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CATALYTICAL REDUCTION IN GREEN CHEMISTRY: A REVIEW.

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ABSTRACT

Green chemistry, also known as sustainable chemistry, for the development of chemical products and processes that minimize or eliminate the usage and production of harmful compounds. Catalytical reduction in Green Chemistry reduces the environmental impact of chemical processes and technologies, The goal of this article is to learn more about the Catalytical reduction in green chemical synthesis for a more sustainable future. In the ecolfriwndlybsynthesis of novel and existing compounds, catalytic reduction plays a critical role and require less energy to produce and produce fewer by-products, co-products, and other waste items, indicating increasedbefficiency. Catalysts used in green catalytical reduction are created in such a way that they do not harmful to the environment.

KEYWORDS:

Green chemistry[14]

The “Green chemistry” is the design of chemical products and a processes that reduce of use of generation of hazardous substances.

History: According to Pollution Prevention Act 1990 the idea of green chemistry was proposed by Paul Anastas and John C. Warner in 1998 Synonyms of Green Chemistry is Sustainable Chemistry or low-environmental-impact Chemistry.

*Main Fields of action of Green chemistry.

1) Use different to current used raw material that means raw material should be less toxic, renewable and does not have any harmful impact of manufacturing process on Environment.

2) To replace the hazardous reagent develop safe reagent.

3) Replace hazardous solvent with easy handling and less toxic solvents.

4) Design alternative reaction conditions which consume less energy fast reaction rate and easy to isolate and purify final products.

The 12 principles of Green Chemistry[14]

Paul Anastas is father of Green chemistry. He developed the 12 principles of Green chemistry which are described below.

1) Prevention

It is better to prevent the formation of waste rather than cleaning after its formation.

2) Atom Economy

To minimize the formation of byproduct develop synthetic methods which incorporate with maximum final product.

3) Using methodologies that generate products with reduced toxicity

Develop synthetic methods to generate substances having less toxicity or no toxicity to human health and environment.

4) Generate effective but non-toxic products

Develop such chemical products which Maintains efficacy during reducing their toxicity.

5) Reduce the use of auxiliary substances

If possible, substances which are not essential such as solvents, reagents used to separation should be avoided

6) Reduce energy consumption

Energy requirements should be categorized for their environmental and economic impact. To minimize their impact on environment synthesize methods which are carried at room temperature and osmotic pressure.

7) Use of renewable raw materials

Use renewable raw material rather than exhaustible whenever technically and economically achievable.

8) Avoid unnecessary Derivatization

If possible the Derivatization such as blocking groups, protection / deprotection, temporary modification of physical / chemical processes should be avoided.

9) Enhancing Catalysis

The use of catalysts should be as selective and reusable instead of stoichiometric reagents.

10) Generate biodegradable products

Develop chemicals such having ability to generate biodegradable products which does not cause any harmful impact on environment.

11) Develop analytical methodologies for real-time monitoring

Develop analytical methodologies which allow to monitoring and real-time control of the process, prior to the formation of hazardous substances.

12) Minimize the potential for chemical accidents

Substances used are selected based on the chemical processes so that the risk of chemical accidents is minimized, including releases, explosions, and fires.

Goals of Green Chemistry[14]

The principles and guidelines of Green Chemistry are intended to fulfill the following goals for any chemical process, whether industrial or laboratory scale.

1) Make better use of available resources for the development of a chemical processes.

2) Reduce generation of waste in any preparation or handling of chemicals.

3) Materials should be prepared by change conventional processes that reduce unwanted effects on the environment.

4) Replace toxic reagents and products with others green reagent that have the same properties and applications but have less impact on the environment.

5) Reduce the energy which is required to produce substances of interest, either by the use of much faster processes or by the use of renewable energies involving lower energy cost with equal efficiency.

6) Reduce costs by eliminating any manipulation that is not strictly necessary and decreasing time invested in the preparation of a substance.

7) Encourage all necessary actions to use chemicals compatible with sustainable development.

INTRODUCTION

Catalysis

Catalysis is the process of increasing the rate of a chemical reaction by adding a substance called as catalyst. Catalyst are not consumed in reaction and remain unchanged after it Reduction.

Reduction can be defined in Three ways:

1) The loss of oxygen
2) The gain of Hydrogen
3) Gain of Electron

Catalytic Reduction[1]

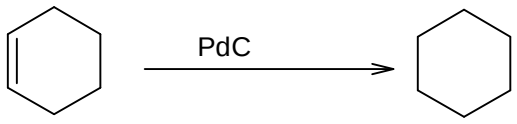
Catalytic reduction reaction is also called as catalytic hydrogenation. catalytic reduction means transfer of one compound into another compound with addition of hydrogen or loss of oxygen by using catalyst.

For example 1) Reduction of alkene into alkane by using palladium catalyst.

2) Reduction of cyclohexene into cyclohexane by using palladium catalyst

1) $H_2C{=}CH_2 \xrightarrow{PdC} H_3C{-}CH_3$

Ethene Ethane

2) 

Cyclohexene Cyclohexane

Role of Catalyst in green chemistry[1,2,3]

Green chemistry is an area of chemistry that focuses on the discovery and use of eco-friendly chemicals and processes. Catalysis is a key elements of green chemistry. Green chemistry, is known as environmentally benign chemistry or sustainable chemistry, minimises toxicity. Its objective is to design and execute pollution avoidance solutions other than waste management that is reduce waste, save energy, and reduce natural resource depletion. Green chemistry is considered eco-friendly because it is thought to reduce carbon emissions and pollution. Catalysis has aided in the reduction of pollution in our environment. Catalysts have been used to improve air quality by removing and controlling NOx emissions, reducing the

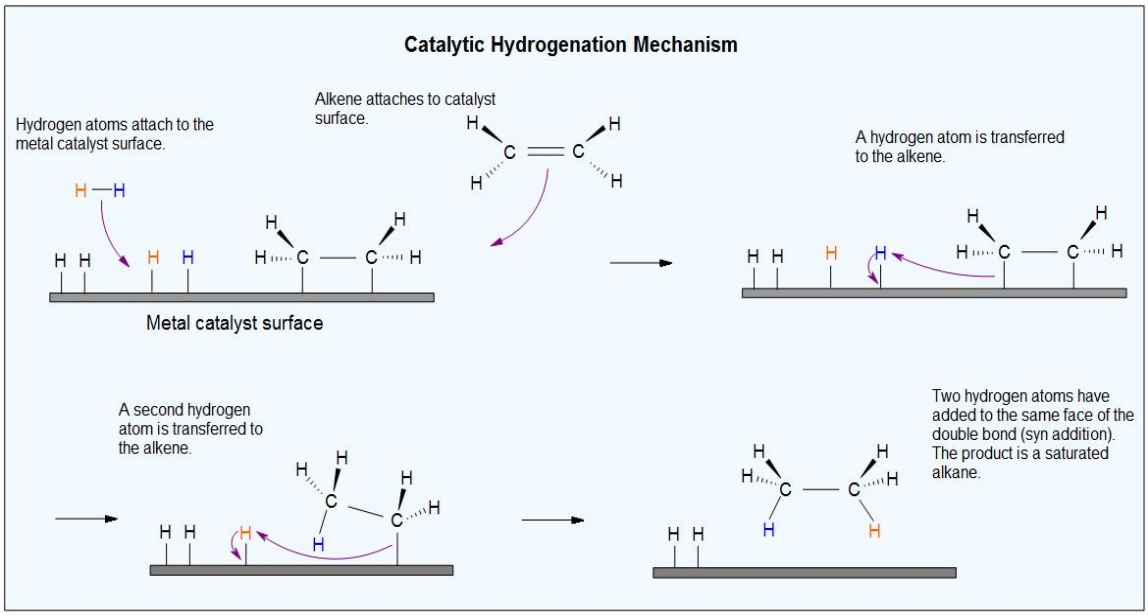
use of Volatile Organic Compounds (VOCsi), developing alternative catalytic technology to replace the use of chlorine or chlorine-based intermediate in chemical synthesis and waste minimization, Catalysis allows for more efficient and selective reactions, resulting in the elimination of high amount of by-products and other waste chemicals.

According to Paul Rylander (1979) Catalytic hydrogenation is one of the most useful and versatile tools available to the organic chemistry. The scope of the reaction is very broad; most functional groups can be made to undergo reduction, frequently in high yield, to any of several products. Multifunctional molecules can often be reduced selectively at any of several functions. A high degree of stereochemical control is possible with considerable predictability, and products free of contaminating reagents are obtained easily. Scale up of the laboratory experiments to industrial processes a presents little difficulty.

*Elements of group VIII on periodic table are used as metal catalyst such as Ni, Pd, Pt, etc.[1] In the form of Ra-Ni, Pd-C, and PtO2 Catalytical reduction is mature technology is mainly used in industry for organic chemicals synthesis and new applications continue to appear sometime in unexpected place For example, a time required reaction in organic synthesis is a Willamson synthesis of ethers[4,5] first explain in 1852 low-salt, alternative catalyst to the Williamson synthesis, involving reductive alkylation of an aldehyde. This avoids the formation of coproduct such as NaCl, which may lead a problem, depending on the production volume and then the aldehyde may, in some cases, be more readily available than the corresponding alkyl chloride.

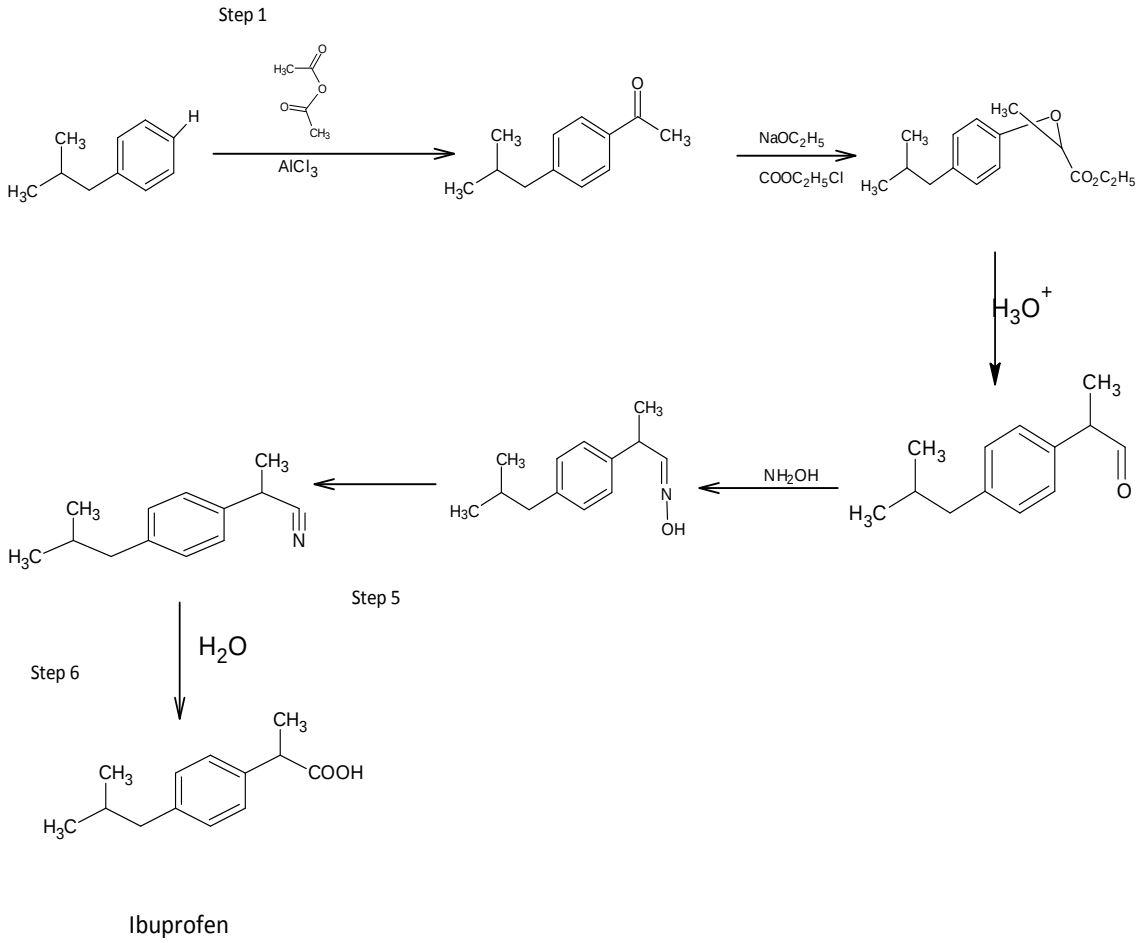
Mechanism of Catalytic Reduction Reaction

In the presence of a metal catalyst, the H-H bond in H2 cleaves, and each hydrogen attaches to the metal catalyst surface, form a metal-hydrogen bonds. The metal catalyst also adsorbs the alkene onto its surface. A hydrogen atom is transferred to the alkene, form a new C-H bond. A second hydrogen atom is transferred and form another C- H bond. At this point, two hydrogens are added to the carbons across the double bond. Due to the physical arrangement of the alkene and the hydrogens on a flat metal catalyst surface, the two hydrogens must add to the same face of the double bond and gives syn addition.



Conventional Synthesis of Ibuprofen[4,5,6,7]

The Boots Pure Drug Company developed ibuprofen in 1961, it prepared Ibuprofen in six steps, by using the toxic aluminum chloride in early stage. In 1992, the Hoechst Company protocol improved this procedure by using recyclable hydrogen fluoride as an alternative catalyst to aluminum chloride. Then after, the synthesis was accomplished using a simple carbon monoxide (CO) insertion method without any additional hydrolysis or dehydration in a three-step procedure and ibuprofen is formed. In conventional synthesis of Ibuprofen the aluminium chloride(AlCl3) catalyst is used this is toxic in nature and reaction needs 5-6 steps to form final product.



Problem

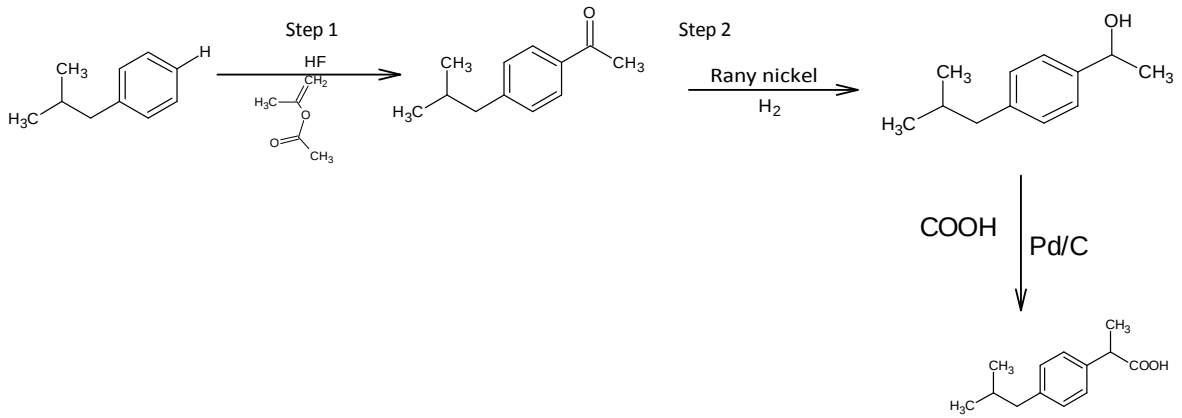
In conventional industrial synthesis of ibuprofen was developed and patented by the Boots Company of England in the 1960s (U.S. Patent 3,385,886). This synthesis involves six-step process and results in formation of large quantities of unwanted waste chemical byproducts. Very Much of the waste that is generated is a result of many of the atoms of the reactants not being incorporated into the desired product (ibuprofen) but into unwanted byproducts (poor atom economy/atom utilization).

Solution

The BHC Company developed and implemented a new greener industrial synthesis of ibuprofen that involves only three steps (U.S. Patents 4,981,995 and 5,068,448, both issued in 1991). In this process, most of the atoms of the reactants are incorporated into the desired product (ibuprofen). The result of this process is only small amounts of unwanted byproducts (very good atom economy/atom utilization).

Green synthesis of Ibuprofen[4,5,6,7]

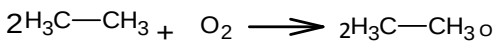
The BHC company synthesis ibuprofen by using green chemistry. BHC company replace the catalyst using in conventional Synthesis of Ibuprofen or Brown synthesis of Ibuprofen that is aluminium trichloride with hydrogen fluoride because aluminium trichloride is a toxic in nature and aluminium trichloride hydrates are generated those are harmful to land. BHC company reduces the steps involved in synthesis of Ibuprofen from 6 steps to 3 steps and also used Rany Nikel and palladium catalyst in step 2 and 3 those are reused catalyst.



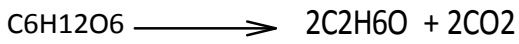
Ibuprofen

Syhtesis of Raw material used For making Plastic and Syhthetic Fabrics

the most commonly used raw material for making plastics, synthetic fabrics, and other manufactured materials is petroleum hydrocarbon. There are many hydrocarbon compounds all containing chemically carbon and hydrogen bound together. In some compound such as ethane,(C2H6) The hydrogen and carbon in a hydrocarbon form, in the most chemically reduced form, but required raw materials are partially oxidized hydrocarbons in which O atoms are bonded to the hydrocarbon (complete oxidation of a hydrocarbon yields CO2 and H2O). Ethanol, C2H6OH, is used in chemical synthesis and as an oxygenated additive to make gasoline burn more smoothly with fewer release of air pollutants is a partially oxidized hydrocarbon. Large amount of materials and high energy are expended in converting petroleum hydrocarbons to partially oxidized compounds used as raw materials. For example, ethanol which is made from ethane taken from petroleum and natural gas by a series of chemical reactions.



This conversion requires relatively severe conditions and a net loss of energy. A greener alternative is used that is glucose sugar produced by photosynthesis to grow yeasts that produce an ethanol product.



This process can be occurs under room temperature conditions. Making of ethanol is a fermentation process which yields carbon dioxide in a concentrated form that can be used for carbonated beverages, supercritical carbon dioxide solvent, or pumped underground for tertiary petroleum recovery. The protein-rich yeast biomass obtained in fermentation makes a good animal feed additive.

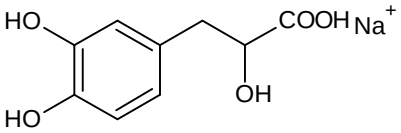
Reduction of Harmful Carbon Dioxide (CO2)

The reduction of carbon dioxide is beneficial for a cleaning of environment and sustainable development, In traditional CO2 reduction uses chemical methods at high temperatures with a high extra energy, electrochemical CO2 reduction in green chemistry reactions can be performed at room temperature using liquid solution. And the an electricity required for the electrochemical CO2 reduction can be obtained from a renewable energy sources such as solar power. A reduction reaction means gains of one or more electrons. In the electrochemical reduction of carbon dioxide, metal nanocatalysts is used it show the high potential to selectively reduce CO2 to a particular carbon product. nickel phthalocyanine is a molecularly engineered electrocatalyst used as green catalyst for reduction of carbon dioxide because it showed superior efficiency at high current densities for converting CO2 to carbon monoxide in the gas-diffusion electrode device, with stable an operation for 40 hours. Nickel phthalocyanine catalyst for green processes of electrochemical CO2 reduction reactions used.

The Green Synthesis of B-(3,4-Dihydroxyphenyl)lactic Acid[4,5,6,7]

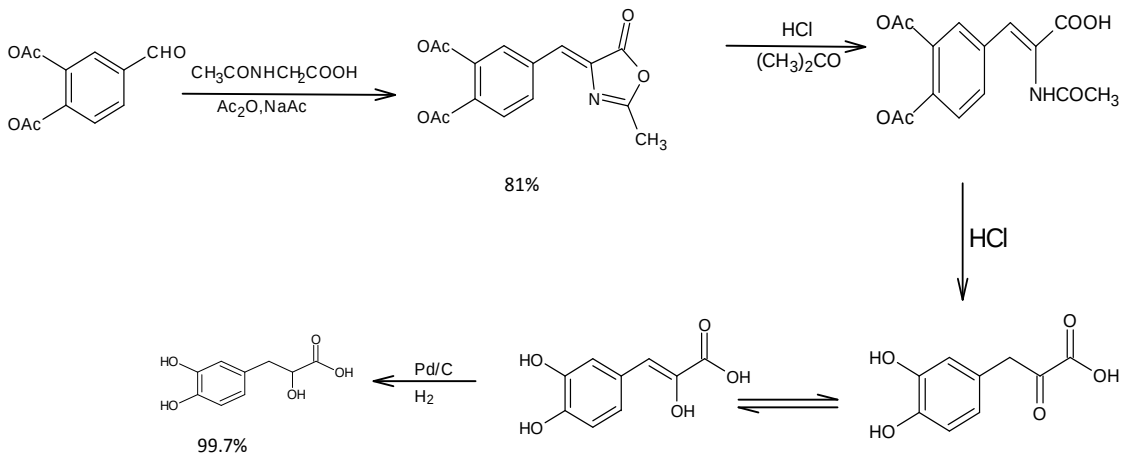
B-(3,4-Dihydroxyphenyl)lactic Acid is a water soluble compound and conventionally it obtained from chinese medicine Salvia miltiorrhiza (Danshen), it reffered as active ingredient for the treatment of myocardial ischemia. Owing to its instability, Previous studies demonstrated its different effects on other conditions, such as dilation of blood vessels, increase in coronary blood flow and antithrombotic. Hence more effort are need to synthesis of β-(3,4-dihydroxyphenyl)-lactic acid (4,5) and its derivatives. Xue et al.[9] complete his study on the chemical synthesis of β-(3,4-dihydroxyphenyl)-lactic acid by using Clemmensen reduction reaction of β-(3,4-dihydroxyphenyl)pyruvic acid. Then Tong et al.[13] used NaBH4

catalyst for the reduction reaction without pollution and results is total yield obtained after a 6-step process is 48.4 %. Recently, Zhang et al. discovered a microwave-assisted heating method as a synthetic process to improve the total yield.



Sodium B-(3,4-Dihydroxyphenyl)lactate

The use of Zn/Hg catalysts in the first step of synthesis causes major problems for the treatment of wastewater containing mercuric salt. Then amount of solvent required during the process is in high amount and the total yield is relatively low. The total yield is increase with microwave heating, the development of this new process in first step of synthesis. The toxic Zn/Hg catalysts is replaced with Pd/C catalysts which is commonly used for hydrogenation[14] and amount of required solvent is reduced and increase the total yield, of final product which is β-(3,4-dihydroxyphenyl)-lactic acid.



Reaction

In Green method catalyst is replace that is Zn/Hg is replace by Pd/C and increase yield upto 99.7%.

Advantages of Green Catalyst

1) Green Catalyst produce less toxic or hazardous byproduct as compared to conventional catalyst.
2) With use of green catalyst Reaction rate is increased and reduce the required time to complete reaction.

3) Green Catalyst are eco-friendly and shows less impact on environment.
4) Green Catalyst produce high yield of product and catalyst are reusable.
5) Green Catalyst are less toxic and easily available as well as renewable.

CONCLUSION

Nowadays, our ecosystem is hampered due to unwanted use of chemicals to reduce this impact on environment green chemistry was introduced. By using eco-friendly substance such as Catalyst. Catalyst are used to increase rate of reaction. Green Catalyst are renewable and reusable as well as they do not produce any toxic or hazardous effect to environment. By using Green Catalyst in reduction reaction such as in synthesis of Ibuprofen, Reduction of Harmful Carbon Dioxide, synthesis of B-(3,4-Dihydroxyphenyl)lactic Acid. Green catalytical reduction is done by replacing conventional catalyst with green catalyst. Green Catalyst helps to reduce pollution and reduce time required to complete reaction and gives high percentage yield. Catalysts are used to reduce energy and resources as well as to improve resources efficiency and lower raw material and utility cost.

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REFERENCES

1. Rylander P.N, Hydrogenation Methods, Academic Press, San Diego, 1990 and preceding volumes.
2. Allison L.B. "Green carrers, case study: Green chemist and pain killer" The magazine for Acs, Green chemistry Generating Reaction, 2015; 14(4): 15.
3. Fache V Bethmont, L. Jacquot M Lemaire, Red Trav chim pays-Bas, 1996; 115: 231-238.
4. Trost, Barry M. The Atom Economy-A Search for Synthetic Efficiency. Science, 1991; 254: 1471-1477.
5. Sheldon, Roger A. Organic Synthesis-Past, Present and Future. Chem. Ind. (London), 1992; 903-906.

6. Sheldon, Roger A. Consider the Environmental Quotient. CHEMTECH, 1994; 24(3): 38-47.
7. Trost, Barry M.; Atom Economy-A Challenge for Organic Synthesis: Homogeneous Catalysis Leads the Way. Angew. Chem., Int. Ed. Engl, 1995; 34: 259-281.
8. Rouhi, A. Maureen. Atom Economical Reactions Help Chemists Eliminate Waste. Chem. Eng. News, 1995; 9: 32-35.
9. Sheldon, Roger A. Catalysis and Pollution Prevention. Chem. Ind, 1997; (Jan 6): 12-15.
10. W.D. Jiang Y.H. Chen, Y.P. Wang, Z.T. Dong. LX. Yuan, Y.Q. Lu, PJ.Wei, Y. Liu and S.Z. Wang, J. Shanghai Med. Unix, 1983; 1: 2013.
11. LP Fei, J. Changchi Med. Coll (CN), 1997; 11: 18. 4. QZ. Zhang, T. He. X.Y. Xiong, G. Chen and B.Y. Su, Chem. Reagents, 2011; 259.
12. QZ. Zhang, Y. Dong, Y.F. Nan. X.D. Cai and X.H. Zhang. Org. Chem, 2016; 29: 1466.
13. YF. Tong, X. Guo and YH. Cheng, Chin. J. Med. Chem, 2007; 17: 92.
14. G. Toth, A. Kovacs, T. Tamai and A. Tungler, Tetrahedron-Asymm, 1993.
15. Manahan SE. Green chemistry and the commandments of sustainability. 2nd edition, Columbia, 2006; 9-11.