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Synthesis of Benzimidazole Derivatives using Ni nps /stilbite Zeolite

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ABSTRACT: In this research article we prepared Ni nanoparticle, then it was deposited on stilbite zeolite and application of this composite was checked in the synthesis of benzimidazole derivatives. The process of Ni nanoparticle synthesis and its deposition on stilbite zeolite is very simple. The catalyst is too much effective for the synthesis of benzimidazole derivatives giving high yields in short reaction time.

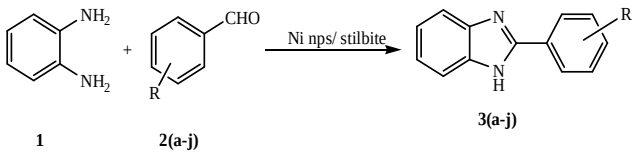
Keywords: Benzimidazole, Microwave, Ni nps/ stilbite, Reusable.

INTRODUCTION: Thin layer chromatography widely used for Heteronuclear molecule such as benzimidazole and its derivatives exhibit significant activity against several viruses, such as HIV[1], herpes (HSV-1)[2], RNA[3], influenza[4] and human cytomegalovirus (HCMV). Substituted benzimidazoles have commercial applications in veterinarian medicine as anithelmintic agents and in diverse human therapeutic areas such as treatment of ulcers and as antihistaminic[5]. Recently, it has been found that two groups of benzimidazoles, namely the 5,6-dinitro and 2-trifiuoromethyl derivatives to be promising candidates for antimicrobial drugs[6]. Benzimidazoles have crucial structures, which are contained in agrochemicals, dyestuffs, and high temperature polymer products[7], and also have interesting biological and pharmacological activities[8], including inhibition of phosphodiesterase IV[9], neuropeptide Y binding and anti-arrythmic and antiviral indications[10,11].

Few recent protocols reported for the synthesis of benzimidazole derivatives include solvent free synthesis of benzimidazoles under microwave irradiation using $Yb(OTf)_3$[12], KSF clay[13], PPA[14], Na_2SO_4[15], metal halide supported alumina[16] and solid support[17]. As many of these processes have limitations, such as use of toxic acids as a catalyst, drastic reaction condition, low yields, high temperature, and tedious work-up procedure. There is need to develop new route for the synthesis of benzimidazole.

Stilbite is a natural zeolite mainly contain Silica and alumina, it has been investigated in different countries by several workers. Investigationn on stilbite from India has been carried out by Sukeshwala et al[18].

In recent years, nanoparticle attracts much more attention because higher surface areas available with the nanomaterial counterparts, nanocatalyst tend to have exceptional surface activity[19]. In present study we prepared Nickel nanoparticle as reported method[20], it was deposited on stilbite zeolite and named as Ni nps / stilbite catalyst. This catalyst was used for the synthesis of benzimidazole derivatives. We found that the reaction procedure is simple, highly efficient and environmentally benign method for the synthesis of benzimidazole derivatives in the presence of catalytic amount of Ni nps/ stilbite under microwave condition. This method gives significant advantages such as short reaction times, simple work-up procedure and excellent yields. The Ni nps/ stilbite was successfully reused for four cycles without significant loss of activity.



Scheme 1: Synthesis of benzimidazole derivatives catalyzed by Ni nps/stilbite zeolite.

EXPERIMENTAL: Melting points were determined in open capillary in paraffin bath apparatus and are uncorrected. The reactions were monitored by TLC

and visualized with UV light. IR spectra were recorded on a matrix of KBr with FTIR-4100 (Jasco, Japan) spectrometer. ^{1}H NMR spectra were recorded on Varian NMR spectrometer, Model Mercury Plus (200 MHz) and the chemical shifts are given in ppm relative to TMS as an internal standard.

Preparation of Ni nps/ stilbite zeolite: The Ni nps prepared by reported method[20] were mixed with 2 gms of stilbite zeolite powder, stirred for 2 hrs, air dried and heated at 200 ºC. in muffle furnace, cooled and named as Ni nps/ stilbite catalyst.

General procedure for synthesis of benzimidazoles: Aldehyde (10 mmol) and 1,2-diaminobenzene (10 mmol) were thoroughly mixed in a 25 mL beaker and then catalyst were added at room temperature and then irradiated at 450W for 3-6 minutes in microwave oven. The progress of reaction monitored by TLC. After completion of the reaction, the reaction mixture poured on ice, filtered, washed with cold water to remove excess of impurities. The crude product obtained was recrystallized from ethanol to afford high purity of the product.

Spectral data of representative compound (3f):
^{1}H NMR (DMSO, δ in ppm): 7.18-7.22 (m, 2H, Ar), 7.52-7.59 (m, 4H), 8.11 (dd, 1H), 8.20 (s, 1H, Ar), 13.01 (s, 1H).
IR (KBr): 3458, 2917, 2850, 2659, 1698, 1573, 1470, 1393, 1317, 1212, 832, 746 cm^{-1}.

RESULTS AND DISCUSSION:

Catalyst Characterization:

Energy Dispersive Spectrum: Ni nps/ stilbite zeolite composite was analyzed qualitatively and quantitatively. It shows that silicon, aluminum, nickel, iron and sodium are present in catalyst containing 28.46, 9.24, 2.37, 0.17 and 0.93 mass% respectively.

X-ray diffraction: The catalyst was characterized by XRD using model D8 Bruker AXS with monochromatic Cu-Kα radiation (40Kv and 30mA) at room temperature. The XRD spectra are shown in fig.2a. The XRD diffraction data are obtained in the 2Θ range of 0 to 50°. From XRD it is seen that, the powder sample shows intense reflection at 2Θ = 6.3, 10.8, 14.9, 22 and 26.4°. The nature is crystalline.

FTIR spectroscopy: FT-IR spectroscopy was performed on Perkin Elmer FTIR spectrometer. The samples were prepared with KBr and pressed into pellet. Spectra were collected in the mid- IR range of 650 to 4000 cm^{-1} with resolution of 1cm^{-1}. The results of IR spectroscopy are shown in figure. Peak at 1068 cm^{-1} is due to Ni-O-Si bond. The peak at 824 cm^{-1} is assigned to Si-O-Si bond and peak at 3375 is due to Si-OH. The fig. 2b shows the FTIR spectra of Ni nps/ stilbite zeolite.

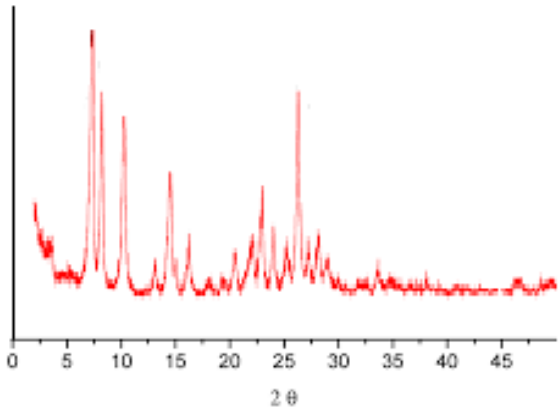


Figure 2a: XRD of Ni nps/ stilbite zeolite.

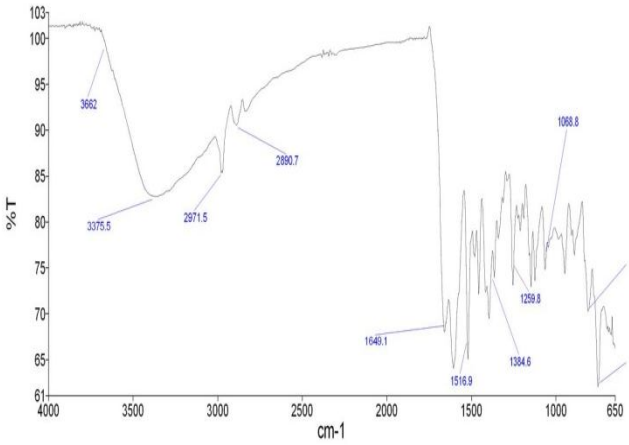


Figure 2b: FTIR of Ni nps/ stilbite zeolite.

In order to get best experimental conditions, initially we have studied the effect of catalyst loading, benzaldehyde (10 mmol) and *o*-phenylenediamine (10 mmol) was chosen as a model substrate. 0.01 and 0.05 gm of catalyst Ni nps/ stilbite zeolite loading gave low product yields (71% and 82%) after 5 min and 4 min. respectively (Table 1, entries 2 and 3). The use of 0.1 gm of catalyst gives excellent yield within 3 min. (Table 1, entry 4). When we increase the amount of catalyst concentration, no any significant changes observed with respective time and yield of product. A quantitative yield (97%) of desired product was obtained in the presence of 0.1 gm of Ni nps/ stilbite zeolite within short spam indicating that the 0.1 gm of catalyst is very active catalytic system for this reaction. It is noteworthy to mention that in the absence of catalyst, reaction did not give any product after 10 min also.

Table 1: Effect of catalyst amount (Ni nps/ stilbite zeolite) in the reaction of *o*-phenylene-diamine and benzaldehyde.

Entry	Catalyst amount (gm)	Time (min)	Yield (%)[a]
1	No catalyst	10	-
2	0.01	5	71
3	0.05	4	82
4	0.10	3	97
5	0.15	3	97
6	0.20	3	96

[a]*Refers to isolated yields.*

Next we have investigated the effect of microwave power for the same model reaction. The results in Table 2 shows the reaction carried out at 450 W gives good results (Table 2 entry 3) as compared to power input from 150 to 600 W.

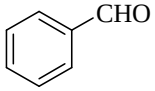
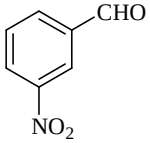
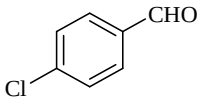
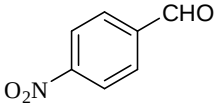
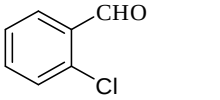
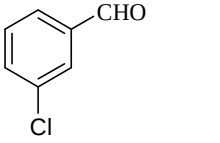
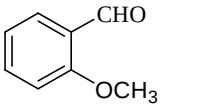
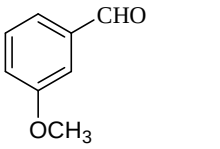
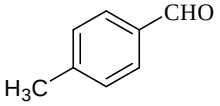
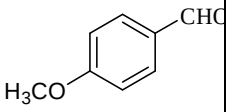
Table 2: Effect of power input temperature in the reaction of *o*-phenylenediamine and benzaldehyde.[a]

Entry	Power (w)	Time (min)	Yields (%)[b]
1	150	5	62
2	300	4.5	75
3	450	3	97
4	600	2.5	93

[a] *All reaction carried out using 0.1 gm Ni/ stilbite,* [b]*Isolated yields.*

With optimized reaction condition in hand, we have synthesized various benzimidazoles from substituted aromatic aldehydes with 1,2-diaminobenzene in the presence of Ni nps/ stilbite zeolite under influence of microwave irradiation. The successful synthesis of benzimidazoles in shorter reaction times (3-6 min.) with excellent yields (90-97%) and avoids the use of hazardous solvent, requires only catalytic amount of the Ni nps/ stilbite to promote the reaction.

Table 3: Synthesis of benzimidazole derivatives using Ni nps/ stilbite zeolite under microwave irradiation.

Compound	Aldehyde	Time (min)	Yield (%)[a]	M. P. (°C)[b]
3a		3	97	292-293
3b		5	93	204-205
3c		3	96	288-289
3d		4	92	>300
3e		3	92	234
3f		3	90	238
3g		4	93	178-180
3h		6	92	205-207
3i		4	91	225-226
3j		3	95	223-225

[a]*Yields refer to isolated products.* [b]*all products are known and spectroscopic data matched with authentic data*[21].

Recovery and reusability of catalyst: The recovery and reusability of the catalyst was tested by performing same model reaction using recovered catalyst and observed that the percentage yield remains almost same as depicted in the Table 4. This indicates that the catalyst could be recycled without much loss of catalytic activity.

Table 4: Recovery and reusability study of Ni nps/ stilbite zeolite in the reaction of *o*-phenylenediamine and benzaldehyde.

Entry	Cycle	Yield (%)[a]
1	Fresh	97
2	First	97
3	Second	96
4	Third	96

[a]*Yield refers to isolated product.*

If we use the Ni nanoparticle only as a catalyst then it may undergo aggregation and suffers from poisoning under the reaction conditions resulting in deactivation and loss of catalytic activity. Therefore, porous materials like zeolite are used as support. Which increase the surface area and prevents the deactivation and loss of activity.

CONCLUSION: The Ni nps/ stilbite zeolite catalyst is highly efficient for the synthesis of benzimidazole derivatives. Aromatic aldehydes bearing electron-donating and electron withdrawing groups did not affect on yield of products. The catalyst is easily recycled and reuse for several times without much loss in activity.

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