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ZINC CHLORIDE–CATALYZED EXPEDITIOUS ROUTE TO NITRILES

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Zinc chloride has been found to be an excellent catalyst for a one-pot synthesis of nitriles from araldehydes and hydroxylammonium chloride under solvent-free conditions. The features of the present method are short reaction time, easy workup procedure, and good yields of the nitriles.

Keywords: Aldehydes; hydroxyl ammonium hydrochloride; microwave; nitriles; $ZnCl_2$

INTRODUCTION

In recent years, increasing interest has been focused on the synthesis of nitriles because of their importance in organic synthesis, as they serve as intermediates in the synthesis of a variety of pharmaceuticals, pesticides, and dyes.[1]

However, zinc chloride is considered to be a high-quality catalyst in organic synthesis because of the numerous advantages associated with it: it is an environmentally safe catalyst, readily available, and inexpensive.

Usually the synthesis of nitriles is accomplished by substitution reactions of alkyl and aryl halides with metal cyanides,[2] oxidation of primary amines,[3] dehydration of primary[4] and secondary amides,[5] and dehydration of aldoximes with dehydrating agents.[6] Other reported methods for the synthesis of nitriles is the one-pot reaction of aldehydes and hydroxylammonium chloride using various catalysts.[7]

The reported methods entail problems such as use of catalysts that are environmentally hazardous, excess catalysts, expensive reagents, tedious workup procedures, and cumbersome methodologies. Therefore, there is a need for a versatile, simple, and environmentally friendly process for a one-pot synthesis of nitriles from aldehydes.

During the past decade, microwave heating has become a convenient and widely used tool in organic synthesis. Microwave irradiation often leads to a remarkable decrease in reaction time, increased yields, easier workup procedure, and use of green chemistry protocols.[8,9]

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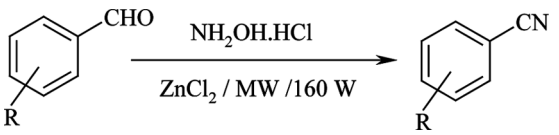
We previously reported the synthesis of nitriles from primary amides using zinc chloride as catalyst in acetonitrile medium,[10] but there has always been a desire to synthesize these nitriles from readily available starting materials under solvent-free conditions. Therefore, we have made use of the readily available aldehydes to synthesize nitriles under solvent-free conditions using microwaves.

RESULTS AND DISCUSSION

To find the best catalyst for the synthesis of nitriles, the reaction of anisaldehyde and hydroxylammonium chloride was carried out in the absence of catalyst and in the presence of various Lewis acids, both under thermal conditions and under microwave irradiation. Best results were obtained when zinc chloride was used as a catalyst under microwave irradiation.

In a typical experiment, aromatic aldehyde, hydroxylammonium chloride, and a catalytic amount of $ZnCl_2$ (10 mol%) were taken in a Pyrex tube, mixed well, and irradiated in a domestic microwave oven at 160 W for less than a minute to get the nitriles in good to excellent yields (Scheme 1). This was confirmed by recording the infrared (IR) spectra for the corresponding nitriles and observing a sharp peak at the frequencies (Table 1).

Encouraged by this success, we attempted the reaction of hydroxyl ammonium chloride with various aromatic aldehydes under similar conditions (Table 1). This protocol is suited for both electron-donating and electron-withdrawing substituents on the aromatic aldehydes.



Scheme 1. Synthesis of various substituted nitriles.

Table 1. One-pot conversion of araldehydes into corresponding nitriles in the presence of cat. $ZnCl_2$ at 160 W of microwave irradiation

Entry	Substrate	Product	Time (s)	Yield (%)	IR (υ cm^{-1})
1	4-Methoxybenzaldehyde	4-Methoxybenzonitrile	25	85	2225.70
2	3-Chlorobenzaldehyde	3-Chlorobenzonitrile	30	80	2235.30
3	3-Nitrobenzaldehyde	3-Nitrobenzonitrile	30	80	2235.34
4	2-Nitrobenzaldehyde	2-Nitrobenzonitrile	30	78	2239.20
5	4-Hydroxybenzaldehyde	4-Hydroxybenzonitrile	28	85	2229.56
6	3,4,5-Trimethoxybenzaldehyde	3,4,5-Trimethoxybenzonitrile	28	80	2227.63
7	2,4-Dimethoxybenzaldehyde	2,4-Dimethoxybenzonitrile	25	88	2221.84
8	3-Methoxy-4-hydroxybenzaldehyde	3-Methoxy-4-hydroxybenzonitrile	25	85	2225.70
9	2-Chlorobenzaldehyde	2-Chlorobenzonitrile	28	90	2226.70
10	4-Chlorobenzaldehyde	4-Chlorobenzonitrile	30	80	2228.70
11	2,4-Dichlorobenzaldehyde	2,4-Dichlorobenzonitrile	30	78	2235.34

CONCLUSION

In conclusion, we have developed a simple, solvent-free, and efficient method to get nitriles by the reaction of different aldehydes and hydroxylammonium chloride in the presence of a catalytic amount of zinc chloride under microwave irradiation within 30 s.

EXPERIMENTAL

Aldehydes, hydroxylammonium chloride, and other chemicals used were commercial. All the reactions were carried out using a conventional (unmodified) household microwave oven (LG, 230 V, 160 W). Reactions were monitored by thin-layer chromatography (TLC) by comparison with the authentic samples. Yields refer to the isolated yields of the products. The infrared (IR) spectra of the products were recorded on a Shimatzu Fourier transform (FT)–IR 8400s spectrophotometer.

Procedure for the Preparation of 4-Methoxybenzonitrile

A mixture of anisaldehyde (0.136 g, 1 mmol), hydroxylammonium chloride (0.08 g, 1.2 mmol), and zinc chloride (10 mol%) was taken in a Pyrex cylindrical tube, mixed well, and irradiated in a microwave oven at 160 W for 25 s. The contents were cooled to room temperature and extracted with dichloromethane (5 ml). The organic layer was dried over anhydrous sodium sulfate, and the solvent was removed under vacuum. The crude product was chromatographed on a short column of silica gel using light petrol as an eluent to get the pure nitrile (0.143 g, 85%).

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