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Leucoemeraldine-Base-Catalyzed Knoevenagel Condensation

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Abstract: A facile method for Knoevenagel condensation has been developed by using Leucoemeraldine base as catalyst to give substituted alkenes in excellent yields. The recycling of the solid catalyst was investigated.

Keywords: Catalysis, Knoevenagel condensation, Leucoemeraldine base

INTRODUCTION

The Knoevenagel condensation, named after Emil Knoevenagel, is one of the most important reactions in organic synthesis for carbon–carbon bond formation. There are many reports of this type of reaction. The Knoevenagel condensation is a base- or acid-catalyzed reaction. It may be performed either in homogeneous or heterogeneous phase. The usual base catalysts are ethylenediamine,[1] piperidine,[2] its corresponding ammonium salts, dimethylaminopyridine,[3] or amino acids such as glycine,[4] alanine,[5] and L-proline.[6] However, many of the methods suffer from generality and use of expensive or toxic reagents, and catalysts cannot be reused. Therefore, the development of a new, efficient, and environmentally benign protocol for the condensation is still needed. To our

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knowledge, there are no reports for Knoevenagel condensation using leucoemeraldine base, Herein, we report the use of Leucoemeraldine base [25233-30-1][7] as a novel and reusable catalyst for the Knoevenagel condensation.

RESULTS AND DISCUSSION

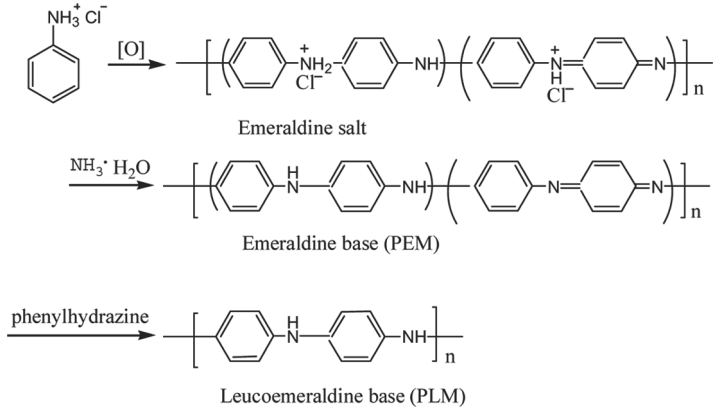
Leucoemeraldine base is a light purple powder prepared from aniline (Scheme 1); because it is insoluble in ethanol and isopropyl alcohol, it can be used as a reusable solid base.

The results are listed in Table 1. They show that Leucoemeraldine base is an efficient catalyst for Knoevenagel condensation (Scheme 2). Moreover, it is cheap, and the protocol is an environmentally benign method.

The rate of reaction of malononitrile and aldehyde is faster than that of ethyl cyanoacetiate and the same aldehyde. The separation of the products is simple: only filtration, not recrystallization, is necessary.

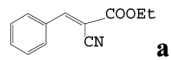
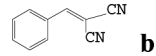
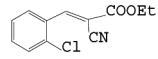
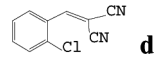
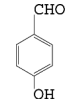
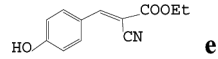
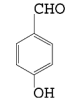
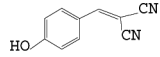
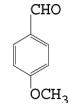
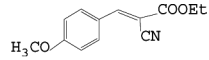
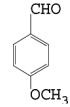
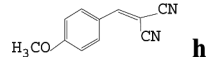
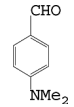
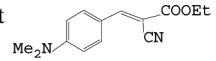
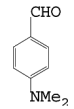
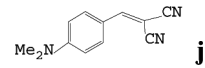
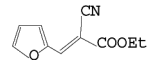
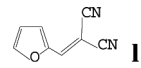
CONCLUSIONS

In conclusion, we have developed a convenient method for Knoevenagel condensation. The procedure offers several advantages, including operational simplicity and inexpensive reagents, and it is an environmentally benign method.



Scheme 1. Preparation of Leucoemeraldine base.

Table 1. Catalyzed Knoevenagel condensation[a]

Entry	substrate	R	Product	Reaction time (h)	Yield (%)
1		COOEt	 **a**	2	88 (87, 86, 86)[b]
2		CN	 **b**	1	93
3		COOEt	 **c**	2	83
4		CN	 **d**	1	88
5		COOEt	 **e**	2	86
6		CN	 **f**	1	90
7		COOEt	 **g**	2	85
8		CN	 **h**	1	90
9		COOEt	 **i**	2	86
10		CN	 **j**	1	90
11		COOEt	 **k**	2	87
12		CN	 **l**	1	91

[a]All the products gave melting points and spectral data consistent with the reported data.[8,9]

[b]Isolated yield after recycling of catalyst.

Scheme 2. The Knoevenagel condensation.

EXPERIMENTAL

General Procedures

Melting points were determined in open capillaries and are uncorrected. ^{1}H NMR was measured on a Bruker 400 MHz spectrometer with tetramethylsilane (TMS) as internal standard. Infrared (IR) spectra were measured on a Nicolet Magna-IR550 spectrometer.

Preparation of Leucoemeraldine Base

Under an N_2 atmosphere, aniline (2.4 g), concentrated hydrochloric acid (2.5 mL), and distilled water (33 mL) were mixed to be a homogeneous solution, and then a solution of ammonium peroxydisulfate (4.5 g) in distilled water (10 mL) was added slowly to the solution at 25°C to initiate the polymerization of aniline. Afer 10 h, the solid product was collected and rinsed with distilled water and then with ethanol to give the Emeraldine salt. The Emeraldine salt was then dispersed in ammonium hydroxide (40 mL, 10%) to give the Emeraldine base form of polyaniline (PEM). PEM (1 g) was dispersed in dimethylformamide (DMF) (40 mL), phenylhydrazine (20 mL) was added and reacted for 8 h, and the powder was collected by filtration, washed with ethanol (80 mL), and dried under vacuum to give the Leucoemeraldine-base form of polyaniline (PLM).

General Synthetic Procedure

Leucoemeraldine base (0.1 g) was added to a mixture of aldehyde (10 mmol) and active methylene compound (10 mmol) in ethanol (10 ml). The solution was stirred for a specified time at reflux. Leucoemeraldine base was removed by filtration, water (100 ml) was added to the filtrate, and the mixture was stirred for a moment, then filtered. The product is pure enough, and recrystallization is not necessary.

Selected Data

Ethyl (E)-2-Cyano-3-phenyl-2-propenoate (a)

Mp 50–51°C. IR (KBr): υ 3030, 2984, 2225, 1721, 1601, 1441, 1257, 1201, 1089, 769 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.41 (t, $J = 7.2$ Hz, 3H), 4.39 (q, $J = 7.2$ Hz, 2H), 7.49–7.59 (M, 3H), 7.99 (d, $J = 7.6$ Hz, 2H), 8.26 (s, 1H).

2-(Phenylmethylene) Malononitrile (b)

Mp 83–84°C. IR (KBr): υ 3033, 2223, 1591, 1257, 1568, 1491, 1450 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 7.55 (t, $J = 8$ Hz, 2H), 7.64 (t, $J = 7.6$ Hz, 1H), 7.78 (s, 1H), 7.91 (d, $J = 7.6$ Hz, 2H).

Ethyl (E)-2-Cyano-3-(2-chloro phenyl)-2-propenoate (c)

Mp 51–52°C. IR (KBr): υ 2992, 2225, 1729, 1609, 1465, 1265, 1201, 753 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.42 (t, $J = 7.2$ Hz, 3H), 4.41 (q, $J = 7.2$ Hz, 2H), 7.40–7.53 (m, 3H), 8.24 (d, $J = 7.6$ Hz, 1H), 8.70 (s, 1H).

2-(2-Chlorophenylmethylene)malononitrile (d)

Mp 95–96°C. IR (KBr): υ 3050, 2231, 1509, 1609, 1464, 1441, 758 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 7.46 (m, 1H), 7.55 (d, $J = 3.6$ Hz, 2H), 8.20 (d, $J = 8$ Hz, 1H), 8.28 (s, 1H).

Ethyl (E)-2-Cyano-3-(4-hydroxy phenyl)-2-propenoate (e)

Mp 172–173°C. IR (KBr): υ 3320, 2993, 2225, 1713, 1585, 1521, 1441, 1281, 1169, 841 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.40 (t, $J = 7.2$ Hz, 3H), 4.37 (q, $J = 7.2$ Hz, 2H), 6.27 (s, 1H), 6.96 (d, $J = 8.8$ Hz, 2H), 7.95 (d, $J = 8.8$ Hz, 2H), 8.19 (s, 1H).

2-(4-Hydroxyphenylmethylene) Malononitrile (f)

Mp 188–189°C. IR (KBr): υ 3400, 3030, 2929, 2231, 1611, 1586, 1567, 1520, 1444 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$). δ 6.00 (s, 1H), 6.95 (d, $J = 8.4$ Hz, 2H), 7.65 (s, 1H), 7.87 (d, $J = 8.8$ Hz, 2H).

Ethyl (E)-2-Cyano-3-(4-methoxy phenyl)-2-propenoate (g)

Mp 82–83°C. IR (KBr): υ 3017, 2992, 2216, 1721, 1577, 1513, 1185, 833 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.39 (t, $J = 7.2$ Hz, 3H), 3.90 (s, 3H), 4.38 (q, $J = 7.2$ Hz, 2H), 6.99 (d, $J = 8.8$ Hz, 2H), 8.00 (d, $J = 8.8$ Hz, 2H), 8.18 (s, 1H).

2-(4-Methoxyphenylmethylene) Malononitrile (h)

Mp 114–115°C. IR (KBr): υ 2852, 2223, 1605, 1571, 1513, 1184, 1154, 937, 834 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 3.92 (s, 3H), 7.01 (d, $J = 8.8$ Hz, 2H), 7.66 (s, 1H), 7.90 (d, $J = 8.8$ Hz, 2H).

Ethyl (E)-2-Cyano-3-(4-dimethylaminophenyl)-2-propenoate (i)

Mp 124–125°C. IR (KBr): υ 2913, 2209, 1665, 1601, 1529, 1369, 1161, 817 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.38 (t, $J = 7.2$ Hz, 3H), 3.12 (s, 6H), 4.33 (q, $J = 7.2$ Hz, 2H), 6.75 (d, $J = 9.2$ Hz, 2H), 7.94 (d, $J = 9.2$ Hz, 2H), 8.09 (s, 1H).

2-(4-Dimethylaminophenyllmethylene) Malononitrile (j)

Mp 179–180°C. IR (KBr): υ 3010, 2220, 1601, 1521, 1160, 818 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$). δ 3.14 (s, 6H), 6.70 (d, $J = 8.8$ Hz, 2H), 7.47 (s, 1H), 7.81 (d, $J = 8.4$ Hz, 2H).

Ethyl (E)-2-Cyano-3-(2-furyl)-2-propenoate (k)

Mp 92–93°C. IR (KBr): υ 3120, 3040, 2917, 2225, 1713, 1617, 1465, 1369, 1265, 1209, 761 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 1.39 (t, $J = 7.2$ Hz, 3H), 4.36 (q, $J = 7.2$ Hz, 2H), 6.66 (q, $J = 1.2$ Hz, 1H), 7.39 (d, $J = 3.6$ Hz, 1H), 7.75 (d, $J = 1.6$ Hz, 1H), 8.02 (s, 1H).

2-(Furyllmethylene) Malononitrile (l)

Mp 72–73°C. IR (KBr): υ 3125, 3042, 2225, 1608, 1509, 1457, 1395, 1152, 1022, 936, 767 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 6.72 (q, $J =$ 1.6 Hz, 1H), 7.36 (d, $J = 3.6$ Hz,1H), 7.52 (s, 1H), 7.81 (d, $J =$ 1.2 Hz, 1H).

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