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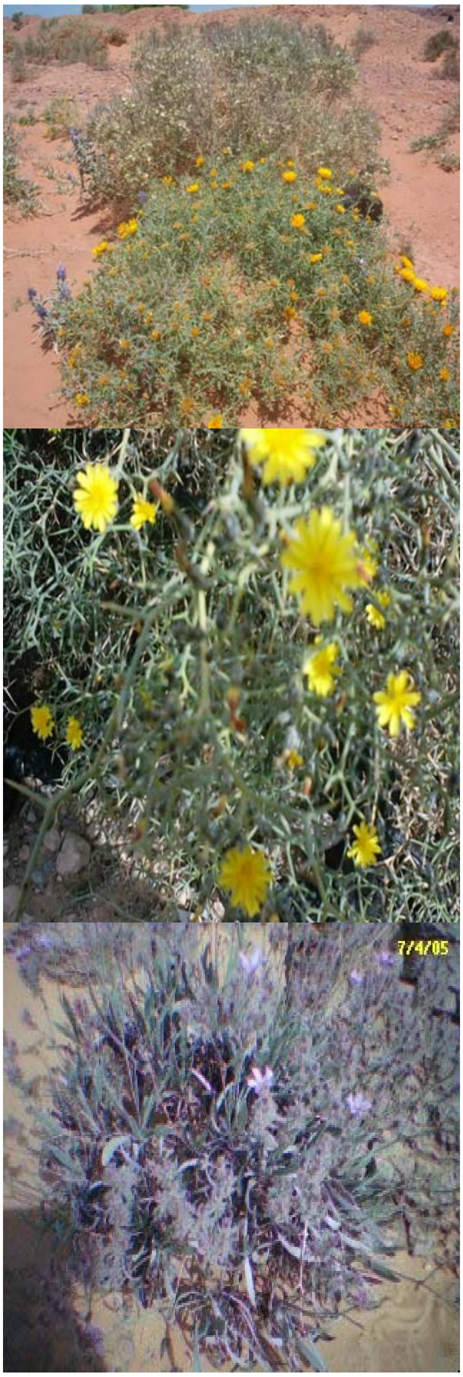

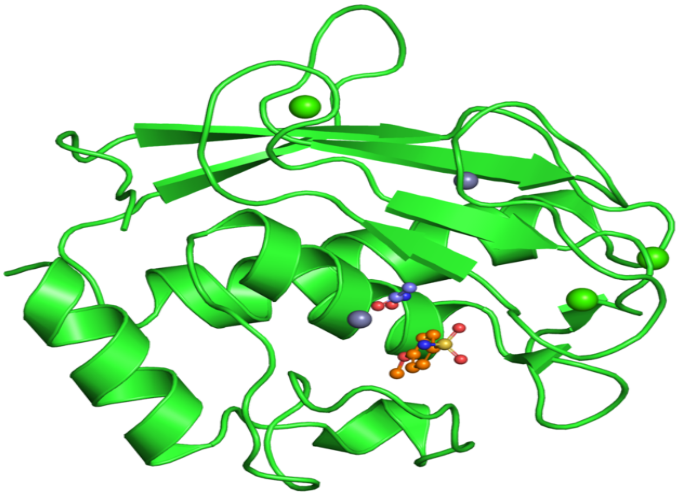

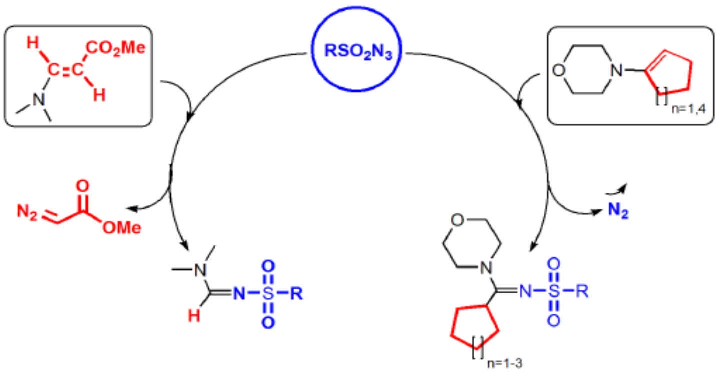

PCBS Journal

Special issue

Dedicated to Pr. *Douniazad* EL ABED
On the occasion of her outstanding contribution to organic chemistry research and her retirement from Oran 1 University (Algeria)

Guest Editor: Pr Salih HACINI

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Special issue dedicated to Professor *Douniazad El Abed*
on the occasion of her retirement from Oran 1 University (Algeria),
in recognition of her significant contributions to organic chemistry research

Nano- and Bio-catalysis in Green Chemistry: Recent Trends and Future Prospects

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Abstract. *Green chemistry involves technologies which are energy efficient, minimize or preferably eliminate the generation of waste, avoid the applications of toxic and hazardous solvents, reagents/materials, and utilize renewable raw materials. Nano and bio-catalysis play significant role in green and sustainable technologies. In this overview, some important issues pertaining to the nano- and biocatalysis in green chemistry as well as recent trends and future prospects are highlighted.*

***Key Words*:** *Biocatalysis; Nanocatalysis; Green chemistry; Sustainability; Environmentally-friendly; Nano-catalysts; Nanomaterials*

1. INTRODUCTION

Currently, green chemistry play significant roles in various areas, including medicine, biomedicine, tissue engineering, pharmaceutics, environmental protection, catalysis, and many other allied fields (1). Various greener and eco-friendly catalytic procedures in green chemistry and engineering disciplines can be applied for protecting human health and environment in an eco-friendly manner (2-5). The development of functionalized nanomaterial sand their utilization with unique morphologies, structures, and physicochemical properties, further empower heterogeneous catalytic reactions, and can open up new avenues green chemical processes (2-9).

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Green chemistry is commonly described as “the design, development, and implementation of chemical processes and products to reduce or eliminate substances hazardous to human health and the environment” (10). Currently, the idea of accomplishing this way of chemistry is gaining more considerations from chemical industry, as today’s most crucial challenges are to attain sustainable production methodologies with minimum energy consumptions and environmental impacts. Moreover, greener and sustainable production processes have to be also industrially and economically beneficial for the enterprises (11). Though, the total impact of green chemistry is still improving to the conventional industrial processes (9); as companies maximize profitability within the current policy limits, while holding an eye on social acceptance. As well-known procedures are often good enough to comply with the regulations, greener processes with less polluting might not be considered for implementation. It appears that innovative green chemistry methods can be presented and applied only if they can provide reasonably attractive paybacks to managers and investors (11). Thus, it should be noted that green chemistry is not merely targeted to lower energy consumption, but rather includes broad concepts regarding waste minimization, usage of safe and nontoxic materials, and encompassing other principles of green chemistry(Figure 1) (10, 11).

- Waste prevention instead of remediation
- Atom economy or efficiency
- Use of less hazardous and toxic chemicals
- Safer products by design
- Innocuous solvents and auxiliaries
- Energy efficiency by design
- Preferred use of renewable raw materials
- Shorter syntheses (avoid derivatization)
- Catalytic rather than stoichiometric reagents
- Design products to undergo degradation in the environment
- Analytical methodologies for pollution prevention
- Inherently safer processes

Figure 1. Important principles of green chemistry

2. BIOCATALYSIS IN GREEN CHEMISTRY

Based on the principles and metrics of green chemistry and sustainable development, biocatalysis is both a greener and sustainable technology (Figure 2) because the reaction conditions are normally mild and environmentally benign, and the catalyst is biodegradable. However, the full impact of biocatalytic procedure needs comprehensive analysis of the whole life-cycle. There are various approaches for using biocatalysts which are ideally suited and profitable than their traditional ones (12, 13). Protein engineering has enabled the optimization of existing enzymes and their invention enabled exclusively new biocatalytic reactions which were previously unidentified. Currently, it is really feasible to improve enzymatic

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transformations to fit predefined parameters, initiating procedures which are actually sustainable by design. For instance, this approach can be effectively applied for the industrial synthesis of active pharmaceutical ingredients. Additionally, the application of protein engineering and the other parts of biocatalysis engineering (such as substrate, medium, and reactor engineering) can be applied for improving the efficiency and cost-effectiveness, and thus, the sustainability of biocatalytic reactions. Moreover, the immobilization of an enzyme can enhance its stability and enable its reuse multiple times, triggering better performance and commercial viability. Consequently, biocatalysis can be extensively applied for the production of pharmaceuticals and some commodity chemicals, a process that can be further stimulated in future by the emerging bio-based economies (14).

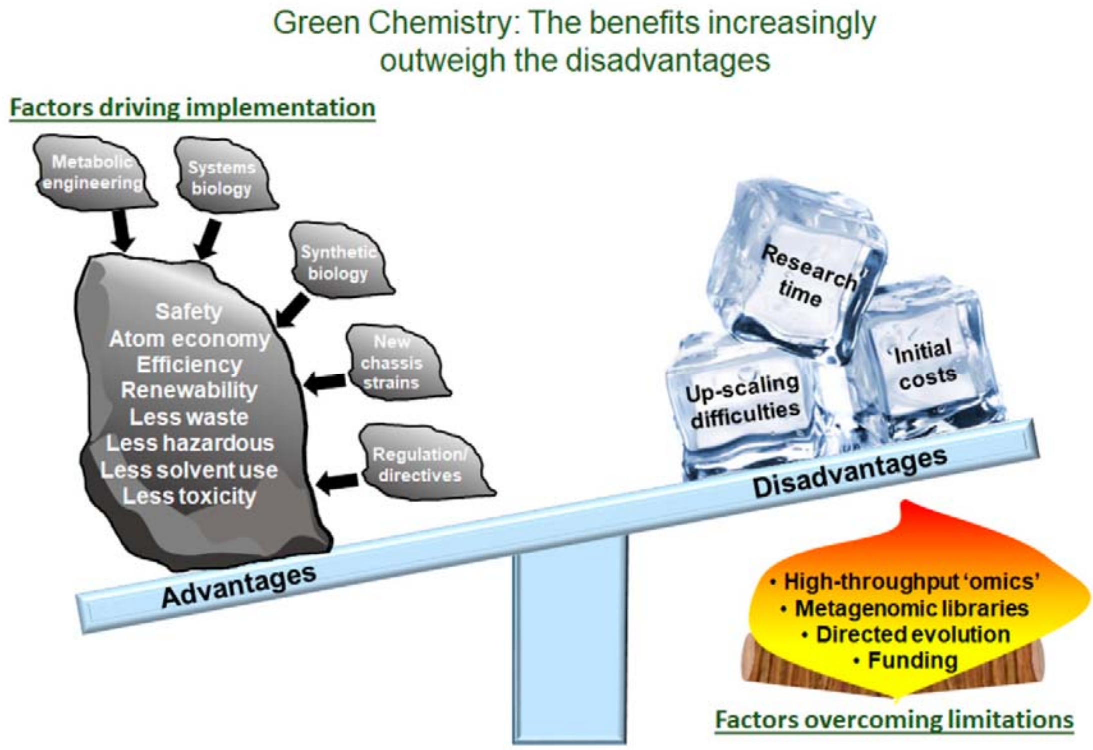

Figure 2. Biocatalysis and green chemistry: Advantages and disadvantages. Reuse from Ref (15). (CC BY 4.0)

Improvements in high-throughput DNA sequencing make it possible to sequence many more bacterial and fungal genomes, and related information has become accessible in the public domain. Indeed, a target gene can be recognized *in silico* by "genome mining" of regarding databases in this field. Then, the gene can be generated and subsequently cloned into a host microorganism and thanks to recombinant DNA technologies; it can be produced on an industrial scale for acceptable prices. Today, it is exceedingly feasible to optimize enzymes to fit a predefined optimum procedure, which is a genuine, benign by design procedure. Additionally, their storage and operational stabilities can be optimized by operative immobilization, thus enabling their cost-effective recovery and multiple recycling as free-flowing solids (16). Consequently, biocatalysis has evolved into an industrially attractive technology and has been integrated into mainstream organic synthesis, especially for the enantioselective production of active pharmaceutical intermediates (APIs) (17-20).The catalyst (an enzyme) is generated from readily accessible renewable resources, and is biodegradable and essentially safe and nontoxic. Furthermore, the application of scarce precious metals and the subsequent costs of removing traces of noble metals from end products are circum vented. Enzymatic reactions are typically completed under mild conditions (ambient temperature and atmospheric pressure) in water, often without the necessity for functional-group activation, protection, and deprotection steps. This affords routes that are more step-economical and generate less waste than conventional organic syntheses (21) rendering biocatalytic approaches as more environmentally attractive, cost-effective, and hence more sustainable. Additionally, procedures with isolated enzymes can be conducted in standard multipurpose batch reactors, and therefore avoiding the necessity for additional infrastructure investments (*e.g.,* inhigh-pressure equipment).Because enzymatic procedures are typically managed under approximately the same conditions of temperature and pressure, it is relatively simple for integrating multiple transformations into environmentally, commercially and economically attractive cascade procedures (22).

One of the important challenges is that not sufficient data is reported and collected on the sustainability of biocatalytic processes. A critical force for the implementation of biocatalysis should be the improved sustainability of processes, but without the measurement and quantification of waste and the resultant calculation of sustainability metrics, it is hard to measure the extent of improvement in a specific case. The development of synthetic approaches requires to realize a certain speed (especially in the pharmaceutical sector); although the development of new biocatalytic methods has been hugely successful in several well-publicized cases, there are also various examples where the speed of development, or the resources needed, could not be justified. Faster and well-organized techniques of process design and development will need the application of computational tools and knowledge about the enzyme to be manipulated, just as much as the process necessities. Sustainable implementation will often favor biocatalysis as it is a renewable catalyst, used under mild conditions but should also emphasize the need for several other features that capitalize on its benefits. It is essential to operate with an enough product concentration, to attain a realistic E factor; this is crucially needed for both economic and environmental reasons (23, 24).

Investigations should apply more power of protein engineering, not only to produce new catalysts (with an extensive substrate reservoir), but also to guarantee that they function successfully in terms of economic and environmental metrics; it is essential to pay adequate attention to the translation from laboratory catalyst to industrial catalyst. Additionally, operating the biocatalytic reaction in the right medium is essential, taking into account the solubility of the compounds involved and the requirements of downstream processing. Further investigations are needed to find when to use slurry-to-slurry reactors and biphasic media, or how to select solvents and make sure enough enzymes stability in such media. Principally, considerations should be focused on cofactor recycle. For instance, application of NADH oxidases is an outstanding method for regeneration of NAD^+ from an environmental perspective because they use molecular oxygen as a co-substrate and yield water (or hydrogen peroxide, that can be converted to water by catalase) as a co-product. However, such systems require substantial protein engineering to increase and improve the stability and activity, for economical production (25).For instance, when coupled with dehydrogenases for the oxidation of alcohols (rather than the usual reduction of ketones), relatively poor procedure performance was noticed, which was attributed, in part, to NADH oxidase inactivation (25). Considerations are needed in equilibrium-controlled conversions, where extra co-substrates can cause extraordinary E factors and ISPR can cause more downstream complications. Applying alternative substrates can be a better method for improvement of the reaction ΔG value(26). In the future, researches should focus on the aforementioned points to realize in its entirety, the sustainable benefits of biocatalysis; more implementation of biocatalytic production across all industries is needed.

3. NANOCATALYSIS IN GREEN CHEMISTRY

Nanocatalysis is a promptly growing field which involves the application of nanomaterials as catalysts for a variety of homogeneous and heterogeneous catalysis applications (Figure 3). Nanocatalysts show various potential benefits as nanostructured catalysts have been the subject of substantial research attentions in recent times (Figure 4 and 5). Nanocatalysts are extensively applicable for hydrogen storage, green diesel production, fuel cell applications, industrial manufacturing approaches and pharmaceutical industries. Recently, the design and production of innovative catalytic procedures for biomass upgrading has garnered considerable interest in the establishment and dissemination of sustainable and green chemistry concepts. For instance, ZSM-5 zeolite stimulated the conversion of biomass derivates not only to highly functionalized molecules, but also to coveted molecules such as aromatic hydrocarbons which until not long ago could only be produced from non-renewable sources. Especially, ZSM-5 zeolites showed significant potential as catalysts in reactions owing to their promising characteristics, such as the tridimensional medium size pore system and the wide Si/Al ratio (27).

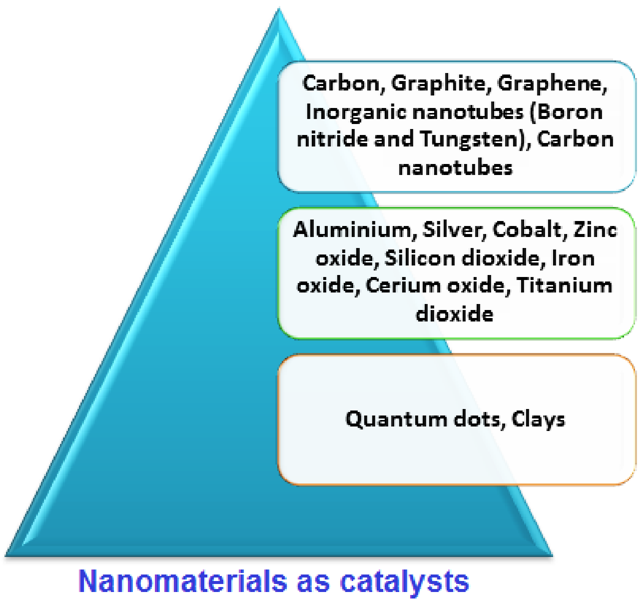

Figure 3. Types of nanomaterials deployed as catalysts

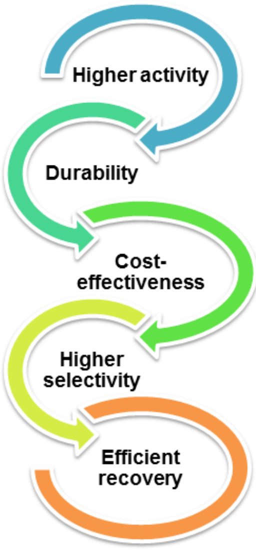

Figure 4. Nanocatalysis and green chemistry: Important advantages

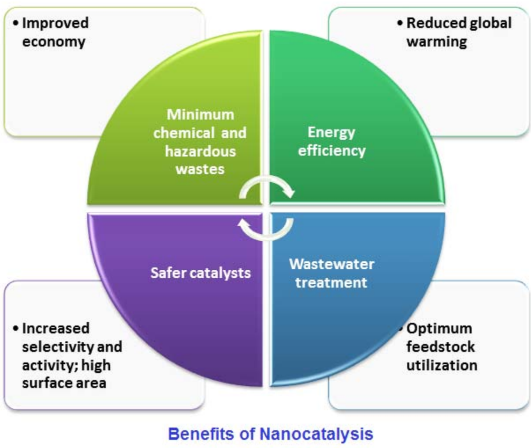

Figure 5. Some significant benefits of nanocatalysts

Well-organized, environmentally-friendly and a simple approach for synthesizing 5-substituted-1H-tetrazoles is catalyzed by magnetite-chitin as a green and recyclable catalyst which was firstly produced via hydrothermal synthesis; uniform cubic shaped magnetite-chitin nanoparticles were well monodispersed. Additionally, magnetic measurement demonstrated that the produced nanocatalyst had super paramagnetic characteristics which has enabled the production of a variety of tetrazoles via the reaction of nitriles with 1-butyl-3-methylimidazolium azide ([bmim][N_3]) under solvent-free conditions (28). In another study, Cu/magnetic chitosan was produced and applied as a green nanocatalyst for extremely efficient formation of 2,4,6-triaryl pyridines through C–N bond cleavage of benzylamines under aerobic oxidation at 90 °C; catalyst can be simply separated from the reaction mixture by an external magnetic field and recycled several times without a substantial loss in activity (29). Furthermore, Zn^{II} doped and immobilized on functionalized magnetic hydrotalcite was produced as a stable, long-lived, highly efficient and exceptional reusable magnetic nanocatalyst for the one-pot multi-component production of acridinediones as a significant class of heterocyclic compounds. Findings revealed the superparamagnetic nature of the catalyst with an average particle size of 20-60 nm are plate-like in shape. The produced nanocatalyst had both acidic sites and basic sites, and can perform as a bifunctional nanocatalyst (30). The role of nanocatalysts cannot be underestimated in the biomass-derived platform chemicals (8) and their own generation using plant-derived antioxidants (7).

4. CONCLUSION

Green chemistry is spearheading extensive out growth in many investigations including diverse industrial areas. Todays, researchers and pharmaceutical companies pay special attention to follow greener procedures while manufacturing pharmaceuticals or fine chemicals. Green solvents, nanocatalysts, and biocatalysts provide various opportunities for such ensuing greener processes wherein impact on the environment and the cost of pharmaceuticals can be reduced. Hopefully, with advantages of green chemistry, industry will substitute conventional approaches with greener ones; nano and biocatalysis will certainly play central roles in sustainable chemistry, and ingreener and sustainable technology. Important challenge in these technologies is their translation from laboratory-scale chemistry to industrial implementation where continuous flow alternatives will become an enabling pathway.

REFERENCES

1. Olveira S, Forster SP, Seeger S. Nanocatalysis: Academic Discipline and Industrial Realities. Journal of Nanotechnology. 2014;2014, http://dx.doi.org/10.1155/2014/324089.
2. Mohammadinejad R, Karimi S, Iravani S, Varma RS. Plant-derived nanostructures: types and applications. Green Chem. 2016;18:20-52.
3. Varma RS. Journey on greener pathways: from the use of alternate energy inputs and benign reaction media to sustainable applications of nano-catalysts in synthesis and environmental remediation. Green Chem. 2014;16:2027-41.
4. (a) Varma RS. Greener and sustainable chemistry. Applied Sciences. 2014;4:493-7;
   (b) Varma RS. Editorial Overview: Sustainability via nanocatalysis.Curr. Opin. Green & Sustain. Chem., 2019; 15: A1-A3. https://doi.org/10.1016/j.cogsc.2018.12.002;
   (c) Chhikara, BS, Varma, RS. Nanochemistry and nanocatalysis science: Research advances and future perspectives. An Editorial. J. Mater. NanoSci., 2019; 6: 1-6.
5. Varma RS. Greener and Sustainable Trends in Synthesis of Organics and Nanomaterials. ACS Sustainable Chem Eng. 2016;4:5866−78.
6. Iravani S. Green synthesis of metal nanoparticles using plants. Green Chemistry. 2011;13:2638-50.
7. Mohammadinejad R, Shavandi A, Raie DS,SangeethaJ, Soleimani M, Hajibehzad SS, Thangadurai D, Hospet R, Popoola JO, Arzani A, Gómez-Lim MA, Iravani S, Varma RS. Plant Nano-Molecular Farming: Production of Metallic Nanoparticles and Therapeutic Proteins Using Green Factories. Green Chem. 2019; 21, 1845–1865.
8. Varma RS. Biomass-Derived Renewable Carbonaceous Materials for Sustainable Chemical and Environmental Applications. ACS Sustainable Chem Eng. 2019;7:6458-70.
9. Varma RS. Greener approach to nanomaterials and their sustainable applications. Current Opinion in Chemical Engineering. 2012;1:123–8.

PhytoChem & BioSub Journal Vol. 14(1) 2020
ISSN 2170-1768
CAS-CODEN:PBJHB3

10. Anastas PT, Warner J, C Green Chemistry: Theory and Practice, Oxford University Press, Oxford, UK, 1998.
11. Poliakoff M, Fitzpatrick JM, Farren TR, Anastas PT. Green chemistry: science and politics of change. Science. 2002;297:807–10.
12. Gan PP, Ng SH, Huang Y, Li SF. Green synthesis of gold nanoparticles using palm oil mill effluent (POME): A low-cost and eco-friendly viable approach. Bioresour Technol. 2012;113:132–5.
13. Abdelaziz R, Disci-Zayed D, Hedayati MK, Pöhls JH, Zillohu AU, Erkartal B, et al. Green chemistry and nanofabrication in a levitated Leidenfrost drop. Nat Commun. 2013;4:2400.
14. Sheldon R.A, Woodley JM. Role of Biocatalysis in Sustainable Chemistry. Chem Rev. 2018;118:801−38.
15. Castilla IA, Woods DF, Reen FJ, O'Gara F. Harnessing Marine Biocatalytic Reservoirs for Green Chemistry Applications through Metagenomic Technologie. Mar Drugs. 2018;16:227.
16. Sheldon RA, van Pelt S. Enzyme immobilization: why, what and how? Chem Soc Rev. 2013;42:6223−35.
17. Huisman GW, Collier SJ. On the development of new biocatalytic processes for practical pharmaceutical synthesis. Curr Opin Chem Biol. 2013;17:284−92.
18. Tao A, Xu JH. Biocatalysis in development of green pharmaceutical processes. Curr Opin Chem Biol. 2009;13:43−50.
19. Zheng G-W, Xu JH. New opportunities for biocatalysis: driving the synthesis of chiral chemicals. Curr Opin Biotechnol. 2011;22:784−92.
20. Hoyos P, Pace V, Hernaiz MJ, Alcantara AR. Biocatalysis in the pharmaceutical industry: a greener future. Curr Green Chem. 2014;1:155−81.
21. Wender PA, Handy ST, Wright DL. Towards the ideal synthesis. Chem Ind (London). 1997:765−9.
22. Sheldon RA. Enzyme-catalyzed cascade reactions. In Multi-Step Enzyme Catalysis: Biotransformations and Chemoenzymatic Synthesis; Garcia-Junceda, E., Ed.; Wiley-VCH: Weinheim, Germany, 2008; Chapter 6, pp 109−135.
23. Truppo MD. Biocatalysis in the pharmaceutical industry: The need for speed. ACS Med Chem Lett. 2017;8:476−80.
24. Currin A, Swainston N, Day PJ, Kell DB. Synthetic biology for the directed evolution of protein biocatalysts: navigating sequence space intelligently. Chem Soc Rev. 2015;44:1172−239.
25. Rehn G, Toftgaard Pedersen A, Woodley JM. Application of NAD(P)H oxidase for co-factor regeneration in dehydrogenase catalyzed oxidations. J Mol Catal B: Enzym. 2016;134:331−9.
26. Gundersen MT, Tufvesson P, Rackham EJ, Lloyd RC, Woodley JM. A rapid selection procedure for simple commercial implementation of ω-transaminase reactions. Org Process Res Dev. 2016;20:602−8.
27. Lima CGS, Jorge EYC, Batinga LGS, Lima TdM, M.W P. ZSM-5 zeolite as a promising catalyst for the preparation and upgrading of lignocellulosic biomass-derived chemicals. Current Opinion in Green and Sustainable Chemistry. 2019;15:13–9.
28. Zarghania M, Akhlaghinia B. Magnetically separable Fe3O4@chitin as an eco-friendly nanocatalyst with high efficiency for green synthesis of 5-substituted-1H-tetrazoles under solvent-free conditions RSC Adv. 2016;6:31850-60
29. Shaabani A, Boroujeni MB, Laeini MS. Copper(II) supported on magnetic chitosan: a green nanocatalyst for the synthesis of 2,4,6-triaryl pyridines by C–N bond cleavage of benzylamines RSC Adv. 2016;6:27706-13.
30. Zareia Z, Akhlaghinia B. ZnII doped and immobilized on functionalized magnetic hydrotalcite (Fe3O4/HT-SMTU-ZnII): a novel, green and magnetically recyclable bifunctional nanocatalyst for the one-pot multi-component synthesis of acridinediones under solvent-free conditions New J Chem. 2017;41:15485-500.

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