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Green chemistry applications: A brief review on variety of uses

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Abstract
Applications of green chemistry in this technical growing world allows mild and highly selective and mild transformation and synthesis in a facile and environmentally friendly manner. Green chemistry provides an attractive environment for chemist and researchers for chemical reactions. The approach of green chemistry is totally non-polluting having several advantages such as shorter reaction time, mild reaction conditions and easy workup.

Keywords: Green chemistry, environment benign, economic, sustainable

1. Introduction

Green chemistry is the branch of chemistry that involves tools techniques and technologies. It is helpful to researchers in new innovation, development and production, for improve more ecofriendly and efficient products which may also have economic benefits. It is going to now become an essential tool in green chemistry [1]. It is a new idea for organic synthesis and the design of drug molecules, provides important ecofriendly and economical advantages over conventional synthetic processes [2]. The term green chemistry [3] was first used in 1991 by Paul T. Anastas in a special program launched by US Environmental Protection Agency (EPA) to apply sustainable development in chemistry and chemical technology in industrial, research and government level. In 1996 the working party of green chemistry was formed, acting within the framework of International Union of Pure and Applied Chemistry (IUPAC). One year later the Green Chemistry Institute (GCI) was formed with combined unity of 20 countries to start contact between governmental agencies and industries with universities and research institutes to design new chemicals. The concept of green chemistry provides a new approach [4-9] to the synthesis, processing and application of chemical substances in such a way to reduce hazard to health and environment.

2. Basic Principles of Green Chemistry

Anastas and James C. Warner (1998) proposed a set of 12 principles which represents the green chemistry as a sustainable approach.

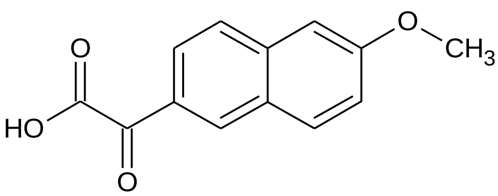
1. **Prevention:** It is to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy:** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less hazardous chemical synthesis:** Synthetic methods should be designed to use and generate substances that posses very low or no toxicity to human health 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 substance should be made unnecessary wherever possible.
6. **Design for Energy Efficiency:** Energy requirements of chemical processes should be recognized for their environmental and at low temperature and pressure.
7. **Use of Renewable feedstocks:** A raw material or feedstock should be renewable rather than depleting whenever technically and practicable.
8. **Reduce Derivatisation:** Unnecessary derivatization should be avoided whenever possible.
9. **Catalysis:** Catalytic reagents are superior to stoichiometric reagents.
10. **Design for Degradation:** Chemical products should be designed so that at the end of their function they do not persist in the environment and breakdown into innocuous degradation products.

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. **Inherentaly safer chemistry for accident prevention:** Substances and the form of substance used in a chemical process should chosen so as to minimize the potential for chemical accidents, including releases, explosion and fires.

3. Applications of Green Chemistry in various fields

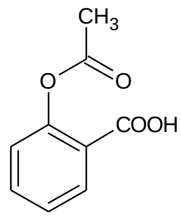
3.1 Green Chemistry in Pharmaceuticals: Pharmaceutical companies showing a great improvement in production of drug molecules and saves the environment by utilzing green chemistry [10]. These methods are more effective and less toxic and could benefit millions of patients [11], some of them described below.

Anastas *et al* [12] have been synthesized Naproxen with chiral metal catalyst containing BINAP (2,2'-bis(diphenylphosphino)-1,1'-binaphthyle) ligand with good yield and mild reaction procedure.



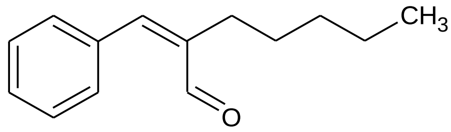
Neproxen

Ingrid *et al* [13] have been designed the synthesis of Aspirin by solvent free approach. This study shows new alternative and greener methodology for conventional synthetic procedure.



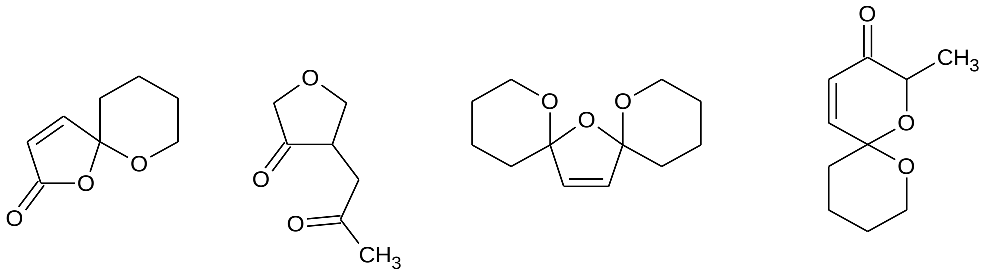
Aspirin

Sudheesh *et al* [14] proposed the synthesis of jasminaldehyde by condenssation reaction between 1-heptanal and benzaldehyde in 1:5 ratio in the presence of chitosan as a catalyst in nitrogen atmosphere to prevent the formation of acids from aldehyde. This method has less reaction time and no toxic waste production.



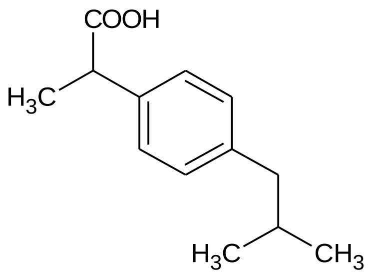
Jasminaldehyde

A greener way of utilizing air, sunlight, water and spirulina to synthesize pharmaceutically useful polyoxygenated derivatives of furan which are readily available and commonly found in natural products is now possible with green chemistry [15].



Furan polyoxygenated derivatives

Kjonaas *et al* [16] synthesized ibuprofen in a new way and reduce the production of unwanted bi-products. This new way of ibuprofen (non steroidal and anti-inflammatory drug) synthesis is based on the principles of "Green Chemistry". This improved synthesis won the president green chemistry challenge greener synthetic pathways award in 1997.



Ibuprofen

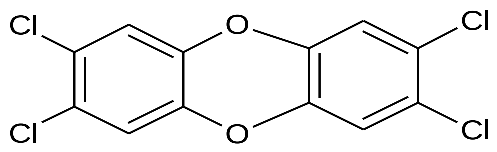
3.2 Green Chemistry in Daily Life: Green chemistry also plays an important role in day to day life and the brief examples given below shows the importance of green chemistry in our daily life.

Perchloroethane (PERC) is commonly being used as a solvent for dry cleaning. Joseph *et al* developed a new technology known as Micell technology [17]. In this technology they used liquid CO_2 as a solvent and a surfactant for dry cleaning. This new idea of dry cleaning removes the use of halogenated solvents.

Used and exhausted vegetable oil has been used currently by researchers as a fuel for vehicles by making very less modifications in the cars of present use and a shocking result was found that by using vegetable oil CO_2 emmision has been reduced to almost 67% without affecting the efficiency of the vehicle [18].

In paper manufacturing sodium hydroxide (NaOH) and sodium sulphide (Na_2S) are used aswood desolving solvents.

By this process about 80-90% of lignin is decomposed. After that remaining lignin is removed by chlorine gas (Cl_2) for good quality paper but this Cl_2 also reacts with aromatic ring of lignin and forms dioxins which are very carcinogenic in nature. These halogenated compounds involves in food chain and harmful for living being. Hence, Green chemistry provides a number of safe bleaching agents like hydrgen peroxide (H_2O_2), ozone (O_3) and oxygen (O_2) which are environmentally benign. These bleaching agents find use in laundry and result in lesser use of water [19].



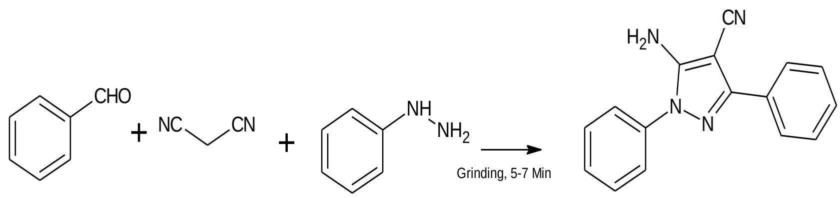
2,3,7,8- Tetrachlorodibenzo-p-dioxin

Tamarind seed kernel powder, produced as an agriculture waste, is a good agent to clean the industrial and municipal waste water. Generally the aluminium salts are used to treat the waste water, but the major drawback of this method is that these salts increases the poisionious ions in water and causes Alzeimer's like disease. On the other hand Tamarind seed kernel powder are non toxic and cost effective.

One of the best examples of green technology would be solar cell. The solar cell converts the sunlight into electrical energy. Generating electricity from this process means less consumption of fossil fuels, reduce the pollution and green house gas emmision.

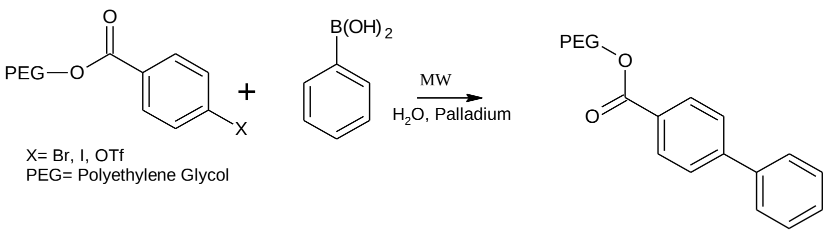
3.3 Green Chemistry in Research Laboratories: Researchers and chemists have been used a large number of biocatalysts and green catalysts in the synthesis of chemical compounds by using green chemistry principles. These green synthetic approach gives a clean and safe pathways for reaction mechanisms.

Bhale *et al* [20] synthesized polysubstituted amino pyrazoles by simple grinding, catalyst free, one pot, three component system. This method showed that the most of the pyrazoles synthetic strategies involves multistep sequences, expensive catalyst, anhydrous conditions, inert atmosphere, long reaction time (Scheme 1).



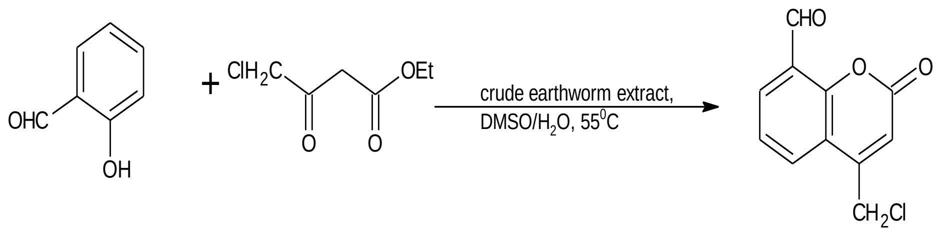
Scheme 1

Lew *et al* [21] synthesised highly fluorinated compounds on solid phase PEG. This is a safe reaction with microwave assisted and PEG is a soluble polymeric support for small molecule synthesis and provides easy purification after reaction (Scheme –2).



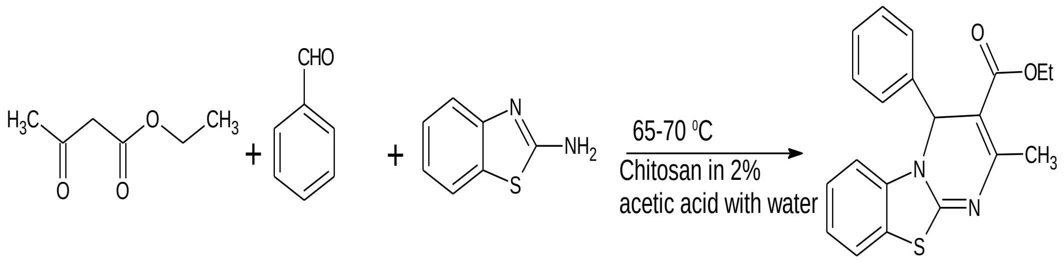
Scheme – 2

Guan *et al* [22] synthesized coumarin derivatives by the reaction of various salicaldehyde derivatives with different β-ketoesters in the presence of crude earthworm extract. They reported that various coumarin derivatives were obtained in yields of 32-87% in DMSO/Water. The main advantages of using the crude earthworm extract as a catalyst are ecofriendly, environmentally benign, safe cheap, easily accessible and stable (Scheme -3).



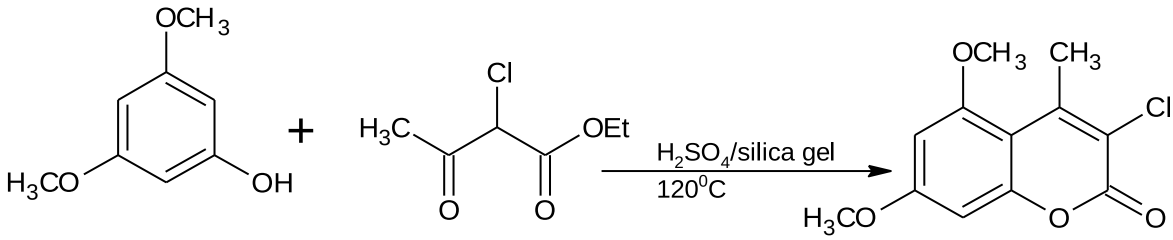
Scheme – 3

Sahu *et al* [23] reported the synthesis of 4H-pyrimido [2,1-b] benzothiazole derivatives by using an efficient, reusable and biodegradable biocatalyst. This is a multicomponent reaction of substituted aromatic aldehydes dicarbonyl and 2-aminobenzothiazole/3-amino-1,2,4-triazole/urea/thiourea in 2% acetic acid in aqueous media with chitosan as green catalyst at 60-65 ºC temp (Scheme - 4).



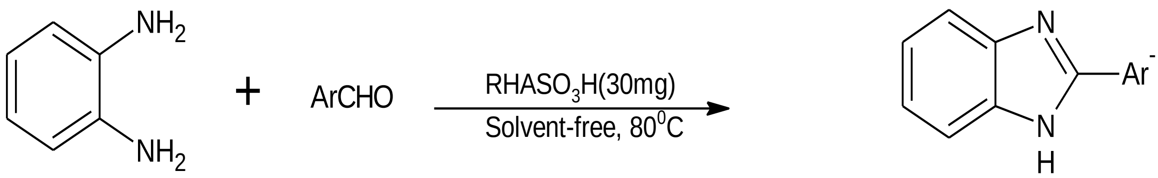
Scheme – 4

Reddy *et al* [24] reported one-pot synthesis of coumarin catayzed by silica gel supported sulphuric acid under solvent free conditions. This method provides a green pathway for synthesis of coumarin by avoiding toxic catalyst and solvents (Scheme -5).



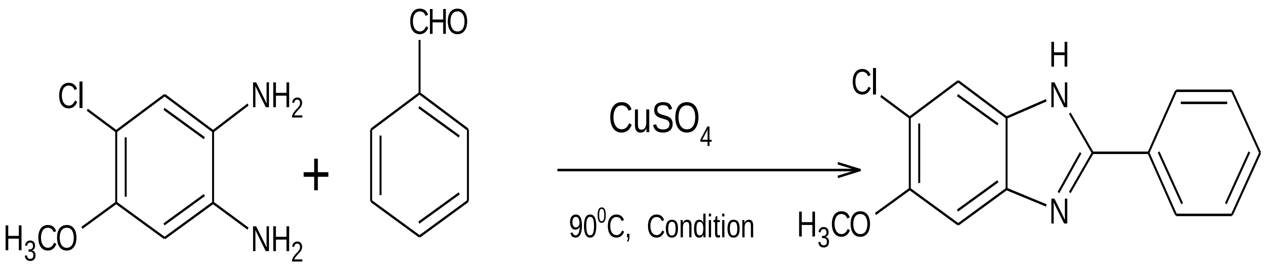
Scheme – 5

Sani *et al* [25] reported a green method for the preparation of benzimidazoles and quinoxalines by condensation of ortho-phenylenediamine with substituted aldehydes in presence of sulphonated rice husk (RHA-SO_3H). This method provides short reaction time and catalyst reusability (Scheme - 6).



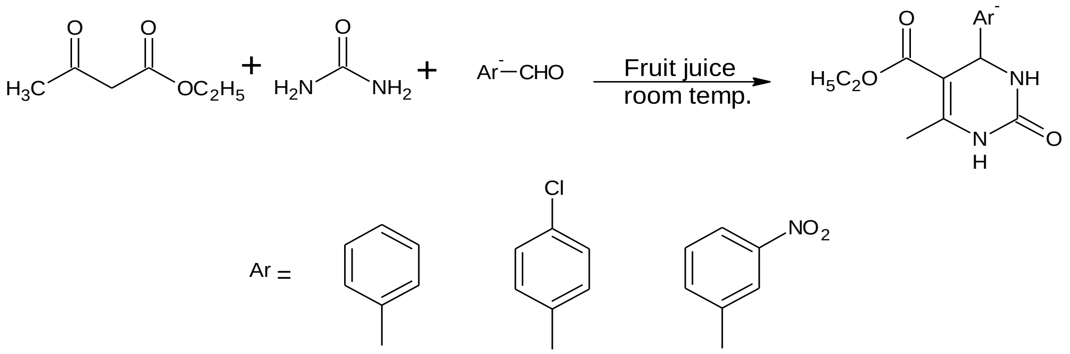
Scheme – 6

Karimi *et al* [26] performs an easy, green, efficient and simple approach for synthesis of benzimidazole derivatives using Copper sulphate in aqueous media. This is a one-pot synthesis of biologically active benzimidazole derivatives under solvent free conditions (Scheme - 7).



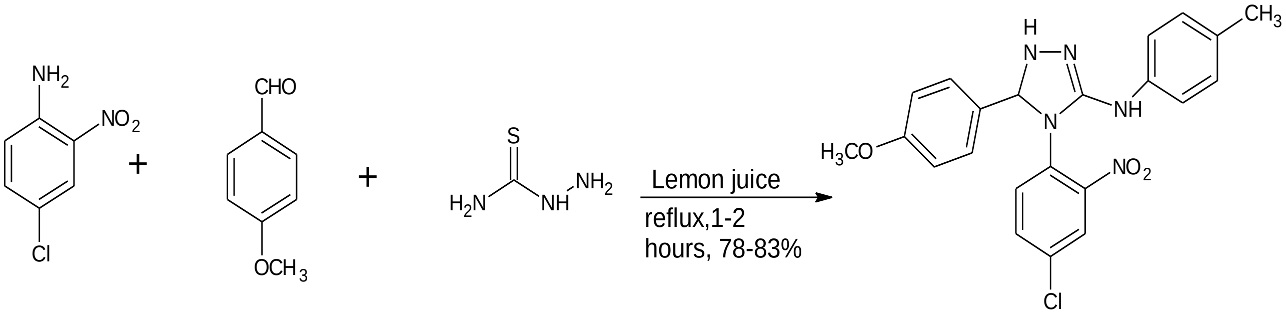
Scheme – 7

Dihydropyrimidinone have been synthesized by Patil *et al* [27]. These derivatives synthesized by using extract of lemon juice by reacting aldehydes, 1,3-dicarbonyl compounds with urea at room temperature under solvent free conditions. This is a one-pot multi-component system reaction where lemon juice acts as a green catalyst (Scheme -8).



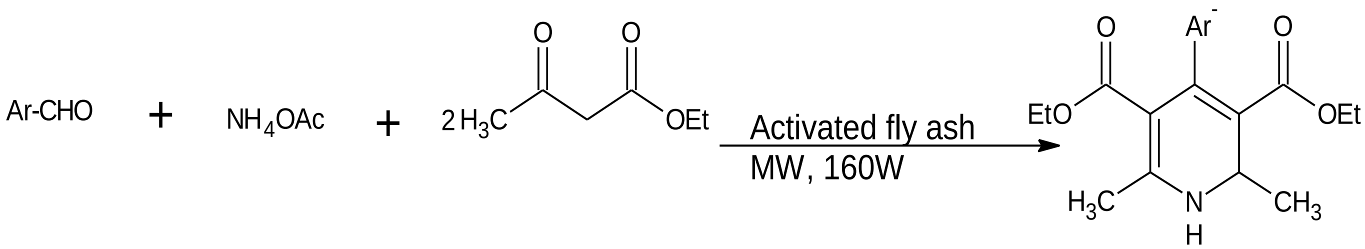
Scheme – 8

Sachdeva *et al* [28] reported the 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. They found that lemon juice plays a role of biocatalyst which provides a non hazardous and mild conditions which are basic principle of green chemistry (Scheme-9).



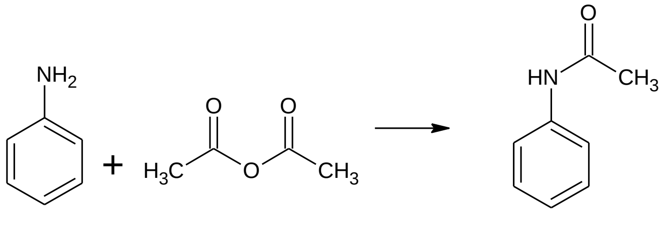
Scheme – 9

Gopalkrishnan *et al* [29] reported a simplified green chemistry approaches to organic synthesis in solid media. Activated fly ash, an industrial waste which is an efficient and mild catalyst for some selected organic reactions in solvent-free conditions under microwave irradiation (Scheme –10).



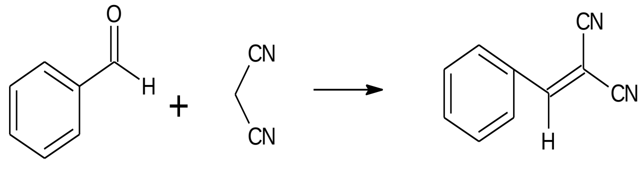
Scheme -10

Mote *et al* [30] reported a rapid, benign and one pot convenient procedure for amines using acetic anhydride under room temperature by using pods of *Acacia concinna* fruit as a green catalyst (Scheme-11).



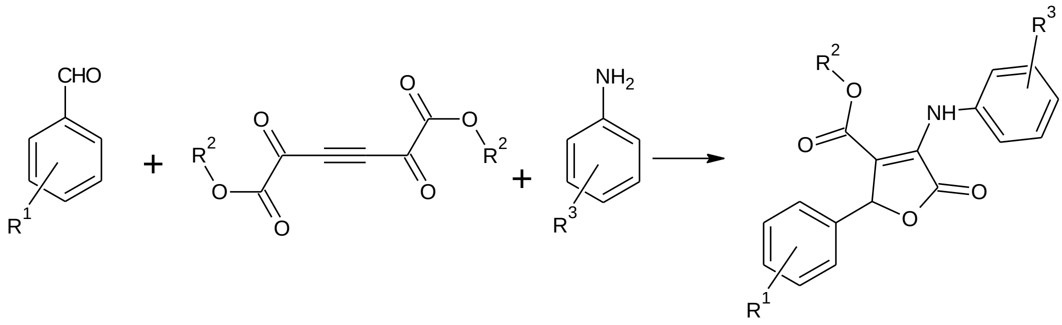
Scheme-11

Pal [31] reported the synthesis of arylidenemalononitrile by Knoevenagel condensation reaction of aldehydes and malanonitrile under visible light produced by tungsten bulb. Aqueous extract of keora fruit can catalyze the Knoevenenagel condensation with a good yield of products. Aqueous extract of keora is acidic and hence it could be work as acid catalyst for reaction (Scheme-12).



Scheme-12

A mild and environmentally benign synthesis of 3,4,5-substituted furan-2(5)-ones was reported by Hazeri *et al* [32] employing seedless barberry as a biocatalyst. This method prevents the generation of waste rather than the conventional chemical reagent (Scheme-13).



Scheme-13

4. Conclusion

It is clear that by using green chemistry procedures and principles, we can minimize the waste of materials, maintain the atom economy and prevent the use of toxic chemicals. Green chemistry provides 'Enviro-economics' circumstances for researchers to design an ideal process that starts from non-polluting materials. This review paper mainly focus on that green chemistry has grown from a small idea but gives an open sky for a new approach to the scientifically based environmental protection.

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