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Crown Ether complex Cation Like Ionic Liquids: Synthesis and Catalytic Applications in Organic Reaction

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ABSTRACT

A series of novel crown ether complex cation ionic liquids (CECILs) have been synthesized and characterized by IR, ¹H NMR, ¹³C NMR, and mass spectroscopy. Their catalytic applications in organic reactions along with recyclability without loss of catalytic activity have been studied.

Keywords: Dibenzo-18-crown-6 ether, organic/ inorganic potassium or sodium salt, ionic liquid.

INTRODUCTION

Recently, however a new class of solvent has emerged as ionic liquids (ILs), defined as molten salts whose melting point below 100⁰C; exhibiting low vapour pressure, low combustibility, excellent thermal stability, wide liquid regions and favourable solvating properties [1]. Many classes of organic reactions such as hydrogenation, oxidation and C-C bond forming reactions can be performed in ionic liquids [2]. Thousands of ionic liquids were synthesized in the last decades, they commonly consisted of N,N'-dialkylimidazolium or N-alkylpyridinium cations [3]. Herein, crown ether complex cation ionic liquids (CECILS) have been synthesized by crown ethers chelated with alkali metal cations. It is known that electrostatic interaction between large cations and large anions are relatively weak, whereas the Van der Waals forces are strong, which induces a decrease in lattice energy and melting point [4]. Only few reports available on the synthesis of crown ether complex cation ionic liquids [5], but these are time consuming and catalyst prepared is much expensive than present crown ether catalyst. On the basis of these assumptions, we synthesized a series of novel crown ether complex cation ionic liquids (CECILs), which have melting point below 200⁰. Further their catalytic applications in organic reactions such as Knoevenagel condensation and one pot synthesis of pyrazolo [1,2-b] phthalazine dione have been studied.

MATERIALS AND METHODS

All chemicals and solvents were AR grade and used as purchased without any further purification. The progress of reaction was monitored by TLC (Silica gel 60 F₂₅₄). IR spectra were recorded on Perkin-Elmer Spectrometer. The ¹H NMR and ¹³C NMR were recorded on Bruker 300 AVANCE II with CDCl₃ as solvent and TMS as internal standard. Mass spectra was carried out on a Bruker Daltonics spectrometer. Melting points were determined in open capillary tube and are uncorrected.

General procedure for the synthesis of CECILs:

The organic/ inorganic potassium or sodium salt (1 mmole) was mixed with dibenzo-18-crown-6 (1 mmole) in 15 ml methanol. After stirring for 1h at 60°C, the methanol was removed under reduced pressure. The residue was vacuum dried to generate the desired CECIL in 100% yield.

General procedure for the Knoevenagel condensation:

A mixture of aldehyde (1 mmole), malononitrile (1.3 mmole) and [dibenzo-18-crown-6K][OH] (30 mol%) at room temperature until the reaction was completed (TLC). The mixture was extracted with ethyl acetate : pet ether (3:7). The product was recovered from ethyl acetate. The pet ether was evaporated and the residue was dried under vacuum to recover [dibenzo-18-crown-6K][OH] for the next cycle.

General procedure for the synthesis of pyrazolo [1,2-b] phthalazine dione:

A mixture of malononitrile (1mmole), phthalhydrazide (1mmole), aldehyde (1mmole) and [dibenzo-18-crown-6Na][OH] (10 mol%) in methanol was stirred at 60°C for 30 min. The precipitate obtained was then filtered and recrystallized from methanol. The filtrate was collected, evaporated and the residue was dried under vacuum to recover [dibenzo-18-crown-6K][OH] for the next cycle.

RESULTS AND DISCUSSION

In the present work we dissolved the crown ether and inorganic/organic salts in methanol to generate the desired CECILs. CECILs obtained in 100% yield, high purity and good stabilities. All CECILs synthesized are white solids at room temperature. They melted over wide temperature range (142-154°C). The formation of CECILs was carried out by mixing of the correct molar ratio of crown ether and relevant salts in methanol at 60°C, followed by evaporation and finally evacuated under vacuum. We performed detailed analysis of IR, ¹H NMR, ¹³C NMR, and mass spectroscopy.

Table I. The properties of the CECILs

Entry	CECIL	Colour	M.P.[°C]
a	[Dibenzo-18-C-6K][OH]	White	154
b	[Dibenzo-18-C-6Na][OH]	White	145
c	[Dibenzo-18-C-6Na][OAc]	White	142
d	[Dibenzo-18-C-6K][Br]	White	150

We also reported the excellent catalytic activity of [dibenzo-18-crown-6K][OH] and [dibenzo-18-crown-6Na][OH] for Knoevenagel condensation and one pot synthesis of pyrazolo [1,2-b] phthalazine dione respectively. In Knoevenagel condensation, under solvent free condition both aromatic aldehydes with electron withdrawing or electron donating groups generated in high yields (65-95%) (Table II).



Scheme-I] Knoevenagel condensation catalysed by [dibenzo-18-crown-6K][OH]

Table II. Knoevenagel condensation catalysed by [Dibenzo-18-C-6K][OH]

Entry	R	t [min]	Yield [%]
a	H	30	60
b	4-Cl	25	90
c	2,4-Cl	20	94
d	2-Br	30	85
e	2-OCH ₃	27	95

We have demonstrated a simple, ecofriendly protocol for the synthesis of pyrazolo [1,2-b] phthalazine dione using [dibenzo-18-crown-6Na][OH], which proceeds very efficiently in methanol in high yield (85-95%) (Table III).



Scheme-II] One pot synthesis of pyrazolo [1,2-b] phthalazine dione

Table III. One pot synthesis of pyrazolo [1,2-b] phthalazine dione catalysed by [Dibenzo-18-C-6Na][OH].

Entry	Ar	t [min]	Yield [%]
a	H	30	90
b	4-Cl	40	87
c	2-Cl	35	85
d	3-OH	35	85
e	3-NO ₂	25	85

The recovered catalyst reused for several times successfully without loss in the catalytic activity concerning yield and reaction time.

In conclusion, CECILs were found to be a efficient and reusable solid catalyst for the various organic reactions. The main advantage of the present work is the recyclability and excellent yields of the products with the simple work up procedure.

Spectroscopic data of CECILs:

[1a][Dibenzo-18-C-6K][OH]: IR (KBr): 3434, 3065, 2949, 2925, 2585, 2039, 1647, 1596, 1509, 1490, 1474, 1454, 1330, 1291, 1255, 1231, 1131, 1080, 1061, 996 cm^{-1} ; ^1H NMR (CDCl_3 300 MHz): δ = 4.01-4.04 (q, 8H), 4.15-4.18 (q, 8H), 6.83-6.91 (m, 8H); ^{13}C NMR (CDCl_3 300 MHz): δ = 147.70, 147.41, 121.20, 111.93, 111.63, 69.28, 67.28, 67.40.

[1b][Dibenzo-18-C-6Na][OH]: IR (KBr): 3453, 3067, 2949, 2922, 2880, 2582, 2035, 1649, 1596, 1506, 1454, 1330, 1080, 1061, 996, 934 cm^{-1} ; ^1H NMR (CDCl_3 300 MHz): δ = 4.02-4.05 (q, 8H), 4.09-4.17 (q, 8H), 6.82-6.9 (m, 8H); ^{13}C NMR (CDCl_3 300 MHz): δ = 147.71, 147.42, 121.23, 111.93, 111.60, 69.20, 67.67, 67.41.

[1c][Dibenzo-18-C-6Na][OAc]: IR (KBr): 3412, 3063, 2949, 2925, 2876, 2589, 1646, 1596, 1454, 1409, 1290, 1255, 1231, 1130, 1080, 1061, 996, 933 cm^{-1} ; ^1H NMR (CDCl_3 300 MHz): δ = 1.85 (s, 3H), 4.02-4.04 (q, 8H), 4.15-4.18 (q, 8H), 6.83-6.92 (m, 8H); ^{13}C NMR (CDCl_3 300 MHz): δ = 148.70, 121.20, 113.28, 77.35, 76.92, 76.50, 69.85, 68.61.

[1d][Dibenzo-18-C-6K][Br]: IR (KBr): 3065, 2949, 2925, 2585, 2039, 1647, 1596, 1509, 1490, 1474, 1454, 1330, 1291, 1256, 1231, 1131, 1080, 1061, 996 cm^{-1} ; ^1H NMR (CDCl_3 300 MHz): δ = 4.12-4.17 (q, 16H), 6.82-6.93 (m, 8H); ^{13}C NMR (CDCl_3 300 MHz): δ = 147.73, 147.47, 121.23, 111.94, 111.63, 69.29, 67.68, 67.48.

[1a & 1d][Dibenzo-18-crown-6K][x]: m/z = 399.1 [M^+].

[1b & 1c][Dibenzo-18-crown-6Na][x]: m/z = 383.1 [M^+].

Spectral data for Knoevenagel Condensation:

[2a] 2-Benzylidenemalononitrile: ^1H NMR (CDCl_3 300 MHz): δ = 7.55 (t, 2H), 7.64 (t, 1H), 7.78 (s, 1H), 7.91 (d, 2H); ^{13}C NMR (CDCl_3 300 MHz): δ = 169.9, 134.60, 130.9, 130.7, 129.6, 113.7, 112.5, 83.5.

[2b] 2-(4-Chlorobenzylidene)malononitrile: ^1H NMR (CDCl_3 300 MHz): δ = 7.85 (d, 2H), 7.74 (s, 1H), 7.52 (dd, 2H); ^{13}C NMR (CDCl_3 300 MHz): δ = 158.2, 141.1, 131.8, 130.0, 129.3, 113.4, 112.3, 84.0.

[2c] 2-(2,4-Dichlorobenzylidene)malononitrile: ^1H NMR (CDCl_3 300 MHz): δ = 7.44 (d, 1H), 7.57 (d, 1H), 8.14 (d, 1H), 8.18 (s, 1H); ^{13}C NMR (CDCl_3 300 MHz): δ = 154.5, 141.0, 137.1, 130.1, 128.3, 127.4, 113.0, 111.7, 86.0.

[2d] 2-(2-Bromobenzylidene)malononitrile: ^1H NMR (CDCl_3 300 MHz): δ = 8.22 (s, 1H), 7.74 (dd, 1H), 7.42-7.53 (m, 2H); ^{13}C NMR (CDCl_3 300 MHz): δ = 158.7, 134.9, 134.0, 130.7, 129.8, 128.3, 126.4, 113.1, 111.7, 86.0.

[2e] 2-(2-Methoxybenzylidene)malononitrile: ^1H NMR (CDCl_3 300 MHz): δ = 3.93 (s, 3H), 6.99 (d, 1H), 7.08 (t, 1H), 7.58 (t, 1H), 8.18 (dd, 1H), 8.30 (s, 1H); ^{13}C NMR (CDCl_3 300 MHz): δ = 158.9, 154.4, 136.5, 128.8, 131.1, 120.1, 114.3, 112.9, 111.5, 81.3, 55.9.

Spectral data for One pot synthesis of pyrazolo [1,2-b] phthalazine dione:

[3a] 3-Amino-1-phenyl-5,10-dihydro-5,10-dioxo-1H-pyrazolo [1,2-b] phthalazine-2-carbonitrile: ¹H NMR (DMSO-d₆ 300 MHz): δ = 6.1 (s, 1H), 7.4 (m, 5H), 7.9 (bs, 2H, NH₂), 8.09 (t, 3H), 8.2 (q, 1H); ¹³C NMR (DMSO-d₆ 300 MHz): δ = 157, 154, 151, 138, 135, 134, 129.13, 129.06, 128.90, 128.69, 127.74, 127.21, 127.15, 116, 63, 61.

[3b] 3-Amino-1-(4-chlorophenyl)-5,10-dihydro-5,10-dioxo-1H-pyrazolo [1,2-b] phthalazine-2-carbonitrile: ¹H NMR (DMSO-d₆ 300 MHz): δ = 6.1 (s,1H), 7.4 (d,2H), 7.5 (d, 2H), 7.9 (bs, 2H, NH₂), 8.1 (m, 4H); ¹³C NMR (DMSO-d₆ 300 MHz): δ = 157, 156, 152, 139, 137, 135, 129.30, 128.96, 127.7, 127.5, 118, 116, 63, 61.

[3c] 3-Amino-1-(2-chlorophenyl)-5,10-dihydro-5,10-dioxo-1H-pyrazolo [1,2-b] phthalazine-2-carbonitrile: ¹H NMR (DMSO-d₆ 300 MHz): δ = 6.4 (s, 1H), 7.2-7.5 (m, 4H), 7.96 (s, 2H, NH₂), 7.97-8.3 (m, 4H); ¹³C NMR (DMSO-d₆ 300 MHz): δ = 154.01, 151.62, 134.35, 128.83, 127.18, 127.17, 116, 63, 62.

[3d]3-Amino-1-(3-hydroxyphenyl)-5,10-dihydro-5,10-dioxo-1H-pyrazolo [1,2-b] phthalazine-2-carbonitrile: ¹H NMR (DMSO-d₆ 300 MHz): δ = 6.4 (s, 1H), 7.2-7.5 (m, 4H), 7.96 (s, 2H, NH₂), 7.97-8.3 (m, 4H); ¹³C NMR (DMSO-d₆ 300 MHz): δ = 157, 156, 153, 150, 134.84, 133.83, 129.79, 128.96, 128.78, 127.75, 127.21, 117, 116, 115, 113, 63, 61.

[3e] 3-Amino-1-(3-nitrophenyl)-5,10-dihydro-5,10-dioxo-1H-pyrazolo [1,2-b] phthalazine-2-carbonitrile: ¹H NMR (DMSO-d₆ 300 MHz): δ = 6.3 (s, 1H), 7.6 (t, 1H), 7.9-8.3 (m, 9H); ¹³C NMR (DMSO-d₆ 300 MHz): δ = 157, 154, 151, 148, 140, 134.89, 134.12, 134.07, 130, 129, 128, 127.73, 127.16, 123, 122, 116, 62, 61.

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