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Original Article

SYNTHESIS OF TETRA-SUBSTITUTED IMIDAZOLE DERIVATIVES BY CONDENSATION REACTION USING ZEOLITE H-ZSM 22 AS A HETEROGENEOUS SOLID ACID CATALYST

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ABSTRACT

Objective: The present work deals with the synthesis of tetrasubstituted imidazoles using environmentally benign and green catalyst H-ZSM-22.

Methods: The synthesized catalyst was characterized by FTIR, XRD and the products by FTIR and NMR.

Results: H-ZSM-22 has been used as an efficient catalyst for an improved and rapid synthesis of 1,2,4,5 tetrasubstituted imidazoles derivatives using reactants: Benzil, Aldehydes, Amines and Ammonium acetate having excellent yield under solvent conditions. Different derivatives of aldehyde have been used in this reaction. For all the synthesized derivatives, ambient reaction time was found to be of 15-30 min.

Conclusion: The main advantage of this reaction is small reaction time, high purity yield, easy work-up and pollution free.

Keywords: H-ZSM-22, One-pot synthesis, Multi-component reaction, Tetra-substituted imidazoles.

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INTRODUCTION

Imidazole and its derivatives represent an important class of Heterocyclic organic compounds that provides important applications of both biological and pharmacological activities. They are having fungicidal [1-2], analgesic [3], anti-inflammatory, [4], antibacterial [5] and antitumor activities [6]. Some members of this family have been widely used as selective inhibitors of P 38 mitogen-activated protein (MAP) kinase [7-8] and B-Raf kinase [9]. In transition metals such as iron, copper and zinc imidazoles derivatives provide main role in potential corrosion inhibitors [10]. Several methods have been used for the synthesis of tetrasubstituted imidazole derivatives; these methods include condensation of diones, aldehydes, primary amines and ammonia [11], condensation of benzoin or benzoin acetate with aldehydes, primary amines and ammonia in the presence of copper acetate [12], four-component condensations of diones, aldehydes, primary amines, and ammonium acetate in HOAc under reflux conditions [13] and conversion of N-(2-oxo) amides with ammonium trifluoro acetate under neutral conditions [14].

Here we have presented a novel, and efficient method for the synthesis of 1,2,4,5 tetrasubstituted imidazoles using H-ZSM-22 as a heterogeneous solid acid catalyst.

MATERIALS AND METHODS

Synthesis of catalyst H-ZSM-22

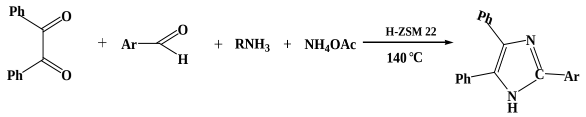
Take SiO_2 and Al_2O_3 at a ratio of 90: 1 in a 100 ml beaker; dissolve 1.0 g of KOH in 4.55 g of deionized water. Add an aqueous solution of 0.44 g $Al_2 (SO4)_3.16H_2O$ prepared in 4.55 g of deionized water. Mix thoroughly. Dissolve separately 2.6 g of 1, 8-diaminooctane in 18.2 g of deionized water and add into the beaker under constant stirring using a magnetic stirrer. Stire the mixture for 30 min until a clear solution is obtained. Add 11.9 g of colloidal silica into 6.74 g of deionized water and add it to the solution under constant stirring. Continue stirring for 90 min until a gel is obtained. Keep the gel in a polypropylene bottle for 24 h for aging. Now keep the gel in a Teflon-lined autoclave for 2 to 3 d at 160 °C for crystallization. The solid phase is then separated by filtration, washed with deionized water, and dried for 12 h. In an oven at 353 K. The conversion of Na-ZSM-22 Zeolite into H-form involves the following procedure:

Mix 9.0 of Na-ZSM-22 g, 7.23 g of NH4Cl and 13.80 ml of deionized water with 0.1 M HCl solution (5 ml) to reach pH 4. Stire the mixture at 60 °C for 6 h. Filter the material under suction and wash with deionized water. After the removal of chloride, the resulting material NH4+-Zeolite is then placed in an oven at 60 0c for 24 h. The ammonium form of Zeolite is converted into H-form by calcination over 60 min at 500 °C

Synthesis of tetrasubstituted imidazoles using ZSM-22 in refluxing ethanol

General procedure

A mixture of Benzil (1 mmol), Amine (1 mmol), Aldehyde (1 mmol), Ammonium acetate (5 mmol), and catalyst (0.08g) in ethanol (5 mL) was heated on the oil bath at 140 °C. After completion of the reaction monitored by TLC. The reaction mixture was cooled at room temperature. Add ethanol to remove catalyst and gives the pure product.



Synthesis of tetrasubstituted imidazoles

Characterization

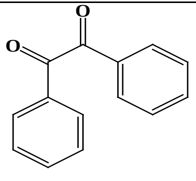
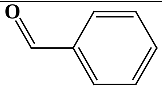
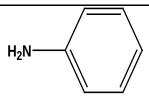
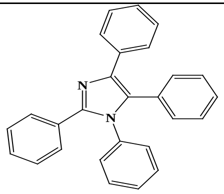
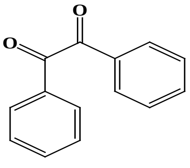
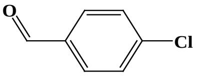
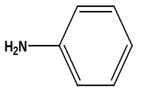
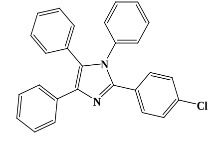
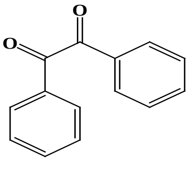
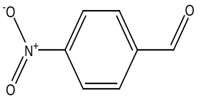
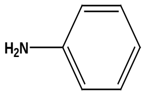
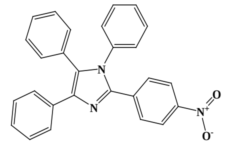
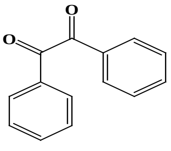
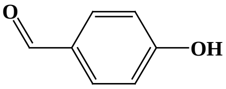
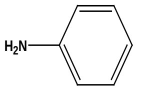
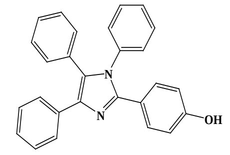
X-Ray diffraction (XRD)

For X-ray diffraction analysis, the samples were placed in aluminum sample holder equipment. Copper Kα radiation at the speed of 20/min gives 2θ range scanning from 0 ° to 60 °. The only d-spacing of interest in X-ray patterns were the basal spacing's along c axis.

Fourier-transform infrared (FT-IR) spectroscopy

In FTIR analysis, ZSM-22 was treated with KBr method which consists of mixing 0.007 g of the sample and 0.1 g of KBr in order to form pellet that allows the passage of light. In FTIR analysis wavelength ranges from 3000 to 400 $cm^{-1,}$ with increments of 500 cm^{-1}. Again Characterization of the products was performed on SHIMADZU FT-IR spectrometer, and the sample was prepared with KBr method and form pellet. The wavelength of spectra ranges from 500–4000 $cm^{-1.}$ NMR of the products was performed on BRUKER ADVANCE II 400 NMR spectrometer.

Table 1: Synthesis of tetra-substituted imidazole derivatives using H-ZSM-22 through a condensation reaction between Benzil, Aldehyde, Amine and Ammonium acetate

Entry	Benzil	Aldehyde	Amine	Ammonium Acetate	Product	Time min	Yield %
1.	 benzil	 benzaldehyde		NH4OAc	 1,2,4,5-tetra-phenyl-1H-imidazole	30	81
2.	 benzil	 p-chloro benzaldehyde		NH4OAc	 2-(4-chlorophenyl)-1,4,5-triphenyl-1H-imidazole	15	86
3.	 benzil	 p-nitrobenzaldehyde		NH4OAc	 2-(4-nitrophenyl)-1,4,5-triphenyl-1H-imidazole	17	87
4.	 benzil	 p-hydroxy benzaldehyde		NH4OAc	 2-(4-hydroxyphenyl)-1,4,5-triphenyl-1H-imidazole	20	76

Spectral data of tetra-substituted imidazole derivatives

Entry 1: 1, 2, 4, 5-Tetraphenyl-1H-imidazole ($C_{27}H_{20}N_2$) White powder; m. p. 210–2150c FT-IR (KBr): υmax (in Cm–1) 3058 (C -H aromatic), 1589 (C=C aromatic), 1448 (C=N) 1H NMR (400 MHz, CDCl3): δ (ppm) 7.11–7.58 (m, 20H, H–Ar) (fig. 3-4)

Entry 2: 2-(4-Chlorophenyl)-1, 4, 5-triphenyl-1H-imidazole ($C_{27}H_{19}ClN_2$): Cream crystal; m. p. 151-156 ◦ C; FT-IR (KBr): υmax (in Cm–1) 3050 (C -H aromatic), 1589 (C=C aromatic), 1448 (C=N) 1065 (C–Cl) 1H NMR (400 MHz, CDCl3): δ (ppm) 7.15–7.37 (m, 17H, H-Ar), 7.5 (d,2H, H-Ar) (fig. 5-6)

Entry 3: 2-(4-Nitrophenyl)-1,4,5-triphenyl-1H-imidazole ($C_{27}H_{19}NO_2N_2$): m. p. 185-1900c; FT-IR (KBr): υmax (in Cm–1) 3056 (C-H aromatic), 1591 (C=C aromatic), 1515 (C=N) 1338 (C–NO2) 1H NMR (400 MHz, CDCl3): δ (ppm) 6.6-7.8 (m, 17H, H-Ar),8.2(d,2H, H-Ar) (fig. 7-8)

Entry 4: 2-(4-Hydroxyphenyl)-1, 4, 5-triphenyl-1H-imidazole ($C_{27}H_{19}OHN_2$): m. p. 278-2800c; FT-IR (KBr): υmax (in Cm–1) 3006 (C-H aromatic), 1577 (C=C aromatic), 1442 (C=N)1085 (C–OH) 1H NMR (400 MHz, CDCl3): δ (ppm) 6.5-7.8 (m, 17H, H-Ar),7.9(d,2H, H-Ar) (fig. 9-10)

RESULTS AND DISCUSSION

Characterization of Zeolites and products

The x-ray diffraction patterns of H-ZSM-22 are shown in fig. 1. The XRD analysis shows that the synthesized materials are crystalline in nature. Further, it was found that in diffraction signals, the sharp peak value (2 θ) for H-ZSM-22 is 23.6 are already reported [15]. FT-IR spectrum of H-ZSM-22 is shown in fig 2. In FT-IR analysis, H-form of ZSM-22 shows absorption band at 450 cm^{-1} which corresponds due to Si, Al-O bond and those at around 1000 and 790 cm^{-1} were respectively due to asymmetric and symmetric stretches of the Zeolite framework.

The main point is to consider the synthesis of tetrasubstituted imidazole derivatives. The reaction was carried out by using H-Form of ZSM-22 through a condensation reaction between Benzil, Aldehydes, Amines and Ammonium acetate using ethanol as solvent at 140 ^{o}C and the products are shown in table 1. It was found that the catalyst is highly selective resulting 87% isolating yield of tetra-substituted imidazole derivative. It was found that without catalyst the reaction could not occur, thus, catalyst plays an important role in this reaction. The synthesis of tetra-substituted imidazole derivatives was carried out by using different amounts of H-Form of Zeolite ZSM-22 at temperature 140oc which occurs at a reaction time of 30 min and the results are shown in table 2. It was noticed that the yield increases from 56%-87% with an increase in the weight of the catalyst from 20 to 80 mg respectively. The product yield remains constant with further increase in the amount of catalyst. For the rest of the studies, we used the weight of catalyst as 80 mg. Also, it was noticed that with further increasing the amount of catalyst, there is an increase in the yield of product, but there is no effect on the reaction time which remains same for all the cases as shown in table 2.

Table 2: Effect of weight of H-ZSM-22 on the synthesis of tetrasubstituted imidazole derivatives

Weight of catalyst Mg	Reaction time min	Yield %
20	30	56
40	30	62
60	30	68
80	30	87

Reaction conditions: substrate

Benzil, Aldehydes, Amines and Ammonium acetate, reaction temperature: 1400c, solvent: ethanol.

The result and catalytic efficiency of H-ZSM-22 for the synthesis of tetrasubstituted imidazoles using various derivatives of Aldehydes, Benzil, Amines and Ammonium acetate are shown in table 1. In all these cases the reactions are highly efficient and completed within 20-30 min. The catalyst shows a good performance in all these cases and the product yield of various derivatives of tetrasubstituted imidazoles are 76%-87%. The product yield of tetra-substituted imidazole derivatives depends on the nature of the functional group on the aromatic ring of the aldehyde. Aldehydes with electron-withdrawing groups afford more pure products compared with electron-donor groups. In all these cases the reaction work is very simple and easy. The catalyst was recycled using ethanol as a solvent which was evaporated. The efficiency of the recovered catalyst was verified by the reaction of Aldehydes, Benzil, Amine and Ammonium acetate and was found between 79-87 % as shown in table 3. The efficiency of the recovered catalyst decreased after three reaction cycles due to the loss of catalyst or catalyst structure during recovering process.

Table 3: Effect of catalyst recycling on percentage yield of tetra-substituted imidazole derivative

Runs	% Yield
1st run	87
2nd run	86.4
3rd run	83.3
4th run	79.6

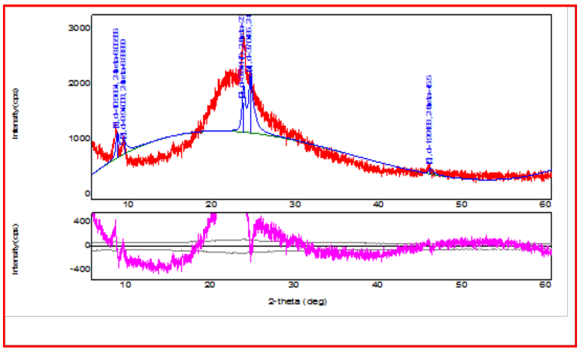


Fig. 1: XRD spectrum of H-ZSM-22

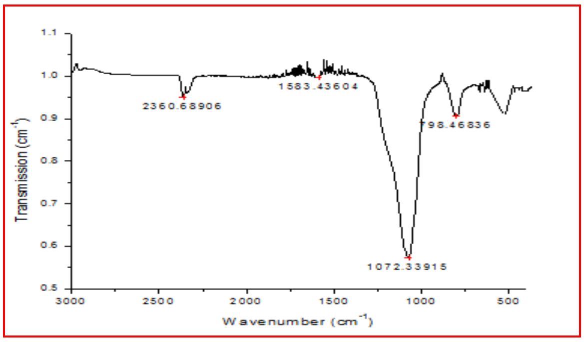


Fig. 2: FTIR spectrum of H-ZSM-22

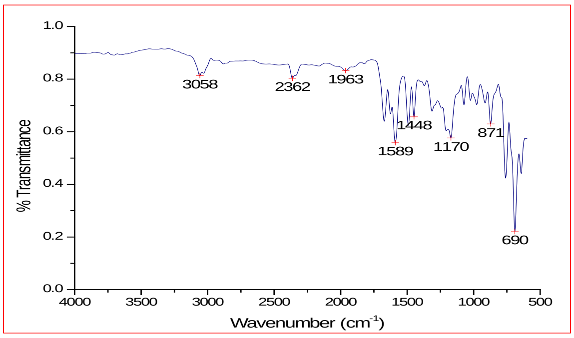


Fig. 3: FTIR spectrum of 1, 2, 4, 5-tetra phenyl 1H-imidazole

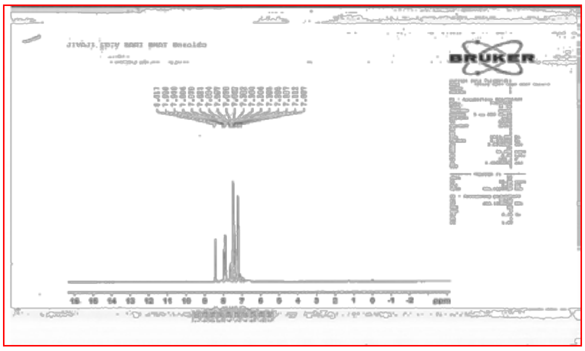


Fig. 4: 1H-NMR spectrum of 1, 2, 4, 5-tetraphenyl-1H-imidazole

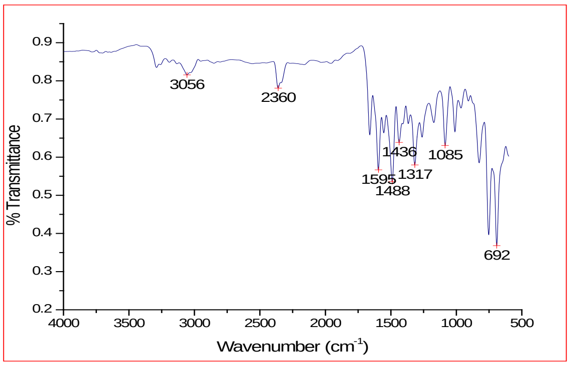


Fig. 5: FTIR spectrum of 2-(4-chlorophenyl) 1, 4, 5-triphenyl-1H-imidazole

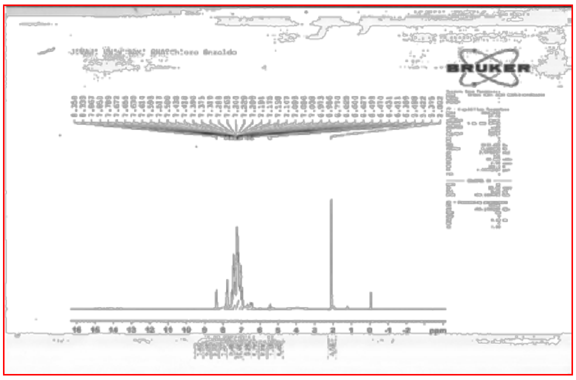


Fig. 6: 1H-NMR spectrum of 2-(4-chlorophenyl) 1, 4, 5-triphenyl imidazole

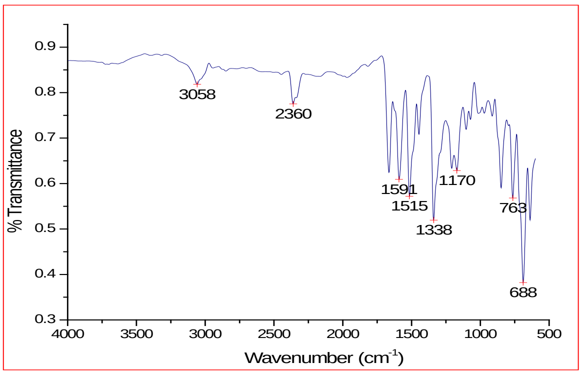


Fig. 7: FTIR spectrum of 2-(4-nitrophenyl) 1, 4, 5-triphenyl 1H-imidazole

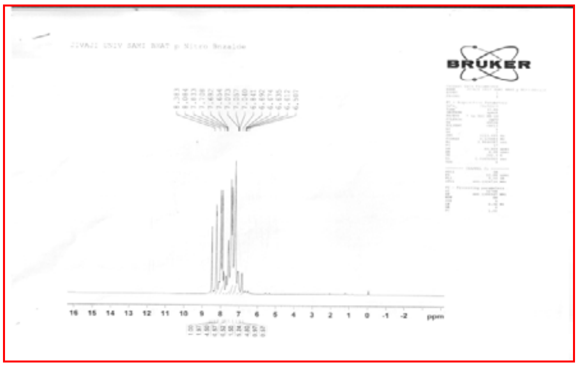


Fig. 8: 1H-NMR spectrum of 2-(4-nitrophenyl) 1, 4, 5-triphenyl 1H-imidazole

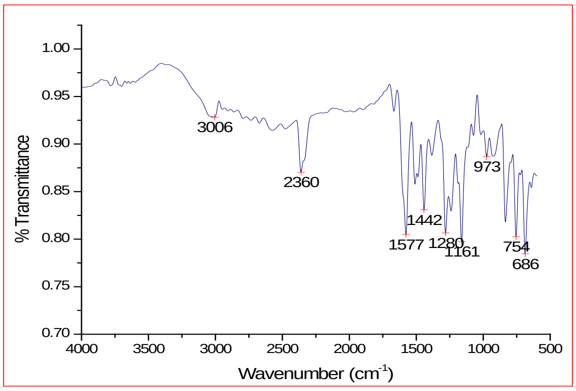


Fig. 9: FTIR spectrum of 2-(4-Hydroxyphenyl) 1, 4, 5-triphenyl 1H-imidazole

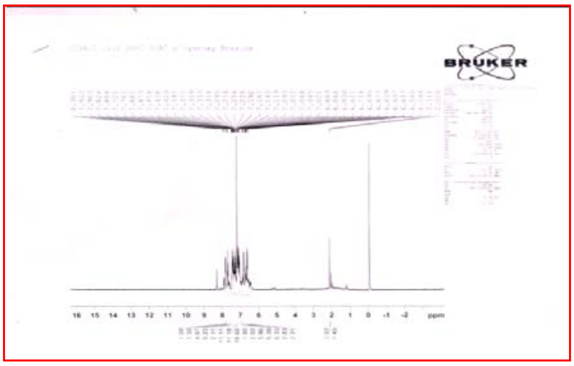


Fig. 10: 1H-NMR spectrum of 2-(4-Hydroxyphenyl) 1, 4, 5-triphenyl 1H-imidazole

CONCLUSION

H-ZSM-22 has been introduced as an efficient catalyst for the synthesis of tetrasubstituted imidazoles. This catalyst provides an alternate way for the above synthesis in terms of small reaction time, better product yield, minimum waste production, reusability of the catalyst as compared to other catalysts. In conclusion, we have demonstrated a simple method for the synthesis of tetrasubstituted imidazoles using H-ZSM-22 as an eco-friendly, inexpensive and efficient catalyst.

ACKNOWLEDGMENT

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CONFLICT OF INTERESTS

Declare none

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