



Original Research Article

Nano CeO₂ as a new green and recyclable catalyst for the synthesis of 2-aryl Benzoxazole

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ARTICLE INFORMATION

Received: 28 February 2021
Received in revised: 9 May 2021
Accepted: 16 May 2021
Available online: 21 June 2021

DOI: [10.48309/JMNC.2021.4.1](https://doi.org/10.48309/JMNC.2021.4.1)

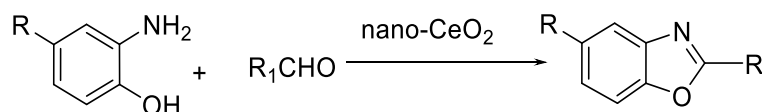
KEYWORDS

Nano-CeO₂
O-aminophenols
Aldehydes
2-Arylbenzoxazole

ABSTRACT

2-Aryl benzoxazole derivatives have been reported to have a wide range of biological and pharmacological activities. Some of these derivatives have anticoagulant, antispasmodic, diuretic, anti-cancer and anti-anaphylactin properties. In this research, a simple method for the synthesis of high-efficiency 2-aryl benzoxazole through the reaction of aminophenols and aldehyde derivatives under solvent-free conditions in the presence of a catalytic amount of nano-CeO₂ is presented. The results revealed that this synthetic reaction is very simple and benzoxazole derivatives produced with good yields compared to other studies. Mild conditions, high speed and short reaction time, simplicity of product separation process, high efficiency and purity of synthesized derivatives are the advantages of the proposed method. As shown in Table 5, the highest efficiency (95%) in a short time (15 min) was obtained in this study, which is very important compared to other previous methods presented.

Graphical Abstract



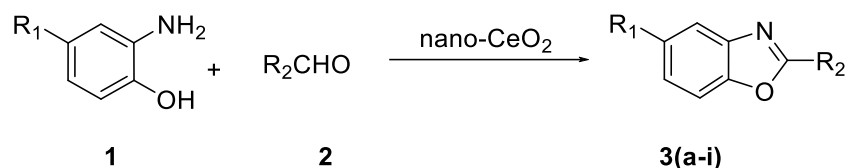
Introduction

Benz-fused azoles are an important group of organic molecules and are important heterocyclic scaffolds common in biologically active and pharmaceutically active compounds [1]. Benzoxazoles are present in a variety of natural products and are very important in the discovery of drugs [2]. Benzoxazoles are utilized as HIV protease inhibitors [3], partial 5-HT₃ receptor agonists [4], HT uptake inhibitors [5], thrombin inhibitors [6], COX inhibitors [7], virus antagonists, and siotmagalu yansanibe virus protease inhibitors [8].

2-Aryl benzoxazoles are important biaryl drugs and have various biological activities including antitumor and antimicrobial properties [9]. For instance, recently 2-aryl benzoxazole JI9561, isolated from *Streptomyces* extract and acts as a cytotoxic metabolite [10]. 2-Aryl benzoxazoles are also used in industry as vulcanization accelerators, antioxidants and as narcotics in light emitting organic electroluminescence apparatus [11, 12]. Several methods have been developed for

the synthesis of 2-aryl benzoxazoles. The most common method for the synthesis of 2-aryl benzoxazoles is the reaction between a carboxylic acid or benzoyl chloride or aldehyde and aminophenol [13–16].

However, most of these methods involve the use of harsh conditions, expensive reagents, long reaction times, and difficult purification methods. As a result, there is a need to devise new methods for the synthesis of these compounds under more appropriate conditions. In our effort to develop new catalytic systems, in this study, we presented a suitable and efficient protocol for the preparation of 2-aryl benzoxazoles through the reaction of aldehydes and aminophenols in the presence of a catalytic amount of nano-CeO₂ in solvent-free conditions (Scheme 1). In this research, nano-CeO₂ catalyst has been used for the synthesis of benzoxazole compounds and also compared to other articles, the reaction has been done in a shorter time and higher efficiency.



Scheme 1. Synthesis of 2-arylbenzoxazole derivatives

In recent years, nanoparticles due to the amazing properties that have shown themselves in various industries such as textile, defense and security industries, medical fields, separation and filtration industries, chemical industries, paint and coating industries, oil industries and industries aerospace, the automotive industry has received a lot of attention. Nanoparticles are materials that have at least one dimension at the nano scale. As the nanoparticle size decreases, the effective surface-to-particle volume ratio increases, the

surface effects become stronger, and the catalytic properties increase. nano-CeO₂ has very important applications in industry, including them as a catalyst to convert harmful exhaust gases from car exhaust and convert them into less harmful gases. Another important application is in the field of production and storage of hydrogen. The main reason for these applications is the presence of oxygen vacancies on the surface of the series that act as active sites in the reactions [17]. In this paper, we investigate the application of

nano-CeO₂ as a catalyst in the synthesis of benzoxazole derivatives.

Experimental

Materials and methods

All products were characterized by mp, IR, ¹H NMR and GC/MS. Melting points were measured by using the capillary tube method with an electro thermal 9200 apparatus. ¹H and ¹³C NMR spectra were recorded on a Bruker DRX Avance spectrometer at 500 and 125 MHz, respectively, with CDCl₃ as a solvent. IR spectra were recorded from KBr disk on the FT-IR Bruker Tensor 27. GC/MS spectra were recorded on an Agilent Technologies 6890 network GC system and an Agilent 5973 network Mass selective detector. Thin layer chromatography (TLC) on commercial aluminum-backed plates of silica gel, 60 F254 was used to monitor the progress of reactions. All products were characterized by spectra and physical data.

Preparation of Nano-CeO₂

Nano-oxide powder was prepared using CeCl₃·7H₂O (Merck, purity > 99.5%) and NH₃ (Merck, purity > 99%). Initially CeCl₃·7H₂O was dissolved in deionized water, the mixture was then stirred for 30 min, after which NH₃ (0.5 mol) was added to aqueous solution until a gel form was formed at a pH of about 8.5. The resulting synthetic gel was then washed with distilled water and dried at 80 °C for 24 hours. The gel was dried and calcinated at 700 °C for two hours. The scanning electron microscope (SEM, SU-70, Hitachi) and transmission electron microscope (TEM, TF 20 Tecnai G2 200 kV FEI) images of the catalyst are demonstrated in [Figure 1](#) and [2](#) [18].

The XRD pattern of the samples were carried out to identify crystalline phases and to estimate the crystalline sizes. [Figure 3](#) demonstrates the XRD morphology of CeO₂ nanoparticles calcined at 1000 °C for 3 h. The exhibited picks correspond to the (111), (200), (220), (311), (222), (400), (331) and (420) of a cubic fluorite structure of CeO₂ identified using the standard data [18].

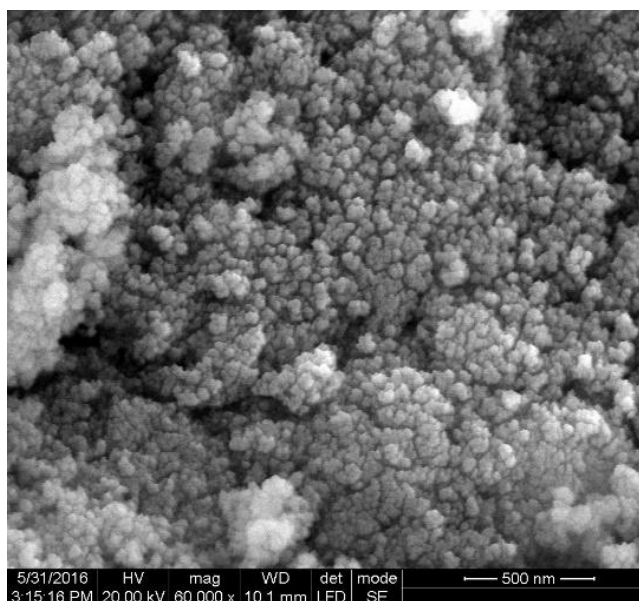


Figure 1. SEM spectra of nano CeO₂

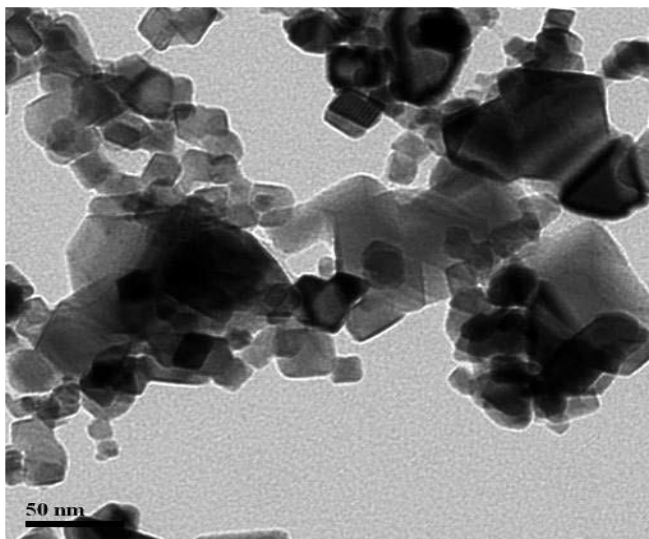


Figure 2. TEM spectra of nano CeO₂

Typical procedure for preparation of 2-arylbenzoxazole derivatives

A mixture of *o*-aminophenol (1 mmol), aldehydes (1 mmol) and Nano-CeO₂ (0.05 g) was heated at 90 °C for the indicated time (Table 1). After completion of the reaction, as indicated by TLC, the reaction mixture was extracted with dichloromethane (3×10 mL) then, the reaction mixture was chromatographed over PTLC using petroleum ether-ethyl acetate (4:1) to afford the pure product.

2-*n*-phenyl benzoxazol (3a): mp 103 °C (lit [19]. mp 102 °C), IR (KBr) ($\nu_{\max}/\text{cm}^{-1}$): 3062, 1625, 1563, 1462, 1451, 1333, 1242, and 1042. ¹H NMR (CDCl₃, 500 MHz): δ 8.2–8.4 (m, 2H), 7.3–7.9 (m, 7H).

2-*p*-tolyl benzoxazol (3b): mp 113–115 °C (lit [19]. mp 113–114 °C), IR (KBr) ($\nu_{\max}/\text{cm}^{-1}$): 3057, 1632, 1546, 1457, 1242 and 1054, ¹H NMR (CDCl₃, 500 MHz): δ 8.07–8.41 (m, 2H), 7.09–7.63 (m, 6H), 2.47 (s, 3H).

Results and Discussion

To optimize the amount of catalyst, the effect of solvent and temperature, reaction of *o*-

aminophenol (1 mmol) with aldehydes (1 mmol) in the presence of a catalytic amount nano-CeO₂ was selected as the model reaction. After optimizing the reaction conditions, different aldehydes, both with electron donating and electron withdrawing groups were investigated for the present protocol. It can be clearly seen from data that, all reactions proceeded were performed well and also produced the corresponding products in good yields and in very short reaction times (Table 1).

In other words, we accomplished effects of varied solvents on the synthesis of 3a. This reaction was performed in presence of different solvents. For instance, water, chloroform, Ethanol, dichloromethane and solvent-free were used. It is evident from data that, the best yields were achieved in Solvent-free condition (Table 2).

To optimize the amount of catalyst, various amounts (0.01, 0.02, 0.03, 0.05, and 0.08 g) of cerium oxide nano-catalyst were used. The results presented in the Table 3 revealed that 0.05 g of cerium oxide nano-catalyst had the best efficiency (Table 3).

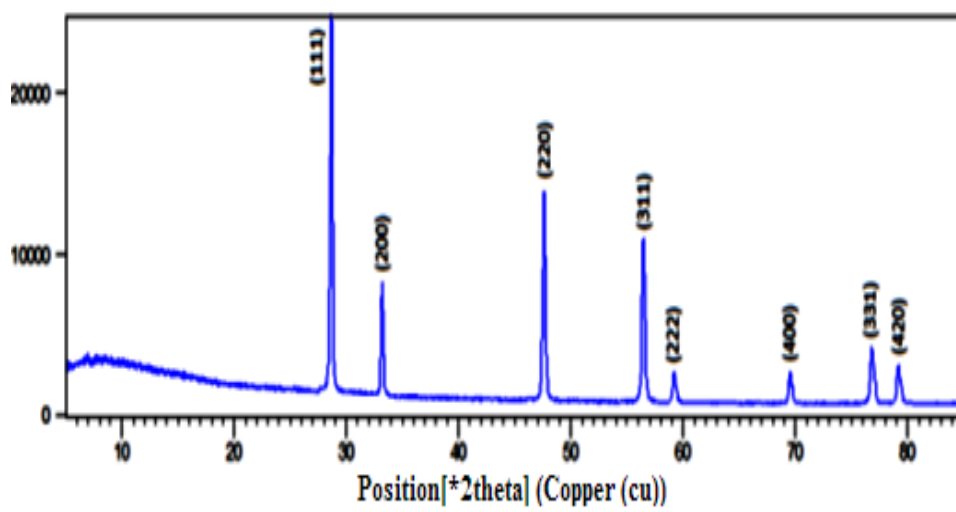


Figure 3. XRD spectra of nano CeO₂

Table 1. Synthesis of 2-arylbenzoxazoles catalyzed by nano-ZrO₂

Entry	R1	R2	Product	Time (min)	Yield(%) ^a
1	H	H	3a	15	95
2	H	CH ₃	3b	15	90
3	H	Cl	3c	15	97
4	CH ₃	H	3d	15	98
5	CH ₃	CH ₃	3e	15	92
6	CH ₃	Cl	3f	15	97
7	Cl	H	3g	15	92
8	Cl	CH ₃	3h	15	93
9	Cl	Cl	3i	15	97

^aYields of isolated products

Table 2. Synthesis of **3a** in the presence of different solvents using nano CeO₂ as a catalyst

Entry	Solvent	Yield(%) ^a
1	DMF	92
2	C ₂ H ₅ OH	87
3	CH ₃ CN	85
4	CHCl ₃	71
5	Solvent-free	95
6	water	91

^aYields of isolated products

Table 3. Comparison of amount of catalysts for the synthesis of **3a**

Entry	Solvent	Yield (%) ^a
1	0.02 g	80
2	0.03 g	89
3	0.05 g	95
4	0.08 g	95

^aYields of isolated products

After the reaction, 10 mL of ethyl acetate was added to the compounds on filter paper containing catalyst. The mixture was stirred at room temperature for 5 min using a magnetic stirrer. The reaction mixture was filtered, and the catalyst remained on filter paper due to its insolubility in ethyl acetate solvent. Then, in

order to reuse the catalyst, the filter material was washed several times with acetone. After drying, the reaction was repeated to check the potency of the catalyst (Table 4). As seen in the Table 4, the reaction can be performed up to five times with good efficiency by the recycled catalyst.

Table 4. Reuse of the nano ZrO₂ for synthesis of **3a**

Entry	Run	Yield (%) ^a
1	First	95
2	Second	91
3	Third	90
4	Fourth	88
5	Fifth	85

^aYields of isolated products

Table 5. Comparison of various catalysts for the synthesis of **3a**

Entry	Catalyst	Yield (%)	Time(h)	Reference
1	AuCl ₃	66	6	[20]
2	AuCl	76	6	[20]
3	NaAuCl ₄ ·2H ₂ O	88	6	[20]
4	Activated carbon	78	4	[21]
5	Nano-MnO ₂	78	16 min	[22]
6	TiO ₂ /ZrO ₂	91	15 min	[23]
8	Nano-CeO ₂	95	15min	Present study

By comparing the reaction results with other methods, we find that the nano-CeO₂ catalyst performs the reaction in shorter time and with higher efficiency (Table 5).

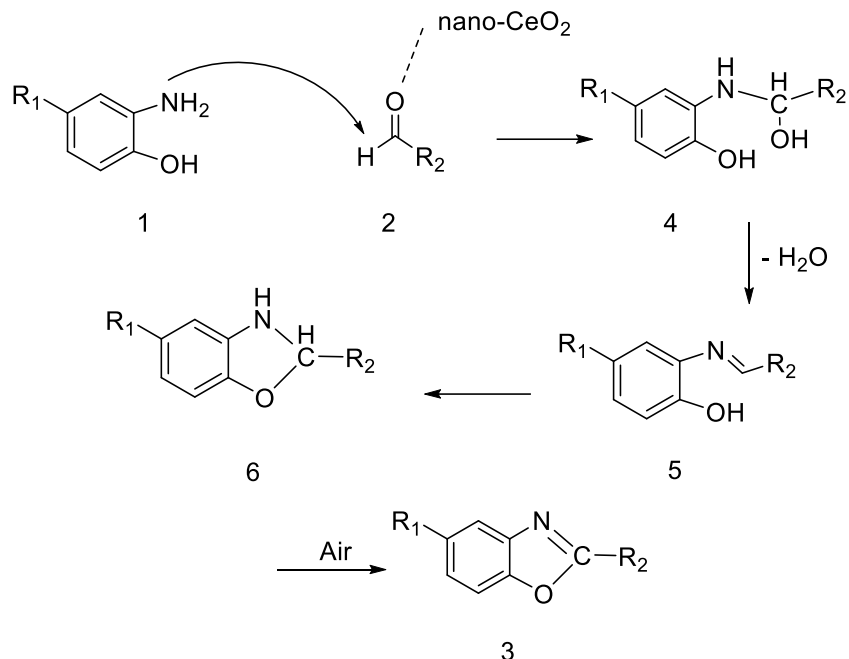
The following mechanism is proposed for the synthesis of 2-aryl benzoxazole derivatives in the presence of nano-CeO₂ (Scheme 2).

First, the o-amino phenol attacks the catalyst-activated aldehyde, and eventually loses water, resulting in an intermediate 5. The hydroxy group then attacks the double bond and after oxidation, the desired product is obtained.

Conclusions

In this research study, we developed a novel, simple and efficient method for the synthesis of

2-aryl benzoxazole derivatives by using nano-CeO₂ as a catalyst with high efficiency and short time reaction. Nano-CeO₂ catalysts are recyclable, heterogeneous, environmentally benign solid catalysts possessing desirable properties such as high thermal and hydrothermal stability. The target nano CeO₂ is prerequisite in green chemistry. There are some remarkable properties which are playing noticeable roles, such as: mildness of the conversion, simple experimental part, and also ability of compatible with various functional groups, impressive and efficient yields, short reaction times, and the easy workup procedure. Finally, these features make target procedure more attractive to synthesize a variety of these derivatives. As shown in Table 5, the highest efficiency (95%) in a short



Scheme 2. Mechanism of the synthesis of 2-arylbenzoxazole derivatives

time (15 min) was obtained in this study, which is very important compared to other previous methods presented. As shown in Table 3, the best efficiency (95%) was obtained in the solvent-free condition.

Acknowledgments

The authors gratefully acknowledge the support of this work by the Payame Noor University.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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How to cite this manuscript: Bita Baghernejad*, Reyhaneh Samaie, Nano CeO₂ as a new green and recyclable catalyst for the synthesis of 2-aryl Benzoxazole. *Journal of Medicinal and Nanomaterials Chemistry*, 3(4) 2021, 236-243. DOI: [10.48309/JMNC.2021.4.1](https://doi.org/10.48309/JMNC.2021.4.1)