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REVIEW ARTICLE

BENTHAM SCIENCE

Reusable Iron/Iron Oxide-based Nanoparticles Catalyzed Organic Reactions

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Abstract: The last decade has witnessed a remarkable progress in the field of nanoscience and nanotechnology. Nanoparticles have been extensively used in diverse areas, including medicine, sensor, and catalysis. The easy accessibility of nanoparticles (NPs) with different shapes, sizes and compositions has inspired researchers to investigate their applications in catalysis. Recently, magnetic nanoparticles, such as iron-based nanoparticles, have attracted much consideration due to their unique properties, such as superparamagnetism, greater surface area, surface-to-volume ratio, and easy separation methodology. They increase the competence of organic reactions in terms of activity, selectivity, yield, simplicity, and sustainability. In this review, we focus on the developments of iron/iron oxide-based nanoparticles-catalyzed organic reactions and some examples of magnetic iron oxide nanoparticles as carriers/support for the main catalyst in organic reactions. Owing to magnetic properties, these nanocatalysts can be easily recovered from the reaction mixture by an external magnet and reused for several runs without loss of catalytic activity. Iron-based nanoparticles are used in a wide range of catalytic processes and applications. Notable focus has been on the hydrogenation of alkenes and alkynes, and also the hydrogenation of nitroarenes to aniline. Other catalyzed organic reactions, such as hydroboration of aldehydes and ketones, oxidative dehydrogenation of *N*-heterocycles, azide-alkyne cycloaddition reactions, synthesis of various heterocyclic compounds, multicomponent reactions, and cross-coupling reactions for C–C and C–heteroatom bond formation have been covered.

Keywords: Catalysis, organic synthesis, iron(0) nanoparticles (NPs), iron oxide (Fe_2O_3/Fe_3O_4) nanoparticles, iron/transition metal mixed oxide NPs, nanoparticles.

1. INTRODUCTION

Intensive research has been conducted on metal nanoparticles (NPs) for their applications in the broad fields of medicine, optics, electronics, and catalysis [1-9]. In the context of catalysis, transition metal nanoparticles (NPs) have been studied significantly in the past few decades due to the fundamental advantages associated with nano-catalysis, such as the remarkable degree of control over selectivity, reactivity and yield of the product *via* controlled modifications in nanoparticle sizes, shapes and their surrounding environments [10-13]. Initial research on NPs catalyzed reactions predominantly focused on NPs of precious transition metals, such as Ru, Pd, Ag, Pt, Au, *etc.* In recent years, the focus on catalysis with NPs has shifted to earth-abundant transition metal nanoparticles, such as Fe, Co, Ni, Cu, and Zn, because of their abundance, cost-effectiveness, lower toxicity and fewer environmental hazards [14, 15]. Iron (Fe), in particular, has appeared as a potential candidate for numerous catalytic reactions of scientific and industrial interest. Iron is the most abundant transition metal in the Earth's crust, and it is an important metal in the life cycle of most living things as various assemblies of biological functions and systems rely upon the rich chemistry of iron-containing enzymes. Owing to the high abundance, inexpensiveness, toxicologically and environmentally benign nature of iron, constant efforts have been made for the expansion of numerous iron-catalyzed reactions [16, 17]. Thus far, many synthetic chemists have made ample contributions in this field, and several iron-catalyzed synthetic organic reactions have been conducted from different aspects [18-32], including substitution, nucleophilic addition, oxidation, reduction, hydrogenation, cycloaddition, rearrangement, heterocycles synthesis, C–H functionalization, polymerization, and those involving certain asymmetric alternates of these molecular transformations. Distinct renowned research groups have also developed iron-catalyzed cross-coupling reactions [33-48]. Although many simple iron-based catalysts or iron-based organometallic catalysts have been developed for different chemical processes/organic synthesis, several of these catalyst systems have limited applications in industrial processes due to the use of complex ligands and lack of reusability of the catalysts. Between molecular-defined iron complexes and nanostructured heterogeneous catalysts, the latter are usually favored due to their easier recovery from the reaction medium and their recycling ability, which is essential for cost-effective industrial processes [49-54]. Recently, iron-based nanoparticles have drawn significant attention due to their novel properties, such as magnetic, electrical, or catalytic, different from the corresponding bulk materials [55-59]. However, to our knowledge, limited reviews have been published in the litera-

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