



Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

ZnO catalyst for Knoevenagel condensation in aqueous medium at ambient temperature

Manohar Basude*, Prasad Sunkara and Veera Somaiah Puppala

Department of Chemistry, Nizam College, Osmania University, Hyderabad, India

ABSTRACT

An efficient method for Knoevenagel condensation of aromatic aldehyde with malononitrile and ethyl cyanoacetate catalyzed by inexpensive and ecofriendly solid catalyst ZnO at room temperature is developed. The reaction was carried out under solvent free condition and in aqueous medium. In addition to this un catalyzed reaction in aqueous medium is reported for comparison.. The alkenes derivatives are obtained in excellent yields in aqueous medium in presence of ZnO catalyst. The potential advantage of the catalyst is alkenes derivatives are obtained in excellent yields in short duration under mild condition using malononitrile. The reaction between aromatic aldehyde and ethyl cyanoacetate was slow and requires longer time for completion. The catalyst is thermally stable, easy to recover, high product yield and can be efficiently recycled without any pretreatment.

Key words: Knoevenagel condensation; solvent free condition; aromatic aldehyde; malononitrile; ethyl cyanoacetate

INTRODUCTION

In organic synthesis C-C bond formation by condensation of aromatic aldehyde and malononitrile is important transformation. In recent past several articles have been published in this area describing condensation of aromatic aldehyde or ketone and malononitrile [1, 2]. Knoevenagel adducts are useful building blocks in Micheal additions [3]. It has numerous applications in synthesis of fine chemicals and in synthesis of carbocyclic as well as heterocyclic compounds of biological significance [4, 5]. The classical Knoevenagel condensations are catalyzed by bases such as primary and secondary amines and their corresponding ammonium salts [6-9]. This reaction is also catalyzed by lemon juice in the absence of the solvent[10]. These catalysts are in homogeneous phase with the reagents, effective in catalyzing the reaction but difficult to separate and are not recycled. Homogeneous catalytic process needs neutralization, regeneration and incineration producing aqueous effluents causing disposal problems.

In organic synthesis developing green experimental procedure is significant. Water as solvent and solvent free organic reactions represents environmentally benign procedures. In view of this focus is on developing environmentally as well as economically benign reaction conditions employing heterogeneous catalysts [11, 12] providing advantage of increased selectivity of the desired product and ionic liquids [13] as solvent for easy workup and reusability. In spite of their potential utility, some of these methods are limited by low yields, longer reaction times, harsh reaction conditions, expensive reagents and use of toxic solvents. Thus, there is increasing interest in development of new catalysts which provides good yields in short time under mild reaction condition. Acid-base properties and thermal stability of zirconia has been exploited in organic transformations and synthesis of fine chemicals [14, 15]. In continuation of our studies to exploit acid-base properties and thermal stability of inorganic

oxides herein, we report simple and efficient protocol for Knoevenagel condensation of aromatic aldehyde with active methylene compounds over ZnO catalyst at room temperature in aqueous medium and solvent free condition.

EXPERIMENTAL SECTION

Catalyst preparation

10 g of zinc acetate dihydrate was dissolved in 100ml of distilled water. pH of the solution is 6.5 To the zinc acetate solution 5N ammonia solution was added drop-wise under continuous stirring using magnetic stirrer until the solution becomes slightly alkaline. Then the total zinc acetate was precipitated as zinc hydroxide. The precipitate was filtered and washed with distilled water until it is free from ammonia and dried in oven at 150°C for 24h. The precipitate was powdered and calcined at 600°C for about 6 hours.

Knoevenagel condensation of aromatic aldehyde with active methylene compounds

In this study chemicals used are commercially available and are used without any further purification. In a typical experimental procedure a mixture of aromatic aldehyde (2 mmol) and active methylene compound (2.2mmol) is taken in a 25 ml round bottomed flask and 0.1 g of the catalyst was added. The reaction mixture was stirred in water and solvent free condition. The progress of the reaction is monitored by TLC and complete disappearance of aldehyde is treated as completion of the reaction. The catalyst was separated from the reaction mixture after completion of the reaction by filtration and reused. The mixture was extracted with ether. The organic layer was dried over sodium sulphate and solvent was removed under vacuum using rotator-evaporator. The product was subjected silica gel column chromatography using ethyl acetate in petroleum ether as eluent to get pure product. Isolated yields are determined quantitatively, qualitatively by NMR, IR and compared with authentic samples

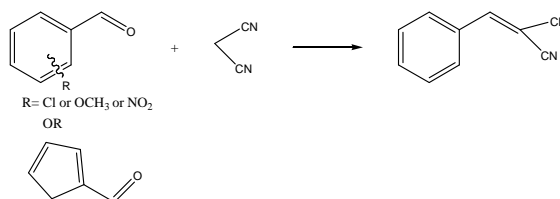
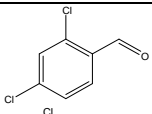
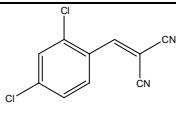
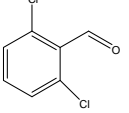
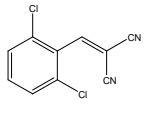
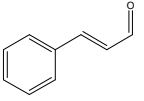
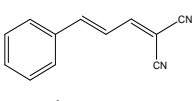
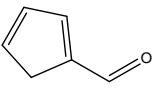
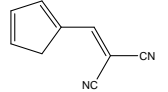
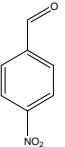
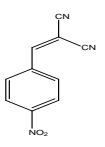


Table 1. Knoevenagel condensation catalysed by ZnO at room temperature in aqueous medium, under solvent free condition and in the absence of catalyst in water

S.No	Reactant	Product	Without catalyst		With catalyst		Without solvent	
			-aqueous medium		aqueous medium		Without solvent	
			Time (min)	Yield (%)	Time (min)	Yield (%)	Time (min)	Yield (%)
1			60	90	20	94	80	92
2			120	81	90	86	112	84
3			135	85	80	87	90	85
4			90	88	08	93	50	90

5			180	80	110	84	180	84
6			25	87	04	96	21	91
7			75	83	11	90	60	88
8			90	85	05	93	30	90
9			30	80	16	85	25	81

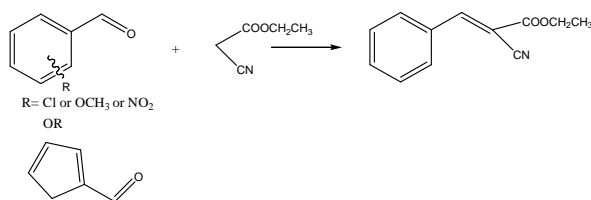
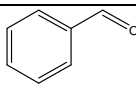
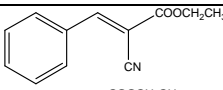
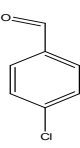
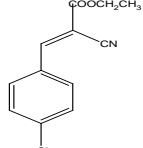
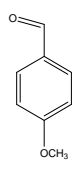
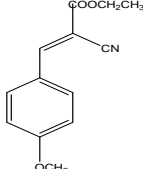
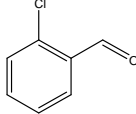
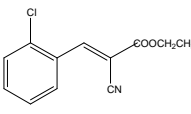
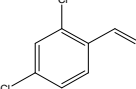
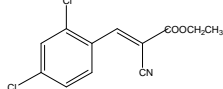
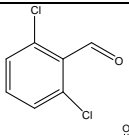
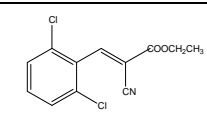
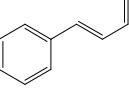
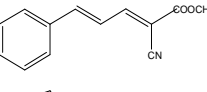
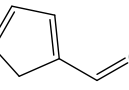
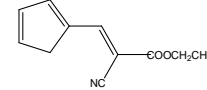
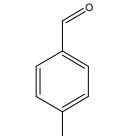
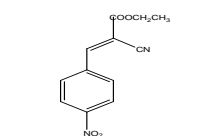


Table 2. Knoevenagel condensation catalysed by ZnO at room temperature in aqueous medium and under solvent free condition

S.No	Reactant	Product	With catalyst			
			aqueous medium		Without solvent	
			Time (hours)	Yield (%)	Time (hours)	Yield (%)
1			04	92	14	82
2			10	84	20	76
3			24	82	30	71
4			05	90	09	82
5			12	84	18	75

6			4.5	91	6.5	85
7			5.5	88	08	82
8			1.5	93	08	83
9			01	95	5.5	81

RESULTS AND DISCUSSION

In our quest to develop newer environmentally benign methods for chemical transformation and catalysts, heterogeneous catalyst ZnO was developed. In this communication, we report Knoevenagel condensation of aromatic aldehyde with malononitrile and ethyl cyanoacetate at room temperature over ZnO catalyst under solvent free condition and in aqueous medium. The results are listed in table 1 and table 2. The reaction was completed in shorter duration producing good to excellent yields of alkenes derivatives in aqueous medium. In addition, the workup procedure is simple and another important feature of this methodology is recyclability of the catalyst. This reduces the cost and amount of waste produced making the catalyst attractive for the Knoevenagel condensation. A systematic and comparative study of Knoevenagel condensation has been undertaken using various aromatic aldehydes bearing electron releasing and electron withdrawing substituent with Malononitrile and ethyl cyanoacetate. The reaction conditions and corresponding yields of alkenes derivatives suggest that aldehyde bearing electron withdrawing substituent are more reactive compared to aromatic aldehyde bearing electron releasing substituent. The time taken for the completion of the reaction is short for furfural, aldehyde bearing electron withdrawing substituent and presence of substituent in ortho position. Malononitrile is more reactive compared to ethyl cyanoacetate and the reaction with malononitrile required short time for completion of the reaction. This may be attributed to the fact that abstraction of a proton from the active methylene group of ethyl cyanoacetate is difficult due to lower acidity.

Table3. Influence of solvent on activity of ZnO catalyst for Knoevenagel condensation of 4-nitro benzaldehyde with malononitrile.

Entry	Solvent	Time (min)	Yield ^c (%)
1	DMSO	22	92
2	DMF	30	90
3	Methanol	18	89
4	Ethyl Acetate	180	88
5	Water	16	96
6	Solvent free	25	95
7	Acetonitrile	85	90

^c Isolated yields.

The influence of the solvent on Knoevenagel condensation catalyzed by ZnO was investigated using the model reaction between 4-nitro benzaldehyde with malononitrile at room temperature and the results are given in table 3. In presence of water and solvent free condition the reaction was completed in 16 min and 25 min. The reaction was slowest in presence of ethyl acetate and acetonitrile. In the absence of solvent reactive aldehyde will give target product with malononitrile yields >90% over a period of time. Homogenization of the solid mixture through dissolution in the solvent and subsequent removal of solvent improved the yields. For reactions in solution at room temperature, quantitative conversion was achieved using THF and ethanol as solvents [16]. Reaction in polar solvents have given yield of the target product >90% in short duration. Our results for Knoevenagel condensation on ZnO and in aqueous media are in agreement with the literature data [17, 18]. Higher activity and selectivity for ZnO

catalyst is observed in aqueous medium. Water is an attractive solvent for Knoevenagel condensation because it is inexpensive and environmentally benign.

With the increase in amount of the catalyst the reaction is completed in shorter time. To investigate reusability of the catalyst 0.1 g of the catalyst was used to catalyze condensation of 4-Nitro benzaldehyde with malononitrile under solvent free condition. After completion of the reaction the catalyst was filtered out and the same wet catalyst was directly used for the next cycle without any additional treatment. No appreciable change in activity was observed for 5-6 runs.

CONCLUSION

In conclusion, we have demonstrated that ZnO is efficient solid heterogeneous catalyst for Knoevenagel condensation of aromatic aldehyde with malononitrile and ethyl cyanoacetate in aqueous medium. Catalyst can be easily separated from the reaction mixture and recycled. A green heterogeneous process and catalyst is developed for C-C bond formation.

Acknowledgements

Authors thank University Grants Commission for the financial support

REFERENCES

- [1]G Li; J Xiao; W Zhang, *Green. Chem.*, **2012**, 14, 2234-2242.
- [2]B Giuseppe; B Marcela; C Armando; D Renato; G Patrizia; M Paolo; S Letizia, *Tetrahedron Lett.*, **2008**, 49, 2555-2557.
- [3]G Kaupp; MR Naimi-Jamal; J Jens Schmeyers, *Tetrahedron.*, **2003**, 59, 3753-3760.
- [4] F Freeman, *Chem. Rev.*, **1981**, 80, 329-350.
- [5]LF Tietze, *Chem. Rev.*, **1996**, 96, 115-136.
- [6]D Fildes; V Caignaert; D Villemin; PA Jaffires, *Green. Chem.*, **2001**, 3, 52-56.
- [7]B Saeed; B Morteza; H Shohreh; S Peyman, *Synth. Commun.*, **2006**, 36, 3703-3711.
- [8]I Yoshitaka; K Yoshiyasu; Y Hisao; I Kenji; H Tadashi, *Chem. Commun.*, **2001**, 2358-2359.
- [9]G Jones, *Org. React.*, **1967**, 15, 204-599.
- [10]MB Deshmukh; SS Patil; SD Jadhav; PB Pawar, *Synth. Commun.*, **2012**, 42, 1177-1183.
- [11]W Yudan; Z Shuguo; Y Shuangfeng; Z Chang; L Shenglian; A Chak-tong, *Catal. Commun.*, **2011**, 12(14), 1333-1338.
- [12]VSR Rajasekhar Pullabhotla; R Ateeq; SB Jonnalagadda, *Catal. Commun.*, **2009**, 10(4), 365-369.
- [13]BC Ranu; R Jana, *Eur. J. Org. Chem.*, **2006**, 3767-3770.
- [14]B Manohar; S Prasad; S Rajkumar; P Lingaiah, *J. Chem. Pharm. Res.*, **2012**, 4(2), 1136-1146.
- [15]B Manohar, *J. Chem. Pharm. Res.*, **2012**, 4(6), 3031-3035
- [16]R Trotzki; M Markus; Hoffmann; B Ondruschka, *Green Chem.*, **2008**, 10, 873-878.
- [17]M Hosseini-Sarvari; H Sharghi; S Etemad, *Helvetica Chimica Acta.*, **2008**, 91, 715-723.
- [18]ML Deb; PJ. Bhuyan. *Tetrahedron Lett.*, **2005**, 46, 6453-6456.