products.

Illustration of the 9th principle: This principle of Green chemistry states that catalytic reagents are superior to stocichiometric reagents. The use of catalysts is preferred because of the following advantages. i) 100% atom economy because the true catalysts are fully recovered without any change in their chemical and physical properties ii) the catalysed reactions are faster i.e. energy save is possible iii) reaction yields are better iv) selective reaction products v) maximum utilization of the

starting materials and minimum production of the waste material.

10) **Life time of a chemical product:** At the end of function, the chemical products (e.g. pesticides) should degrade easily to harmless products i.e. after their function, they should not persist in the environment. DDT is an example of this area. It is an effective pesticide but its stability in the natural environment causes several environmental hazards.

Illustration of the 10th principle: It states that the waste product should degrade automatically to clean the environment. Thus the biogradable polymers and pesticides are always preferred.

11) **Monitoring the generation of hazardous substances:** Analytical methodologies should be further developed to allow for real time in process monitoring and control prior to the generation of hazardous substances in the synthesis of chemical products.

Illustration of the 11th principle: Analytical methodologies should be developed or modified, So that continuous monitoring of the manufacturing and processing units is possible. This is very much important for the chemical industries and nuclear reactions. This efficient monitoring is quite essential to avoid accident.

12) **Use of chemically safer substances:** The substances to be used in a chemical reaction should be selected in such a way that they can minimize the occurrence of chemical accidents, explosions, fires and emissions. In other words, the substances to be used should not be hazardous.

Illustration of the 12th principle: The substances used chemical industries should be in such forms so that he possibility of accidents can be minimized. For example if the chemical process works with gaseous substances, then the possibility of accidents including explosion is relatively higher compared to the systems working with the non-volatile liquid and solid substances. In fact, the risk is minimum if the process works with solid substances at every step.

The presidential Green chemistry challenge (PGCC) Awards.

To encourage the chemists to practice the principles of Green chemistry is real cases. The prestigious PGCC awards were introduced in 1995-96 by U.S.-F.P.A (Environmental Protection Agency). Generally 5 awards are given each year for the outstanding contribution in green chemistry.

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