IRANIAN JOURNAL OF CATALYSIS

Novel Silica-coated Magnetic Nanoparticles and Their Synthetic Applications

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Dr. Shripad Mukundrao Patil was born in Maharashtra, India on November 30, 1993. He received his B. Sc. degree in pure chemistry (2015) and M. Sc. in organic chemistry (2017) from Dada Patil Mahavidyalaya, Karjat-414401, Savitribai Phule Pune University, Pune, Maharashtra, India. He was also awarded his Ph.D. degree in organic chemistry (July 2023) under the guidance of Dr. Runjhun Tandon and Co-guidance Dr. Nitin Tandon, from the School of Chemical Engineering and Physical Science, Lovely Professional University, Phagwara-144411, Punjab, India. He published 16 international research papers in Scopus journal and one on international patent. He also attended three international conferences and two international workshops. His research interest is synthesizing and characterizing novel silica-coated magnetic nanoparticles and their applications in organic transformation. He also worked on the development of organic reactions using green methods.

This feature focuses on a reagent chosen by a postgraduate, highlighting the uses and preparation of the reagent in current research.

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(DOI: 10.30495/IJC.2023.1998671.2054)

Introduction

Nanoparticles are highly effective for various organic reactions due to their high reactivity, availability, and reactive surface area [1-3]. Ferrite nanoparticles, in particular, exhibit acidic properties. Magnetic nanoparticles can be easily dispersed in a reaction mixture using an external magnet and reused multiple times without losing their catalytic properties [4-7]. In organic synthesis, the use of toxic, inflammable, and harmful solvents can harm the environment and humans [8-12]. Therefore, it is essential to use green and sustainable protocols to reduce hazardous substances and control pollution. The organic transformation should generate less waste material or by-products, use less energy, and decrease the use of poisonous and toxic solvents or catalysts. **(Fig. 1)** This approach follows green chemistry principles and is less harmful, cheap, recoverable, and easy to work with [13]. Scientists are driven to create synthetic methods to reduce the creation of toxic material using green chemistry concepts. Organic production and ecological synthesis both require green catalysts [14]. It is the most efficient technique for chemical synthesis since it avoids the need for hazardous volatile solvents, reagents, catalysts, dangerous processes, and the required minimal reaction time without producing hazardous sludge [15].

Recent studies on nanomaterials have led to the development of surface coatings that protect them from surface erosion caused by various reagents, including acid-functionalized compounds, metal oxides, oxidizing agents, and some bases [16-18]. These reagents and catalysts can be used to design novel magnetic nanoparticles for specific

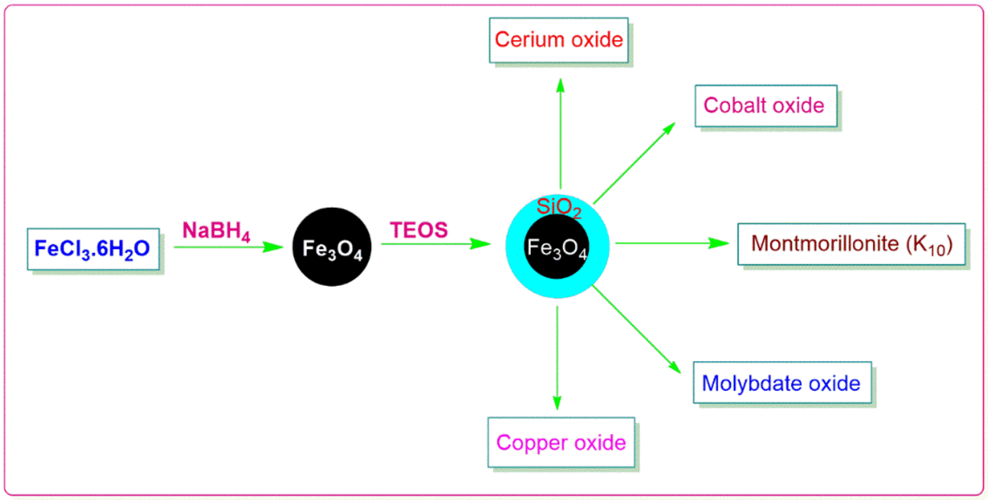
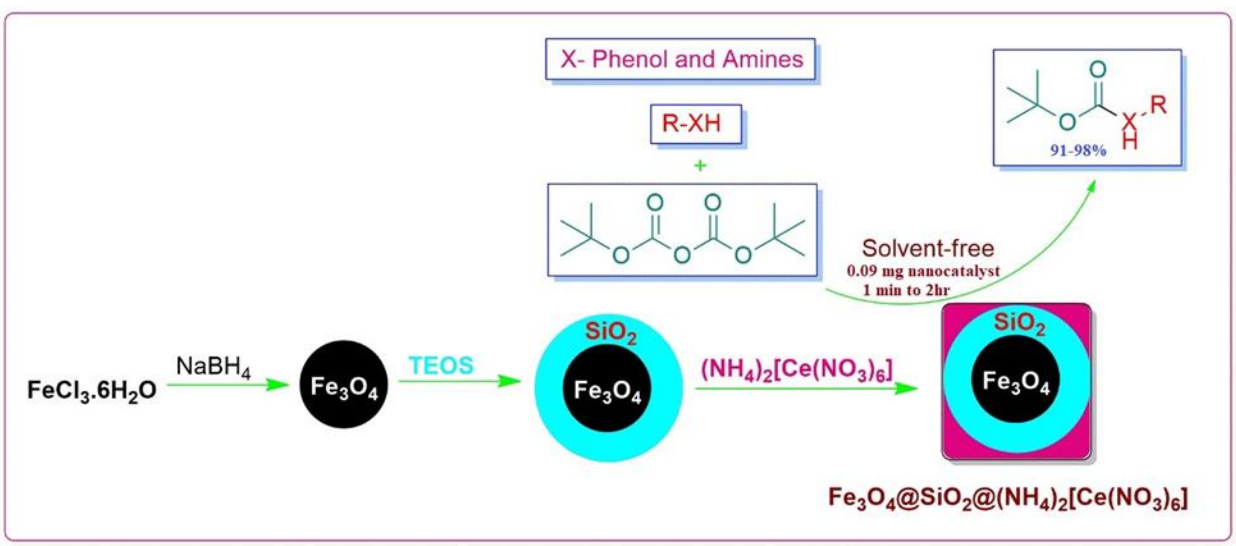


Fig. 1. Overlook of the Novel metal oxide supported silica-coated iron oxide nanoparticles

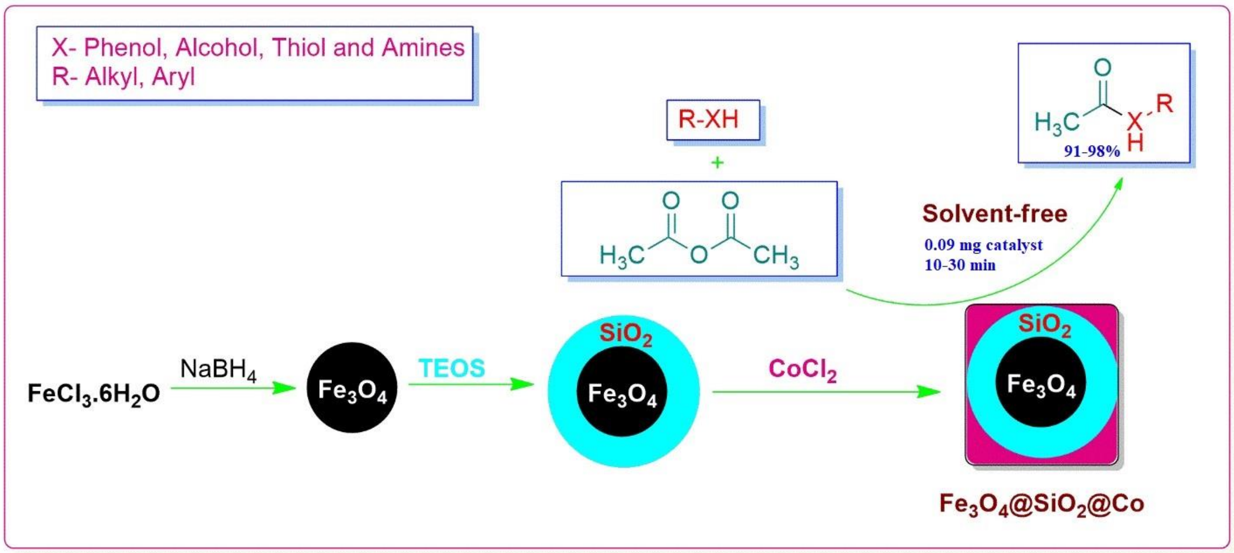
applications in organic synthetic methodologies [24-27]. The sustainability of these catalysts is under investigation, with a focus on properties such as excellent selectivity, easy separability, and simple recoverability from reaction mixtures [29-31]. In this discussion, we have reviewed the recent developments in silica-coated ferrite magnetic nanoparticles and their applications in various organic reactions.

Abstracts

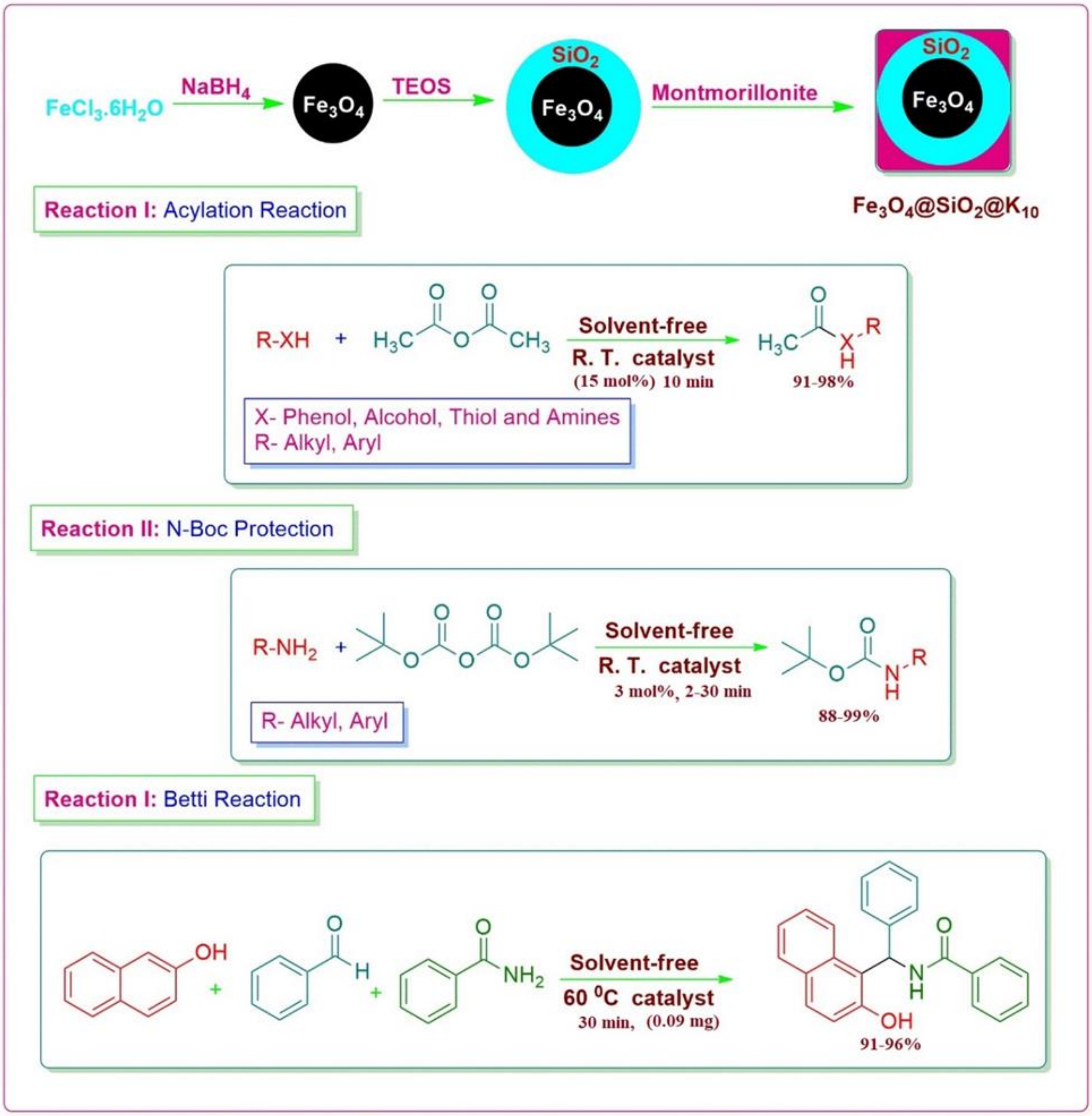
(A) Shripad Patil *et al*. [22] reported the synthesis of novel ceric ammonium nitrate-supported silica-coated $Fe_3O_4@SiO_2@(NH_4)_2[Ce(NO_3)_6]$ magnetite nanoparticles used for the protection of amine and phenol derivatives in the presence of di-ter-butyl carbonate. The iron oxide magnetite nanoparticles were prepared using the co-precipitation technique. After that, nanoparticles were coated with silica using tetra ethyl ortho silicate (TEOS) using the stobber method. Finally, the silica-coated iron oxide nanoparticles have been reacting with ceric ammonium nitrate $(NH_4)_2[Ce(NO_3)_6]$ to form reactive $Fe_3O_4@SiO_2@(NH_4)_2[Ce(NO_3)_6]$ nanoparticles. The prepared nanoparticles were characterized using PXRD, FE-SEM, EDS, WDX, TGA, TEM, ICP-OES, and FT-IR techniques. Finally, 0.09 mg of Nano catalyst was used to protect amines and phenol derivatives under solvent-free conditions giving a 98% yield within 10 minutes. This work studied various amine as well as phenol substrates, out of that phenol substrates are less reactive than amine because phenol substrates are less nucleophilic than amine derivatives. The nanoparticles have been recycled at least 15 times without loss of catalytic activity.



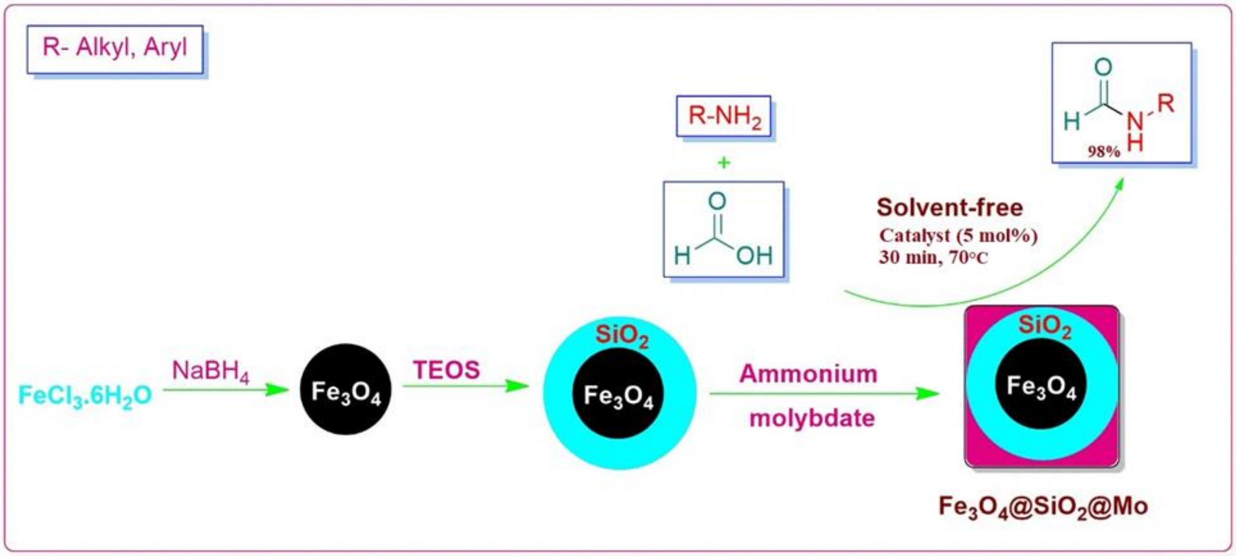
(B) Shripad Patil et al. [23] reported the synthesis of cobalt-supported silica-coated ferrite magnetite nanoparticles ($Fe_3O_4@SiO_2@Co$) used for the acylation of amine, phenol, alcohol, and thiol derivatives in the presence of acetic anhydride. The prepared nanoparticles were characterized using PXRD, FE-SEM, EDS, WDX, TGA, TEM, ICP-OES, and FT-IR techniques after successfully synthesizing and characterizing nanoparticles, which are used for the acylation of amine, phenol, alcohol, and thiol derivatives. The 0.09 mg Nano catalyst is sufficient for the complete conversion. The amine substrate reacts much faster than phenol, alcohol, and thiol substrates, which gave a 91-98% yield. In this work, the nanoparticles have been recycled 10 times without loss of catalytic activity.



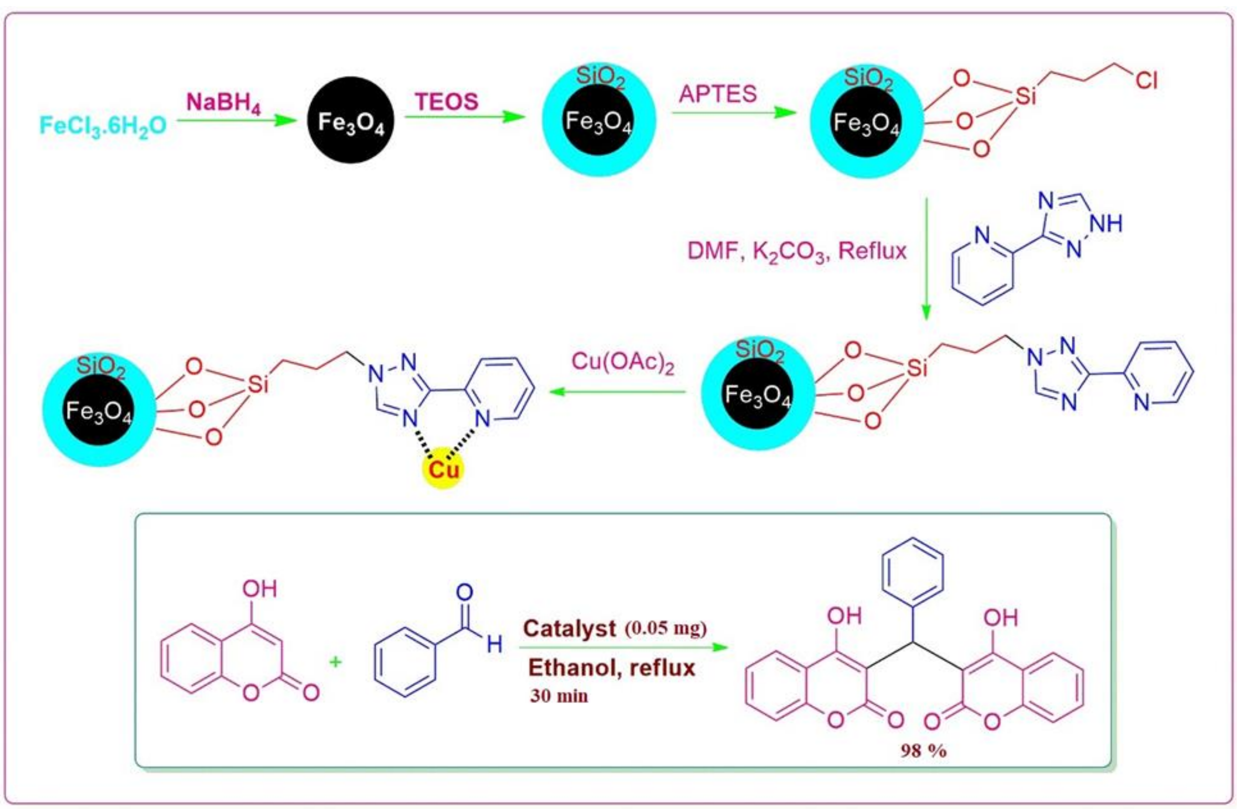
(C) Nitin Tandon et al. [19] reported the synthesis of Montmorillonite-supported silica-coated ferrite magnetite nanoparticles. They characterized using PXRD, FE-SEM, EDS, WDX, TGA, TEM, ICP-OES, and FT-IR techniques. The first application is the acylation of amine, phenol, alcohol, and thiol derivatives in the presence of acetic anhydride. The 15 mol% nanocatalyst is sufficient for the complete conversion. The amine substrate reacts much faster than phenol, alcohol, and thiol substrates, which gave 88-99% yield. In this work, the nanoparticles have been recycled 10 times without loss of catalytic activity. Shripad Patil et al. [20] reported that catalyst is used for the *N*-Boc protection reaction under solvent-free conditions. They characterized using PXRD, FE-SEM, EDS, WDX, TGA, TEM, ICP-OES, and FT-IR techniques. The second application is the protection of amine derivatives in the presence of di-tert-butyl carbonate under solvent-free conditions. The 3 mol% nano catalyst is sufficient for the complete conversion. The aliphatic amine substrate reacts much faster than aromatic amine substrates, which gives an 88-99% yield. In this work, the nanoparticles have been recycled 10 times without loss of catalytic activity. Shripad Patil et al. [28] reported the catalyst is used for the Betti reaction under solvent-free conditions. The reaction performed between aldehyde, benzamide, β-naphthol, and nanoparticles added to the reaction mixture stirred under solvent-free conditions. The catalyst has shown good recyclability about 15 times.



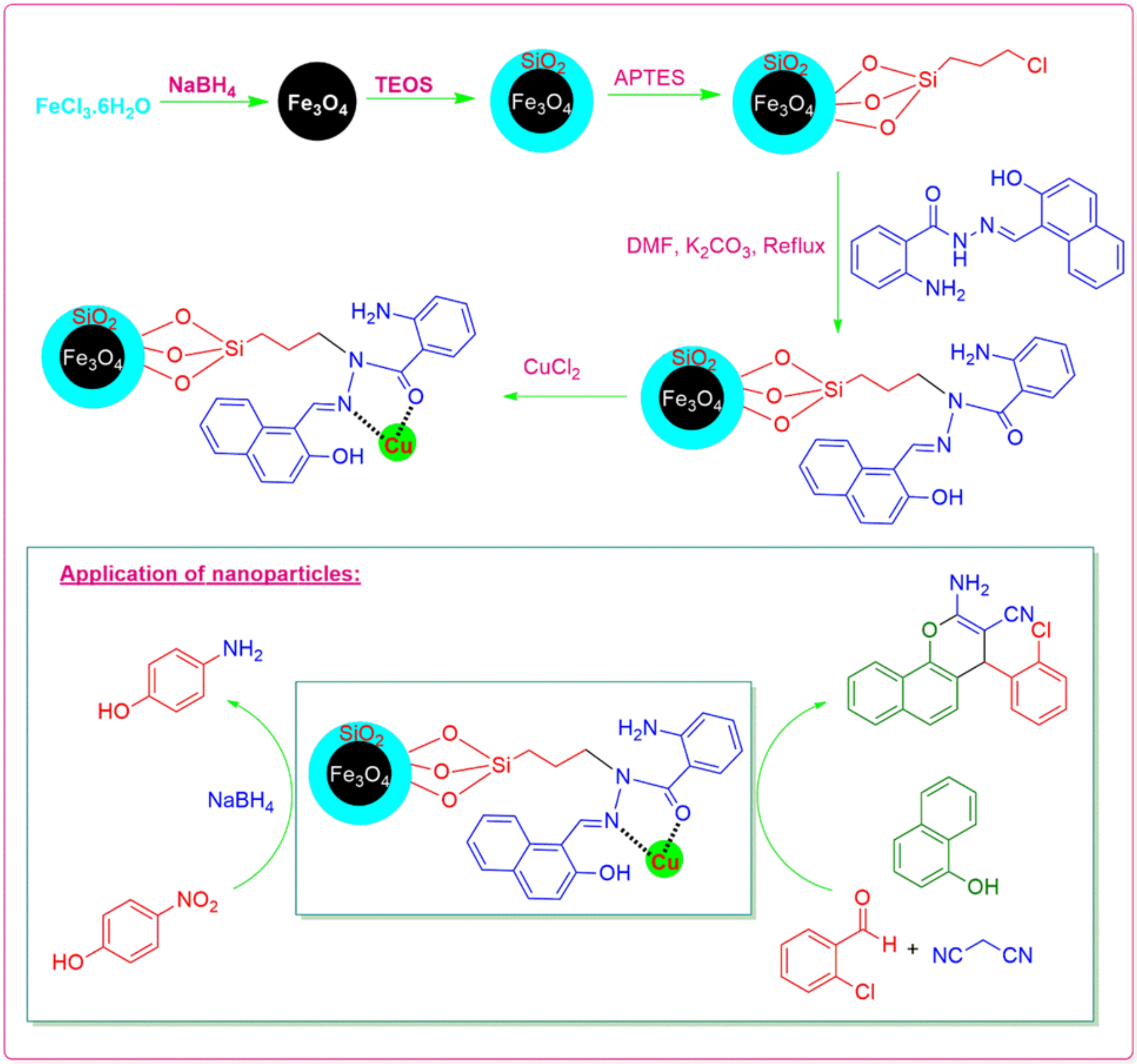
(D) Runjhun Tandon et al. [21] reported the synthesis of Molybdate-supported silica-coated ferrite magnetite nanoparticles used for the *N*-formylation reaction using amine derivatives in the presence of formic acid. The prepared nanoparticles were characterized using PXRD, FE-SEM, EDS, WDX, TGA, TEM, ICP-OES, and FT-IR techniques. The 5 mol% Nano catalyst is sufficient for the complete conversion. The aliphatic amine substrate reacts much faster than aromatic amine substrates which gave 88-98% yield. In this work, the nanoparticles have been recycled 10 times without loss of catalytic activity.



(E) Ali Oji Moghanlou et al. reported the synthesis of Fe_3O_4@SiO_2-$(CH_2)_3$-Pyridine-2- (1H)-tetrazole-Cu(II) nanoparticles have been used for the preparation of bis-coumarin derivatives under the green methodology. The Nano catalysts were prepared using the pyridine-2-(1H)-tetrazole ligand, and the copper nano catalyst complex was treated with silica-coated iron oxide nanoparticles. Those nanoparticles were characterized using atomic absorption, SEM, FT-IR, EDX, VSM, XRD, and BET techniques. Then, prepared nanoparticles were used for the synthesis of bis-coumarin derivatives. The reaction between benzaldehyde and 4-hydroxycoumarin in the presence of ethanol under reflux conditions. The 5 mol% Nano catalyst is sufficient for the complete conversion. The reaction was given an 88-98% yield. In this work, the nanoparticles have been recycled a minimum of 6 times without loss of catalytic activity [32].



(F) F. Rohmatpour et al. [33] reported the synthesis of copper (II) Schiff base complex immobilized on Fe_3O_4 nanoparticles and used for the preparation of 2-amino-4*H*-benzo[*h*] chromenes derivatives as well as the reduction of 4-nitrophenol substrate. The SEM, ICP, VSM, XRD, and EDX techniques were used to thoroughly characterize the as-prepared $Fe_3O_4@SiO_2$ single bond CPS-CuL and its precursors. The 5 mol% Nano catalyst is sufficient for the complete conversion. The reaction was given an 88-98% yield.



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