



Rational design and expeditious synthesis of aromatic cyanodienone derivatives assisted by cyanide-halide exchange

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1-*n*-Butyl-3-methylimidazolium cyanide ([bmim]CN), in the presence of [bmim]Br has been prepared and used for the first time as the medium as well as reagent for the synthesis of aromatic cyanodienones from the corresponding triarylpyrylium perchlorates by cyanide-halide exchange. The [bmim]CN having a reactive anion, is an accelerated reaction technique without external solvent and renders the whole synthesis into a truly eco-friendly protocol. The products can be isolated without aqueous work-up in high purity and excellent yield.

Keywords: Cyanodienone, triarylpyrylium perchlorate, 1-*n*-butyl-3-methylimidazolium cyanide, cyanide-halide exchange, environmentally friendly methodology, ionic liquid

Over the last decade, ionic liquids have attracted rising interest in the context of green chemistry with a diversified range of applications including organic and inorganic synthesis, catalysis, electrochemistry and chemical separations, *etc.*¹⁻⁸ The task-specific ionic liquids (TSILs) where a functional group is covalently tethered to the cation or anion (or both) of the ionic liquid, are the latest generation of ionic liquid. The incorporation of this functionality should imbue the ionic liquid with a capacity to behave not only as a reaction medium but also as a reagent or catalyst in some reactions or processes^{9,10}. TSILs also have the ability to dissolve a wide range of organic, inorganic and polymeric materials within them.

Aromatic cyanodienones are precursors for interesting heterocyclic compounds such as butenolides which have main roles in chemical and biological activities¹¹⁻¹⁹.

The major drawbacks for the synthesis of these biologically important molecules starting from readily available triarylpyrylium perchlorates are much longer reaction times (e.g., 23 h for 1G) and toxicity of cyanide anion leading to vomiting, convulsions, loss of consciousness and eventual death²⁰⁻²². Although our preceding efforts in the green synthesis of these compounds using cyanide impregnated on anion exchange resin²³ and expeditious synthesis of these compounds using neutral alumina as a versatile heterogeneous catalyst²⁴, improved the reaction conditions, it is still a great challenge to construct

these molecules using a safe and simple method that can resolve the both drawbacks simultaneously.

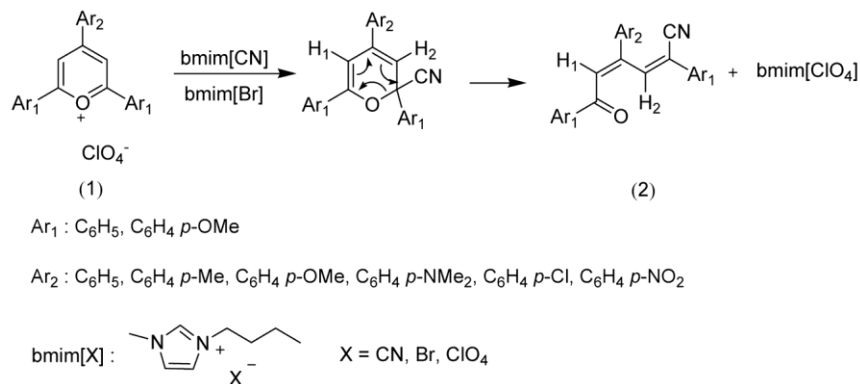
Under this light and in continuation of ongoing work to develop selective, preparative and synthetically useful methodology for preparation, application and other transformation of pyrylium and thiopyrylium salts²⁵⁻²⁸ we have accomplished, for the first time, the use of 1-*n*-butyl-3-methylimidazolium cyanide/ 1-*n*-butyl-3-methylimidazolium bromide ([bmim]CN/[bmim]Br) as a safe reagent and reaction medium for synthesis of aromatic cyanodienones.

Results and Discussion

An improved procedure for the synthesis of various aromatic cyanodienones **2** from the reaction of triarylpyrylium perchlorates contain electron donor and withdrawing groups on para position of phenyl rings **1** with 1-*n*-butyl-3-methylimidazolium cyanide as task-specific ionic liquid is described (Scheme I).

Before introducing general protocol, preliminary tests were carried out to survey the requisite reaction conditions and establish the modifications required for this methodology. Triphenylpyrylium perchlorate was chosen as the model compound to identify and optimize the reaction conditions.

Initially, the relative molar ratio nucleophile and substrate was optimized. In light of this affair, the reaction of model compound with varying amount of sodium cyanide in the presence of [bmim]Br as solvent were investigated. As it can be observed in



Scheme I — Synthesis of aromatic cyanodienones **2** from the reaction of various triarylpyrylium perchlorates **1** with bmim[CN]

Table I, the target reaction is favored by increasing the nucleophile/substrate ratio as shown from the significant decrease in the reaction time. Bearing in mind that the reaction proceeds through an addition then ring opening mechanism, the increase in nucleophile concentration favors the first reaction step and, on the whole, the product formation. The decrease of the yield (76%) by employing a ratio of 2.5 (entry 4) can probably be explained by generation of other products. So the best results were obtained when 2 mmol of nucleophile and 1 mmol of substrate were used (Table I).

It is noteworthy that owing to the high toxicity of sodium cyanide, this method is not very environment-friendly.

To circumvent this dilemma and reduce the toxicity of cyanide ion, the attention was shifted to the design, synthesis and use of new cyanide source that not only possesses high activity and selectivity, but is also simultaneously benign to the environment. Accordingly, a new synthetic strategy commenced with the synthesis of new task-specific ionic liquid was carried out.

Task-specific ionic liquid [bmim]CN was prepared according to a modified literature procedure³².

The use of this task-specific ionic liquid as reagent decreases the reaction time (Table II).

This indicated that the nucleophilicity of the cyanide ion is much higher in [bmim]CN compared to NaCN. This has been attributed to the fact that reactivity of the cyanide ion mainly depends on counterion. Probably, Coulomb interactions, which are maximized in solvent media, lower the reactivity of the nucleophile when the counterion is the smaller Na⁺ cation, while the bigger 1-*n*-butyl-3-methylimidazolium cation has less interaction with cyanide ion.

Table I — Trend of the model reaction with different amount of NaCN in the presence of [bmim]Br as solvent at 80°C

Entry	[Nu]/[Sub]	Time (h)	Yield of 2 (%)
1	1	6	87
2	1.5	4	87
3	2	3	87
4	2.5	1	76

Table II — Reaction of the model compound 1A with two different types of reagents

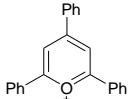
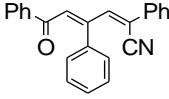
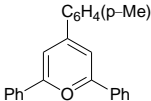
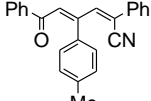
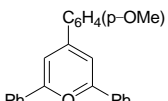
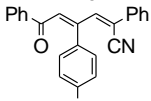
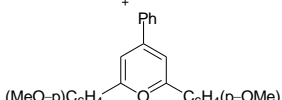
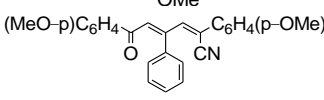
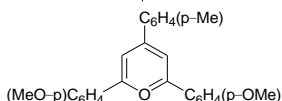
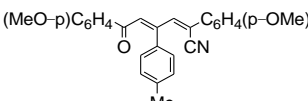
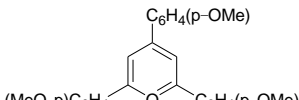
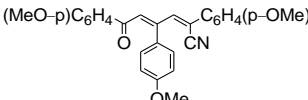
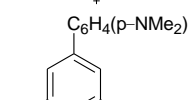
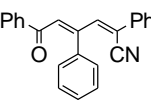
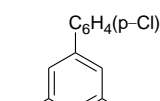
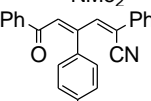
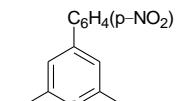
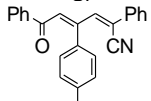
Entry	Solvent	Nucleophilic source	Time
1	[bmim]Br	NaCN	3 h
2	[bmim]Br	[bmim]CN	30 min

On the other hand, driving force of target reaction could be explained by the concept of hard and soft acids and bases (HSAB). Hence, due to the overall hard nature the bmim cation, ion pairing is preferred with a hard anion, such as perchlorate.

In the presence of [bmim]CN alone, a small amount of starting material remained intact. So, in Additional tests, reaction of model substrate with [bmim]CN in the presence of [bmim]Br were carried out. In [bmim]CN/[bmim]Br mixture the reaction was very fast and gave corresponding cyanodienone in 95% yield within 5 minutes. Thus [bmim] CN/[bmim]Br appears as the best reagent giving the best results.

These extraordinary results promoted us to demonstrate the efficiency and the applicability of the present method. Therefore, the reaction was performed for a variety of triarylpyrylium perchlorates with [bmim]CN/[bmim]Br mixture in which corresponding aromatic cyanodienones with excellent yields were obtained (Table III). The structure of all products were settled from their physical and spectroscopic (IR, ¹HNMR, ¹³CNMR) data (see ESI).

Table III — The conversion of various triarylpyrylium salts into corresponding cyanodienones at 80°C

Entry	Substrate	Product	Time (min)	Yield (%)
A			5	95
B			10	87
C			18	86
D			20	83
E			25	80
F			30	80
G			40	82
H			4	93
I			2	93

As shown in Table III, electron donor groups cause the reactions to become slow (e.g., entry A until G). This may be described by considering the fact that these groups decrease positive charge on α -position of heterocyclic ring. The more electron donor groups, exhibit the greater reaction time. In contrast electron withdrawing groups (e.g., entry H and I) accelerate the reactions.

Since the products were fairly soluble in the ionic liquid, they could be easily separated by simple extraction with ether. More importantly, there is no formation of any side-products in this process and there is no need for column chromatography for the purification of the products.

Experimental Section

Solvents and chemicals were obtained from the Aldrich Chemical Co. (Milwaukee, WI, USA) and Merck Chemical Co. (Germany). Monitoring of the reactions was accomplished by thin-layer chromatography (TLC). Infrared spectra of the samples were recorded at room temperature in the range of 4,000–400 cm^{-1} , on a Bomen MB:102 FT-IR spectrophotometer. The spectra of solids were obtained using KBr pellets. ^1H NMR and ^{13}C NMR spectra were recorded on a Bruker spectrometer at 400 and 100 MHz, respectively, in CDCl_3 with tetramethylsilane as an internal standard. Mass spectra (MS) were measured on Anagilent 5975 mass spectrophotometer.

Synthesis of triarylpyrylium perchlorates

All triarylpyrylium perchlorates were synthesized from the corresponding aldehydes and ketones by the method previously described^{29,30}.

Synthesis of [bmim]Br

A mixture of 1-methylimidazole (4.1 g, 0.05 mol) and 1-bromobutane (6.85 g, 0.05 mol) in absence of solvent was heated with stirring at 80°C for 3 h. Then, the product was washed with dimethyl ether and dried in vacuum to afford [bmim]Br³¹.

Synthesis of [bmim]CN

[bmim]CN was prepared according to a modified literature procedure³². [bmim]BF₄ (500 mg, 2.21 mmol) was added at ambient temperature to KCN (144 mg, 2.21 mmol) in ethanol/water (1:1). The mixture was stirred for 2 h and then filtered. The filtrate was dried in vacuo at 40 °C for 30 min, yielding 300 mg [bmim]CN (1.81 mmol, 82%) as pale yellowish liquid.

General procedure for the synthesis of aromaticcyanodienones

Reactions were typically carried out by addition of 1 mmol triarylpyrylium perchlorates to 2 mmol ionic liquid [bmim]CN in 10 ml [bmim]Br and heated to 80°C. After completion of reaction, as indicated by TLC, products were extracted from the reaction mixture using diethyl ether. Then, diethyl ether was evaporated under vacuum and residual recrystallized in EtOH.

Conclusion

A novel [bmim]CN/[bmim]Br system was proved to be an effective reagent for the synthesis of various aromatic cyanodienones starting from corresponding triarylpyrylium perchlorates by playing the triple role of nucleophile, solvent and promoter. Operational simplicity, short reaction times, easy workup, excellent yields of products, greenness of the procedure and the absence of any hazardous organic solvent and toxic catalyst have made this approach distinctly superior over to many other protocols reported earlier.

Supplementary Information

Supplementary information is available in the website <http://nopr.niscair.res.in/handle/123456789/60>.

Acknowledgment

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