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Orginal Research Article

Sulfonic acid supported on Fe_2O_3/VO_2 nanocatalyst: A highly efficient and reusable nanocatalyst for synthesis of spirooxindole derivatives

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Spirooxindole
Isatin
1,3-Cyclohexadiene
Malonitrile

ABSTRACT

$Fe_2O_3/VO_2/SO_3H$ nanocatalyst is reported for simple, and three-component reaction for the synthesis of spirooxindole derivatives by the reaction of isatin, 1,3-cyclohexadiene and malonitrile in solvent-free condition. The method allows easy construction of a library of spirooxindoles in moderate to good yields. The prepared nanocomposite was characterized using fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy (SEM), x-ray diffraction (XRD) analysis, and energy dispersive x-ray spectroscopy (EDX). The nanocomposite was easily recovered using an external magnet and reused several times without a significant loss of the efficiency.

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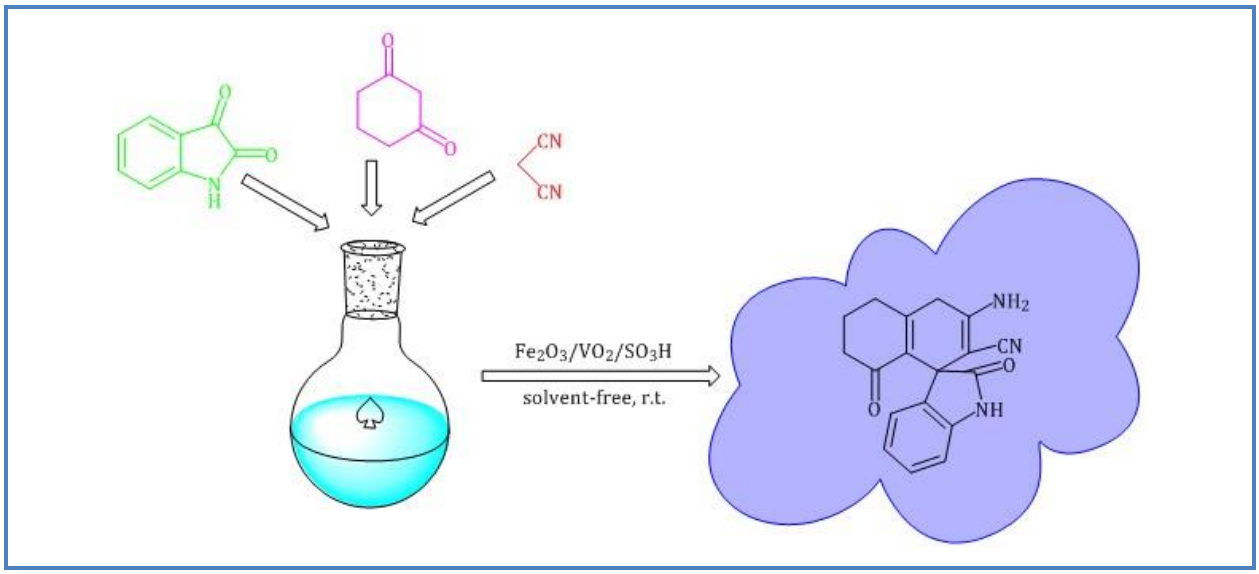
Graphical Abstract



Introduction

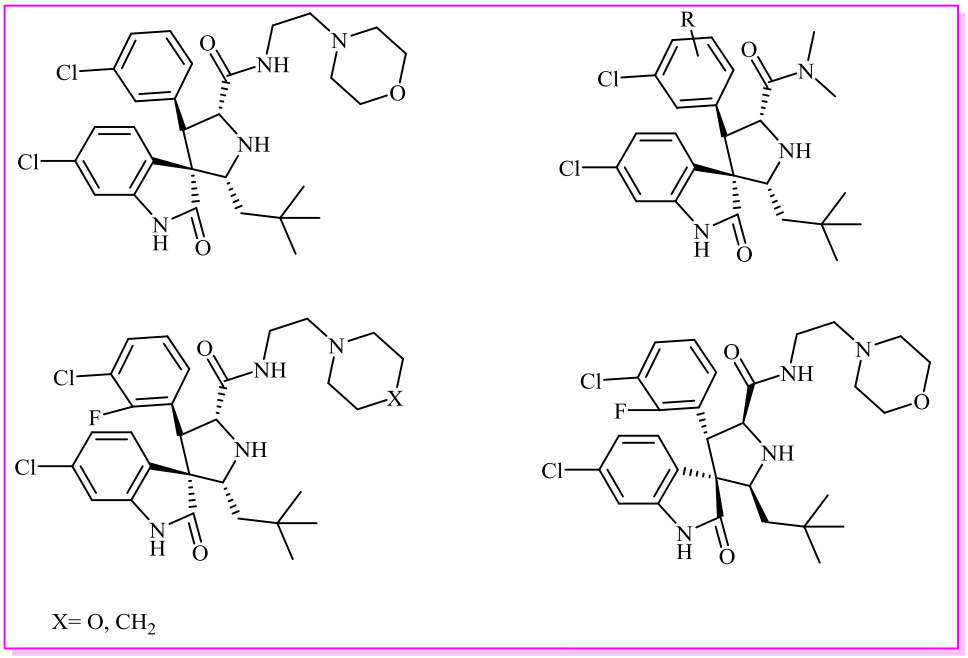
Nanocatalysis has become an important field in organic chemistry due to its high activity, selectivity, and efficient supports for the immobilization of homogeneous catalysts [1]. The nanoscale size, shape and surface area to volume ratio imparts unique properties to nanocatalysts because of the structural and electronic changes which differentiates them from the bulk materials [2]. In the era of nanocatalyst, the reuse of catalysts is a major factor for ecofriendly and economic sustainability demands [3]. Among the various nanoparticles as the core support, Fe core are arguably the most extensively studied [4].

The synthesis of spirooxindole compounds has some challenges due to the high bioactivities and specific physical properties of the spirooxindole compounds [5–7]. The spirooxindole skeletons have high potential for the development of some medicinal agents [8]. Recently, nonpeptide small molecule inhibitors of the MDM2-p53 interaction were successfully designed (Scheme 1) [9].

In recent years, many synthetic methods and efficient catalysts have been developed for the synthesis of spirooxindole including [10–13]. Various catalysts including carbon–SO_3H [14], magnesium oxide (MgO) [15], ZnS NPs [16], triethylbenzyl ammonium chloride (TEBA) [17], $[BMIm]BF_4$ [18], L-proline [19], ethylenediaminediacetate [20], indium chloride ($InCl_3$) [21], triethyle amine (NEt_3) [22], electrogenerated base (NaBr/ROH) [23], cyclodextrin [24], and surfactant metal carboxylates [25] have been studied till now. Although a variety of methods and catalyst are available, some of them have disadvantages such as, harsh reaction conditions, long reaction times, and use of expensive, unsafe, and unreusable catalysts. Therefore, the development

of a new and simple synthetic method for the preparation of spirooxindole derivatives has become an challenge.

Therefore, in this study, synthesis of the sulfonic acid supported on Fe_2O_3/VO_2 nanocatalyst as an efficient, non-toxic, readily available, and simply synthesized and of high surface area resulting in high catalyst loading capacity for immobilization of homogeneous catalysts. We sought development of this procedure by synthesis and characterize $Fe_2O_3/VO_2/SO_3H$ as a nanocatalyst for the synthesis of spirooxindole derivatives by the reaction of isatin, 1,3-cyclohexadiene and malonitrile in solvent-free condition at the room temperature.



Scheme 1. Examples of new inhibitors of the MDM2-p53 interaction

Experimental

Matreials and methods

The reactions were performed under the normal atmosphere condition. All reagents and solvents used in this work purchased from Merck. Analytical thin layer chromatography was performed using Merck silica gel GF254 plates. Plate chromatography was performed using silica gel 60 PF254+366.

General procedure of spirooxindole synthesis

A mixture of isatin (1 mmol), 1,3-cyclohexzadione (1 mmol), malonitrile (1 mmol) and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst (0.003 g) was stirred at 25 °C in solvent-free condition. After

completion of reaction, the reaction mixture was diluted with water (60 mL) and extracted with Characterization of catalyst.

Results and discussion

$Fe_2O_3/VO_2/SO_3H$ nanocatalyst was characterized using fourier transform infrared (FT-IR) spectroscopy, scanning electron microscopy (SEM), and x-ray diffraction (XRD). The FT-IR spectra (Figure 1) demonstrates a stretching vibration at about 590 cm^{-1} for Fe–O–Fe, 1800 and 1350 cm^{-1} for S=O group of spirooxindole. The FT-IR spectrum in this figure is similar to the previous reports and no certain change in the position and shape of the bands has been found, which indicates the structure of the compound is preserved.

The particle morphology and textural properties of the nanoporous were studied using SEM. The SEM images of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst at different magnifications are shown in Figure 2.

The SEM images of the synthesized nanocatalyst confirm the formation of nanoparticles with high quality conical shaped. The average size of nanocatalyst is about 130–150 nm.

XRD is an effective technique for the investigation of the major properties of nano structures. The XRD spectrum of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst is displayed in Figure 3. The XRD pattern of the catalyst shows average size 21 nm by debye-scherrer equation.

The EDS results showed the incorporation of V, Fe, O, and S inside the nanocatalyst (Figure 4).

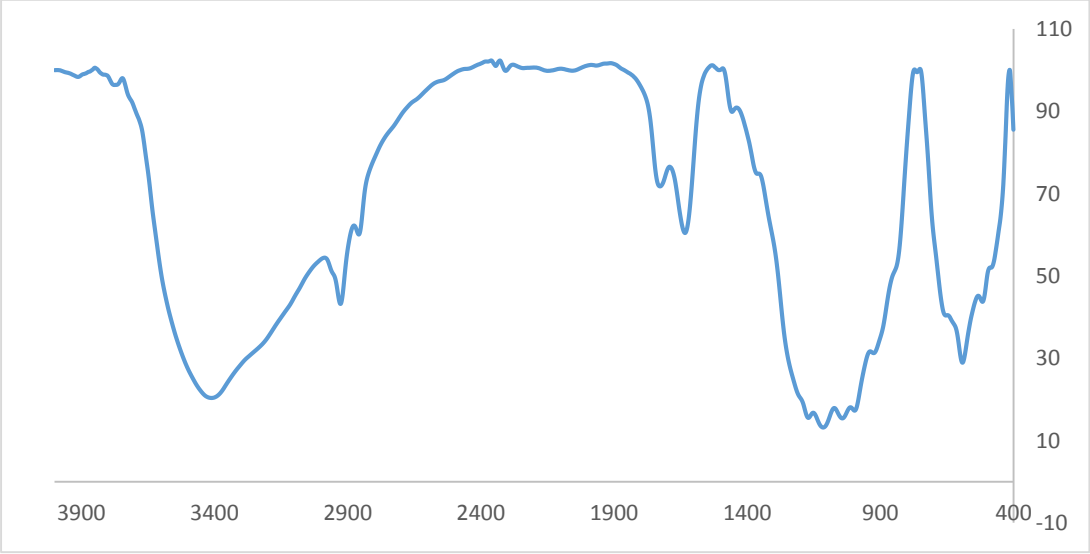


Figure 1. FT-IR spectrum of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst

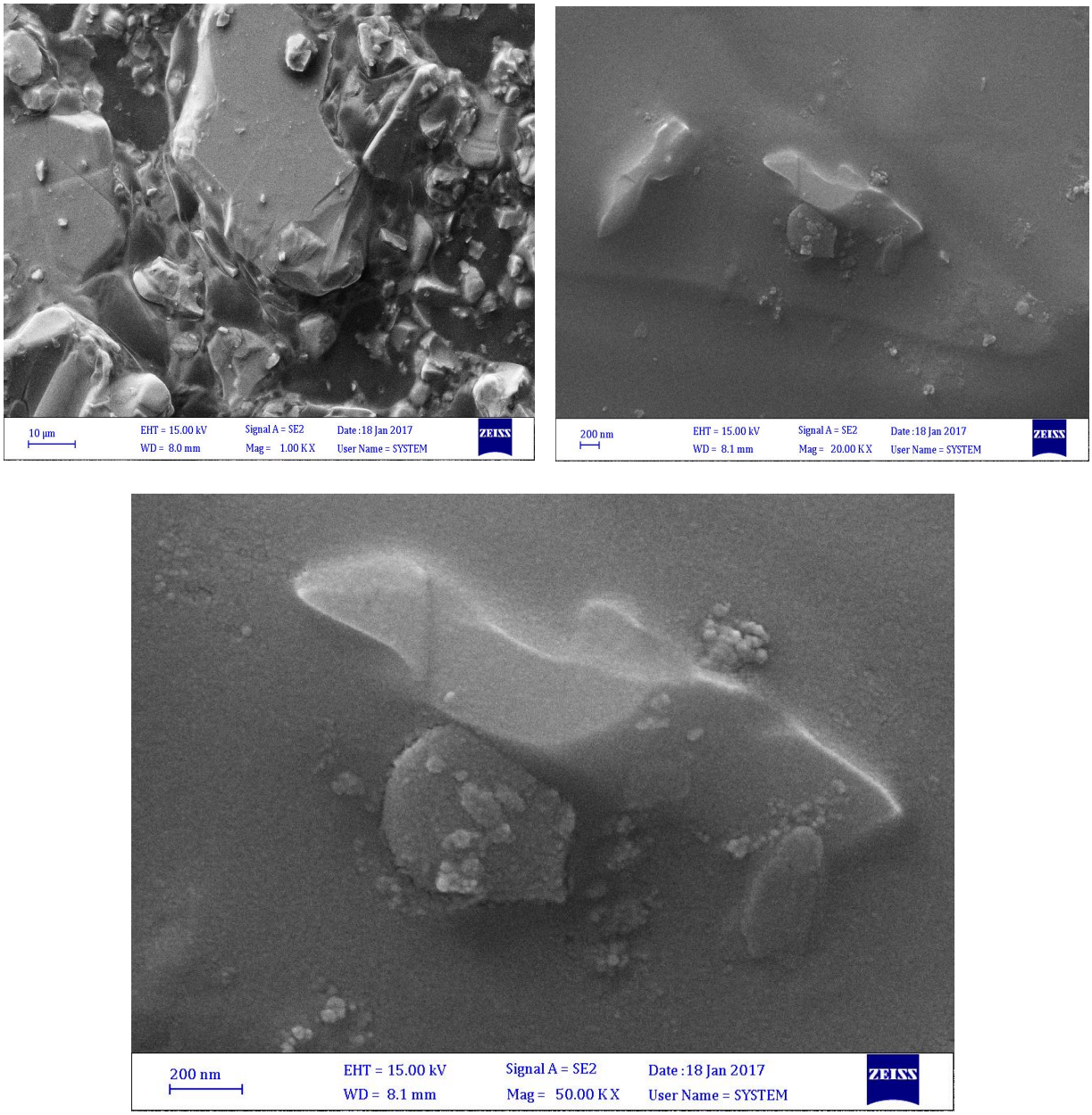


Figure 2. Surface morphology of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst

Catalytic study in the synthesis of spirooxindole

After successful characterization of the prepared $Fe_2O_3/VO_2/SO_3H$ nanocatalyst, the catalytic activity in the synthesis of spirooxindole was studied. To the best of our knowledge, our first step was to optimize reaction to achieve information about the role of amount of catalyst, kind of solvent, temperature and time. In the preliminary experiment, the reaction between isatine, 1,3-cyclohexzadione and malonitrile was studied in the presence of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst at 25

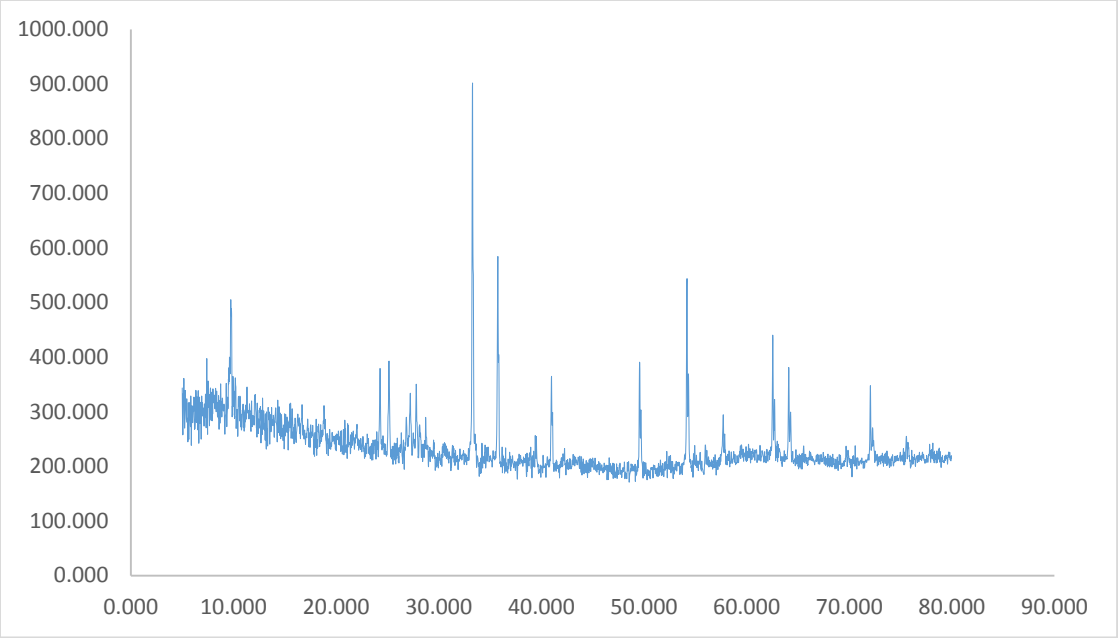


Figure 3. XRD spectrum of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst

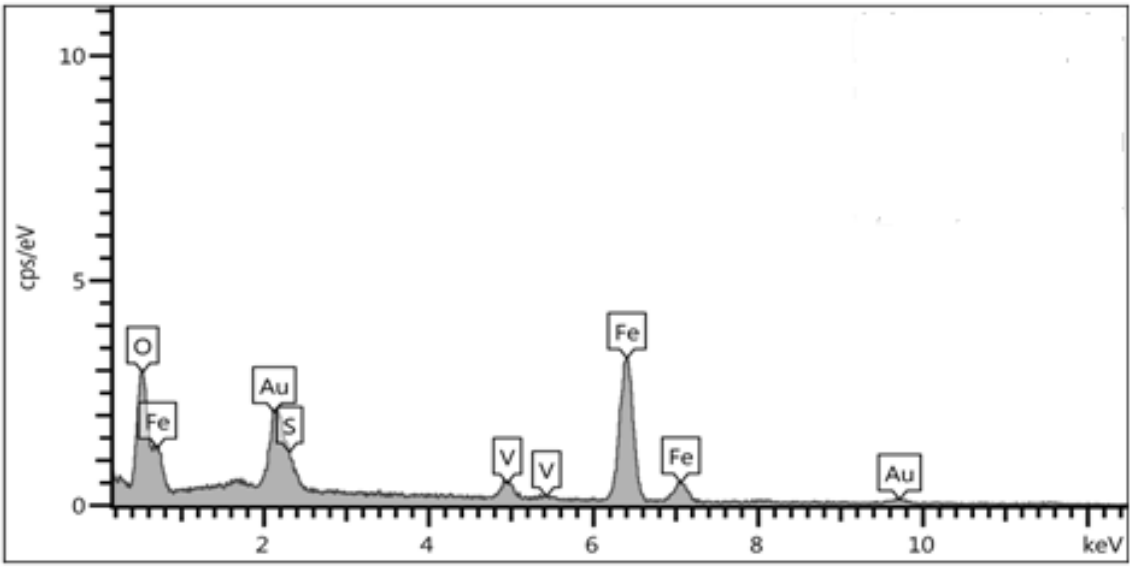


Figure 4. EDX spectrum of $Fe_2O_3/VO_2/SO_3H$ nanocatalyst

°C in solvent-free condition. The effect of temperature on the reaction was studied. The progress of the reaction depended on the temperature; the reaction was found to be complete in 25 °C (Table 1). Afterwards of all, the influence of amount of $Fe_2O_3/VO_2/SO_3H$ was also examined. The results shown, the yield of production was depended on amount of $Fe_2O_3/VO_2/SO_3H$. When the amount of $Fe_2O_3/VO_2/SO_3H$ was decreased to 0.002 and 0.001 g, the reaction was yielded 88% and 75%, respectively (Figure 5, entry 1 and 2). Significant proceed of the reaction was also observed in the

presence of 0.003 gr of $Fe_2O_3/VO_2/SO_3H$ as the product was yielded 95%. According to Figure 5, the highest yield and shortest reaction time of product are obtained in the presence of 0.003 g of $Fe_2O_3/VO_2/SO_3H$ in solvent-free condition at room temperature (Figure 5, entry 3).

Table 1. Temperature optimization in synthesis of spirooxindole

Entry	Temperature (°C)	Time (min)	Yield (%)
1	25	10	90
2	50	10	85
3	80	10	80
4	100	10	88

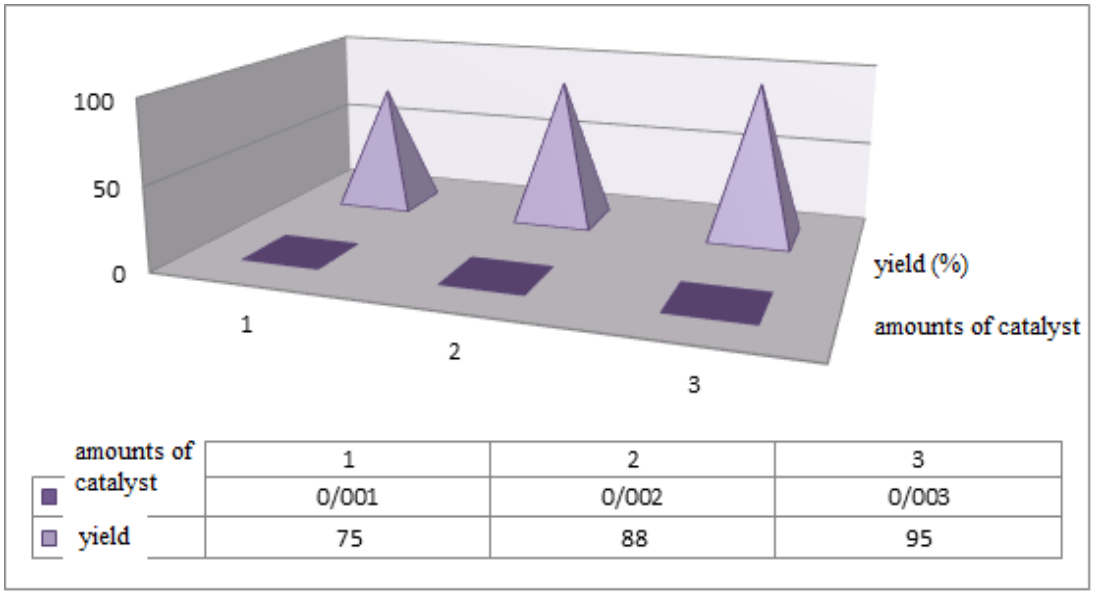


Figure 5. Reaction condition: isatin (1 mmol), 1,3-cyclohexzadione (1 mmol), malonitrile (1 mmol) and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst (0.003 g), room temperature in H_2O (2 mL)

In the first step, we have tried solvents such as EtOH, EtOAc, *n*-Hexane, H_2O and solvent-free conditions. According to the results shown in Table 2, spirooxindole was obtained in 95% yield in siolvent free conditions (Table 2, entry 1).

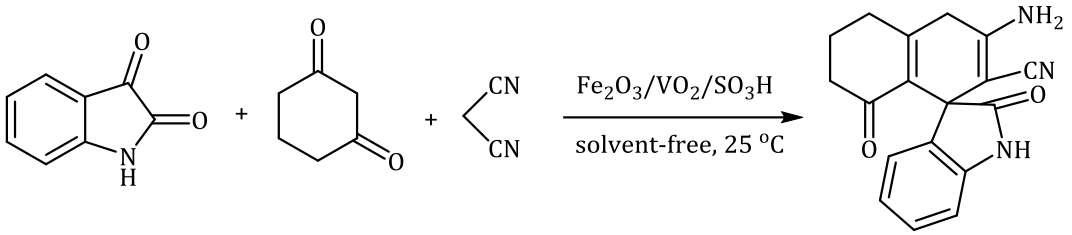
Eventually, spirooxindole derivatives were synthesized by the reaction of isatin, 1,3-cyclohexzadione, malonitrile and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst at the room temperature in solvent-free condition with excellent yields and optimized reaction conditions. The results are summarized in Table 3.

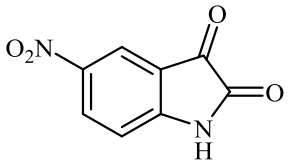
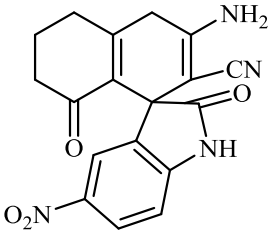
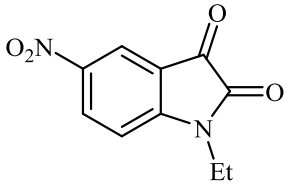
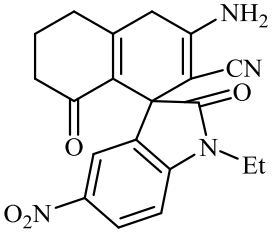
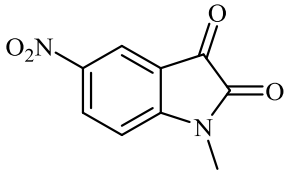
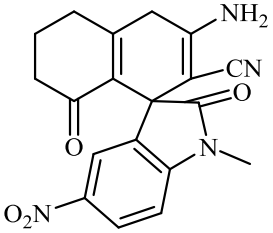
Table 2. Study of influence of solvent on synthesis of spirooxindole in the presence of $Fe_2O_3/VO_2/SO_3H$[a]

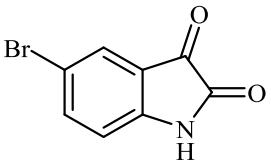
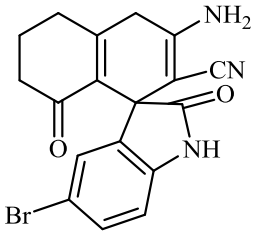
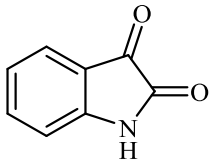
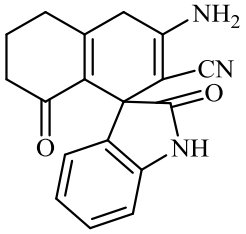
Entry	Solvent	Time (min)	Yield (%)
1	Solvent-free	20	95
2	Ethanol	20	80
3	Ethylacetate	20	70
4	*n*-Hexan	20	60
5	H_2O	20	88

[a] Reaction condition: isatin (1 mmol), 1,3-cyclohexzadione (1 mmol), malonitrile (1 mmol) and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst (0.003 g), room temperature in solvent-free condition

Table 3. Spirooxindole synthesis under optimized conditions[a]



Entry	Isatine	Product	Time (min)	Yield (%)
1			5	98
2			5	90
3			5	90

4			5	85
5			5	95

[a] Reaction condition: isatin (1 mmol), 1,3-cyclohexzadione (1 mmol), malonitrile (1 mmol) and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst (0.003 g), room temperature in solvent-free condition

Recovery and reusability

The recovery and reusability of catalysts are valuable advantages in catalysis research, which makes them very favorable from commercial and economic points of view. In this respect, the reusability of $Fe_2O_3/VO_2/SO_3H$ in the syntheses of product spirooxindole was investigated by repeatedly separating the $Fe_2O_3/VO_2/SO_3H$ from the reaction mixture, washing it and then reusing it over 4 successive runs. After each run, the catalyst was separated from the reaction mixture by simple decantation, and then washed with copious amounts of acetone to remove any physisorbed reagents and dried. Then, the recovered catalyst was reused for a subsequent fresh batch of the reaction. The catalytic activity was studied for several successive runs, showing similar activity (Table 4).

Table 4. Catalyst recycling studies

Entry	Time (min)	Yield (%)
1	10	5
2	10	90
3	10	88
4	10	85

Conclusion

In this study, we developed a straightforward synthetic method for the preparations spirooxindole from isatin, 1,3-cyclohexzadione, malonitrile and $Fe_2O_3/VO_2/SO_3H$ nanocatalyst at the room temperature in the solvent-free condition. It is noteworthy that all products were obtained in

good to excellent yields. The important feature of this method is that we used $Fe_2O_3/VO_2/SO_3H$ as a recyclable and porous catalyst. This protocol revealed some excellent characteristics including: high catalytic activity, simple operation, high yields, simple preparation, and high efficiency in comparison with the available materials.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1]. Polshettiwar V., Varma R.S. *Green Chem*., 2010, **12**:743

[2]. Shylesh S., Schunemann V., Thiel W.R., *Angew. Chem. Int. Ed*., 2010, **49**:3428

[3]. Gawande M.B., Brancoa P.S., Varma R.S. *Chem. Soc. Rev*., 2013, **42**:3371

[4]. Nasir Baig R.B., Varma R.S., *Green Chem*., 2013, **15**:398

[5]. Yu J., Shi F., Gong L. *Acc. Chem. Res*., 2011, **44**:1156

[6]. Shanmugam P., Viswambharan B., Madhavan S. *Org. Lett*.. 2007, **9**:4095

[7]. Liu J., Sun H., Liu X., Ouyang L., Kang T., Xie Y., Wang X. *Tetrahedron Lett*., 2012, **53**:2336

[8]. Galliford C.V., Martenson J.A., Stern C., Scheidt K.A. *Chem. Commun*., 2007, 631

[9]. Ding K., Lu Y., Nikolovska-Coleska Z., Wang G., Qiu S., Shangary S., Gao W., Qin D., Stuckey J., Krajewski K., Roller P.P., Wang S. *J. Med. Chem*., 2006, **49**:3432

[10]. Ra J.N.S., Raghunathan R., *Tetrahedron Lett*., 2012, **53**:854

[11]. Basavaiah D., Reddy B.S., Badsara S.S., *Chem. Rev*., 2010, **110**:5447

[12]. Badillo J.J., Silva-García A., Shupe B.H., Fettinger J.C., Franz A.K., *Tetrahedron Lett*., 2011, **52**:5550

[13]. Tan B., Candeias N.R., Barbas C.F., *Nat. Chem*., 2011, **3**:473

[14]. Maheshwar Rao B., Niranjan Reddy G., Vijaikumar Reddy T., Prabhavathi Devi B.L.A., Prasad R.B.N., Yadav J.S., Subba Reddy B.V., *Tetrahedron Lett*., 2013, **54**:2466

[15]. Karmakar B., Nayak A., Banerji J. *Tetrahedron Lett*., 2012, **53**:5004

[16]. Dandia A., Parewa V., Kumar Jain A., Rathore K.S. *Green Chem*., 2011, **13**:2135

[17]. Zhu S.L., Ji S.I., Zhang Y.A. *Tetrahedron*, 2007, **63**:9365

[18]. Rad-Moghadam K., Youseftabar-Miri L. *Tetrahedron*, 2011, **67**:5693

[19]. Raghuvanshi D.S., Singh K.N. *J. Heterocycl. Chem*., 2010, **47**:1323

[20]. Lee, Y. R.; Hari, G. S. Synthesis 2010, 453.

[21]. Shanthi G., Subbulakshmi G., Perumal P.T. *Tetrahedron*, 2007, **63**:2057

[22]. Litvinov Y.M., Mortikov V.Y., Shestopalov A.M. *J. Comb. Chem*., 2008, **10**:741

[23]. Elinson M.N., Ilovaisky A.I., Merkulova V.M., Demchuk D.V., Belyakov P.A., Ogibin Y.N., Nikishin G.I. *Electrochimica. Acta*., 2008, **53**:8346

[24]. Sridhar R., Srinivas B., Madhav B., Reddy V.P., Nageswar Y.V.D., Rao K.R. *Can. J. Chem*., 2009, **87**: 1704

[25]. Wang L.M., Jiao N., Qiu J., Yu J.J., Liu J.Q., Guo F.L., Liu Y. *Tetrahedron*, 2010, **66**:339

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