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New Crown Ether-Based Nano Ionic Liquid ($[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL): A Versatile Nanocatalyst for the Synthesis of Spiro[indoline-3,2′-quinoline] Derivatives via the Cascade Four-Component Reaction of Arylamines, Dialkylacetylenedicarboxylates, Isatins and Dimedone

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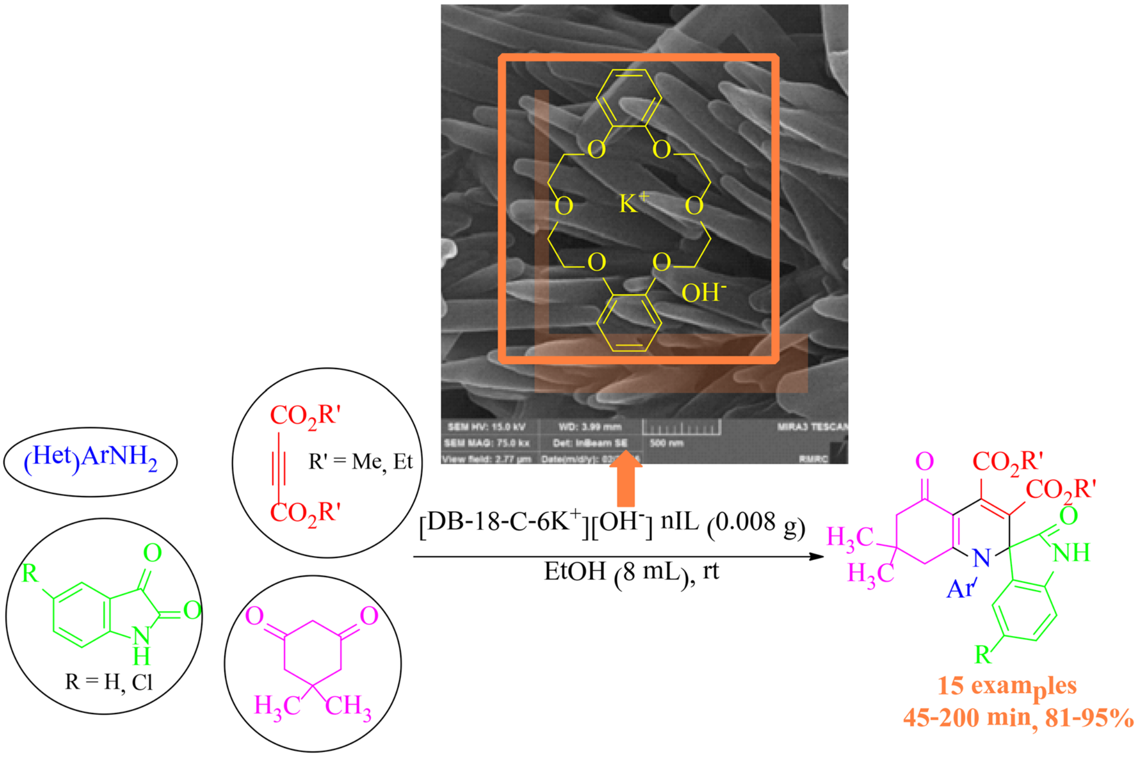
Abstract

A new nano-size crown ether-based ionic liquid on the basis of dibenzo-18-crown-6 ($[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL) has been synthesized via a simple procedure and characterized through fourier transform infrared spectroscopy, nuclear magnetic resonance spectroscopy, high-resolution scanning electron microscopy, energy-dispersive X-ray spectroscopy, thermogravimetric/differential thermal analysis, and UV–Vis spectroscopy techniques The obtained catalyst has been utilized for the one-pot, four-component synthesis of spiro[indoline-3,2′-quinoline] derivatives from the combination of isatins, amines, dimedone, and dialkylacetylenedicarboxylates. The advantages of this protocol included the use of common and easily-available starting materials, utilizing ambient temperature, non-toxic and inexpensive reagent usage, high yields of products, and operationally simple procedure.

Graphical Abstract



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Keywords Crown ether-based nano ionic liquid · Spiro[indoline-3,2′-quinoline] · Spiro compounds · Multi-component reaction · Isatin · Dialkylacetylenedicarboxylates

1 Introduction

Ionic liquids (ILs) possess green properties such as non-flammability, chemical and thermal stability, extended solvation nature, and negligible vapor pressure [1]. Brönsted acidic ionic liquids has been replaced with mineral acids such as sulfuric acid and hydrochloric acid in chemical and industrial processes [2–4]. In recent years, many task-specific ionic liquids (TSILs) were designed and utilized for accelerating various organic transformations [5–7].

Spirooxindoles have contained particular attention in recent years because of their strong activity and interesting structural properties as potent medicinal or biologically active agents. Many heterocycles including these motifs could be used as therapeutic [8], anticancer [9], anti-malaria [10], antimicrobial [11], anti-inflamtory [12], and anti-tumor [13] agents. One group of these spiro-compounds are spiro[indoline-3,2′-quinoline] derivatives. Yan and co-workers in 2012 have reported a novel procedure to obtain these products via a four-component reaction of arylamines, dimethylacetylene dicarboxylate (DMAD), isatins, and dimedone in acetic acid within 24 h [14]. In 2015 Pramanik and Debnath has also achieved these fuctionalized heterocycles via the same four-component reaction in the presence of bimettalic ($ZnFe_2O_4$) nanopowder in water medium [15]. According to the literature surveys there are no reports for this type four-component reactiond expect the two mentioned above.

In this report, we synthesized and characterized a new nano-size crown ether ionic liquid based on dibenzo-18-crown-6 ($[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL) for the first time and examine its catalytic activity to get spiro[indoline-3,2′-quinoline] derivatives via the one-pot, one-step, and four-component reaction of arylamines, dialkylacetylenedicarboxylates (DAAD), isatins, and dimedone in EtOH at room temperature. It must be mentioned that in 2011 Jing and co-workers prepared and characterized some new crown ether complex cation ionic liquids (CECILs) based on [15] crown-5-ether (15-C-5) and [18] crown-6-ether (18-C-6), which have been utilized to promote Michael addition of alkenes ([15-C-5Na][OH], [15-C-5Na][OAc], [18-C-6K][OH], and [18-C-6K][OAc]), Henry reaction of nitromethane and aromatic aldehydes ([18-C-6K][OH] and [15-C-5Na][OH]), and Knoevenagel condensation of aromatic aldehydes and malononitrile ([18-C-6K][OH]) [16]. In addition Abaszadeh and Mohammad in 2017 synthesized some new crown ether complex cation ionic liquids (CECILs) via the reaction of crown ethers (18-C-6 and DB-18-C-6) chelated with sodium benzenesulfonates to catalyze the three-component reactions of aromatic aldehydes and malononitrile with cyclic β-dicarbonyls or cyclic β-enaminoketones to obtain tetrahydro-4H-chromenes and 1,4-dihydropyridines by respectively [17].

2 Results and Discussion

2.1 Characterization of the Nanocatalyst

Crown ether-based nIL ($[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL) has been prepared through the simple mixing of an equimolar ratio of dibenzo-18-crown-6 and potassium hydroxide in methanol as solvent (Scheme 1). After workup procedure, the obtained yellow powder was characterized with fourier transform infrared spectroscopy (FT-IR), high-resolution scanning electron microscopy (HR-SEM), energy-dispersive X-ray spectroscopy (EDAX), nuclear magnetic resonance spectroscopy (^1H NMR), thermogravimetric/differential thermal analysis (TGA/DTG), and UV–Vis techniques.

The FT-IR spectrum of $[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL demonstrated all the bands of crown ether in addition with the band at 3647 cm^{-1} that belongs to the hydroxyl group in the structure (Fig. 1).

^1H NMR spectrum of the nIL, which is recorded in $CDCl_3$, demonstrated two triplets at δ 4.05 $J = 6.7$ Hz and 4.13 ppm $J = 5.78$ Hz related to CH_2 methylene groups of the crown ether ring. Aromatic protons recorded as multiple peak at δ 6.85–6.92 ppm The hydroxyl group appeared as a singlet at 7.26 ppm (Fig. 2).

The TGA/DTG diagram showed at Fig. 3. According to the results, the negligible exothermic weight loss took placed at 150–160 °C which related to losing the adsorbed water on the surface of nIL. The main weight lost displayed at 265–380 °C in a single endothermic step.

The HR-SEM picture of $[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL is appeared at Fig. 4. This image reveals that the product consists of nanorodes with the average diameter of 100–150 nm.

In continue, the EDAX of $[DB\text{-}18\text{-}C\text{-}6K^+][OH^-]$ nIL in Fig. 5 indicated that the catalyst is only made up of carbon, potassium, and oxygen.

An efficient method for evaluating the Bronsted acidity is based on the Hammett function (Eq. 1).

$$H_0 = pK(I)_{aq} + \log\left([I]_s/[HI^+]_s\right) \quad (1)$$

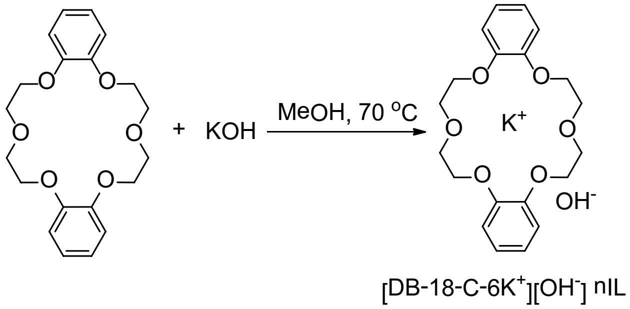
where the pKI_{aq} is the pK_a value of aqueous solution of indicator, $[IH^+]_s$ and $[I]_s$ are the molar concentrations of protonated and unprotonated forms of the indicator in the solvent, respectively. According to Lambert–Beer's Law, the value of $[I]_s/[IH^+]_s$ can be determined and calculated through

UV–Vis spectrum [18, 19]. For this reason, 4-nitroaniline pKI$_{aq}$ = 0.99, as the basic indicator, and DMSO as the solvent were chosen. As it has been cleared in Fig. 6, the maximal absorbance of the unprotonated form of the indicator was observed at 383 nm in DMSO.

When [DB-18-C-6K$^+$][OH$^-$] nIL, as the ionic liquid catalyst, was added to the indicator solution, the absorbance of the unprotonated form of the indicator decreased, which indicated that the indicator was partially in the form of [IH$^+$]. These results, Table 1, affirmed the acidity strength of the nano IL.

2.2 Investigation the Catalytic Activity of the Nanocatalsyt

In the next step the catalytic activity of [DB-18-C-6K$^+$][OH$^-$] nIL has been examined for the synthesis of spiro[indoline-3,2′-quinoline] derivatives. To optimize the reaction conditions, at first the reaction of isatin **1a** (1 mmol), 4-methoxyaniline **2d** (1 mmol), DMAD **3a** (1 mmol), and dimedone **4** (1 mmol) was considered as the model reaction to determine the effect of various parameters. The catalyst amount investigation denoted that 0.008 g is the best amount (Table 2, entries 1–3). The model reaction performed in different solvents as well as solvent-free situations. The best results observed in ethanol. The results in entries 7 and 8 of Table 2 validated that elevating the temperature didn't affect the progress of the reaction. All the entries of Table 2 have been examined in a one-pot and one-step manner. We also carried out this reaction in a domino condition but the desired product didn't achieved.



Scheme 1 Synthesis of [DB-18-C-6K$^+$][OH$^-$] nIL

Terminally, on the basis of the optimized conditions, the reaction of isatins **1a–b**, aniline derivatives **2a–h**, DMAD **3a** or DEAD **3b**, and dimedone **4** followed by [DB-18-C-6K$^+$][OH$^-$] nIL (0.008 g), as accelerator, in ethanol at room temperature (Scheme 2). The resultant of this research are summarized in Table 3.

According to the perceived data in Table 3 aniline **2a** and its electron-donating as well as electro-withdrawing substituents reacted with isatin **1a**, DMAD **3a**, and dimedone **4** to obtain the corresponding products successfully (entries 1–5). 5-Chloroisatin **1b** as another candidate perfumed the same transformations finely (entries 6–10). The condensation of **1b**, dimedone, and DMAD with 1-naphthylamine **2g**, as a sterically hindered aromatic amine, has also yielded to the adduct **5k** very well (entry 11). DEAD **3b** was another successful volunteer that utilized in these examinations good (entries 12–15). All the known products has been isolated and characterized by their melting

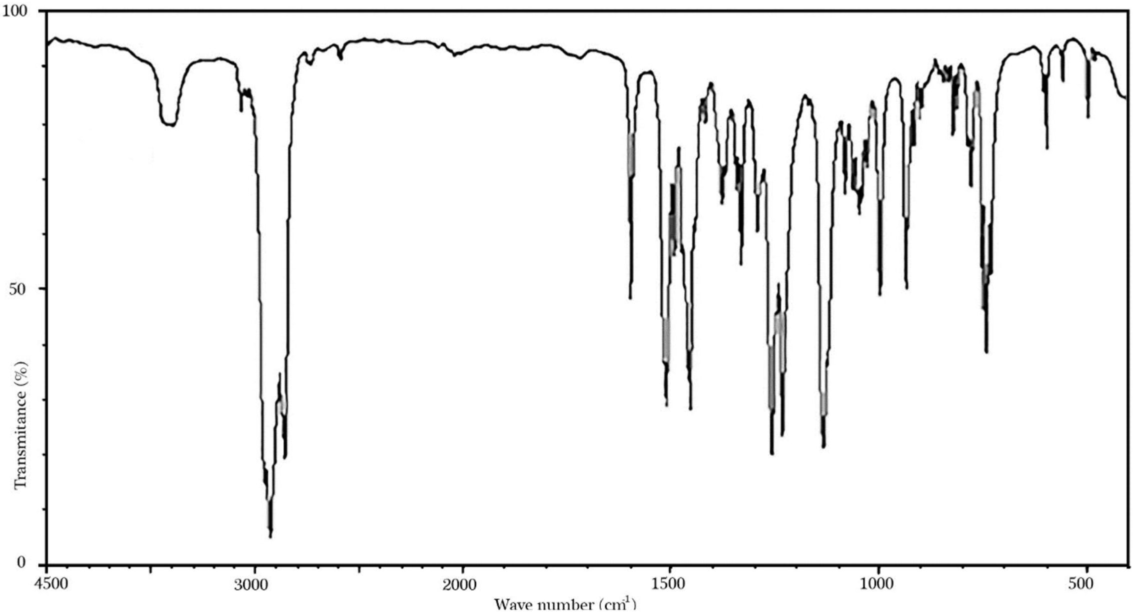


Fig. 1 FT-IR spectrum for [DB-18-C-6K$^+$][OH$^-$] nIL

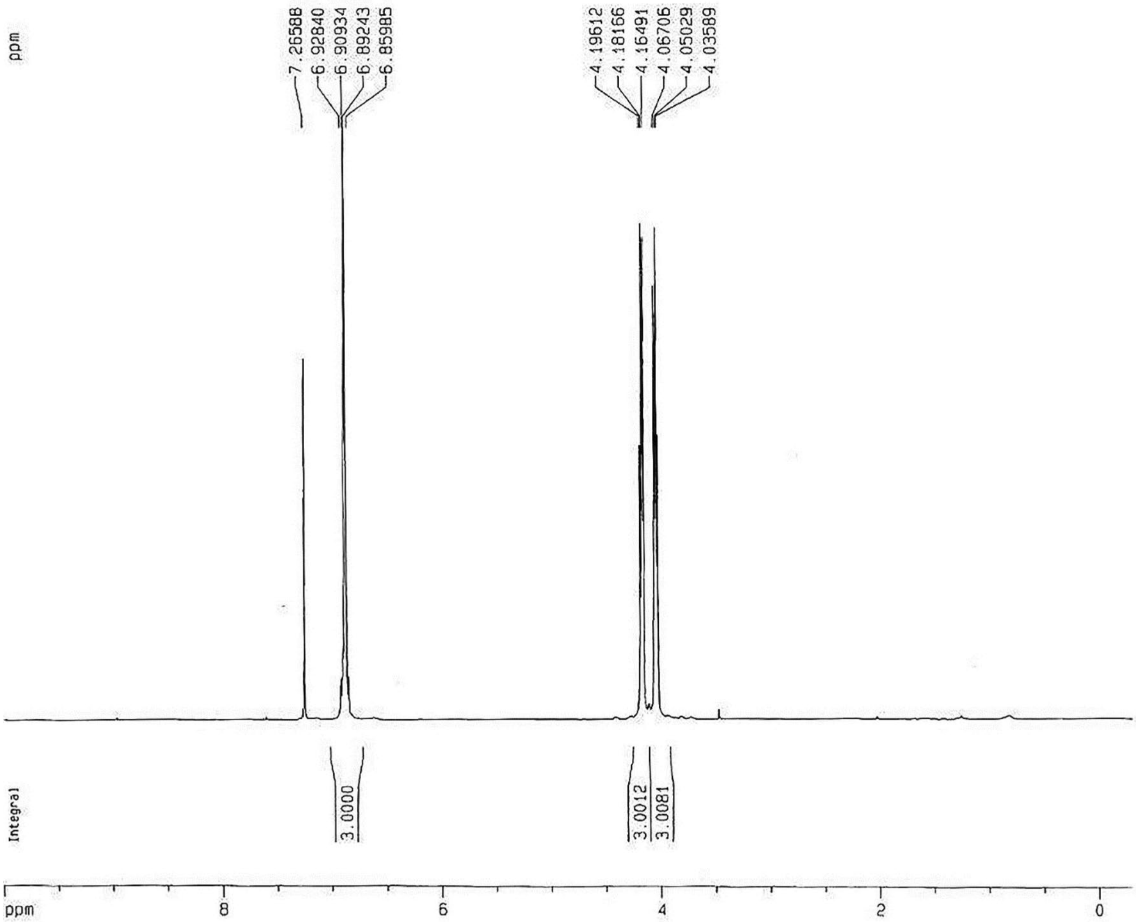


Fig. 2 ^{1}H NMR spectra of [DB-18-C-6K$^+$][OH$^-$] nIL

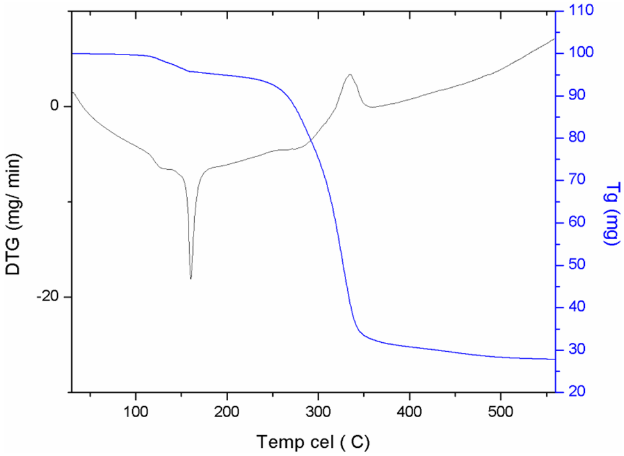


Fig. 3 TGA/DTG diagram of [DB-18-C-6K$^+$][OH$^-$] nIL

point and spectroscopic data FT-IR, ^{1}H NMR, and MASS in comparison with their authentic samples.

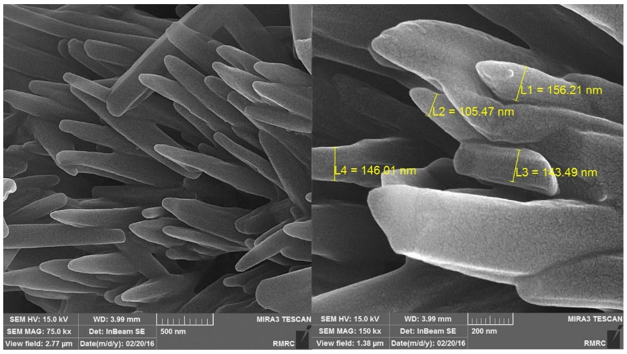


Fig. 4 HR-SEM image of [DB-18-C-6K$^+$][OH$^-$] nIL

The recommended mechanism for this synthesis has been demonstrated in Scheme 3. As the catalyst possessed both acidic (K$^+$) and also basic centers (OH$^-$), at first the catalyst, from its acidic moiety, activated the carbonyl of isatin at its C$_3$ position which reacted with arylamine to give imine **(A)** On the other hand, the α-proton of dimedone **4**, which has been more acidic by the aid of its

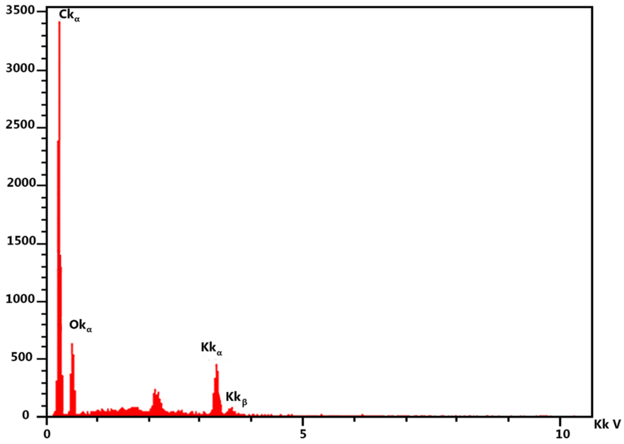


Fig. 5 EDAX diagram of [DB-18-C-6K$^+$][OH$^-$] nIL

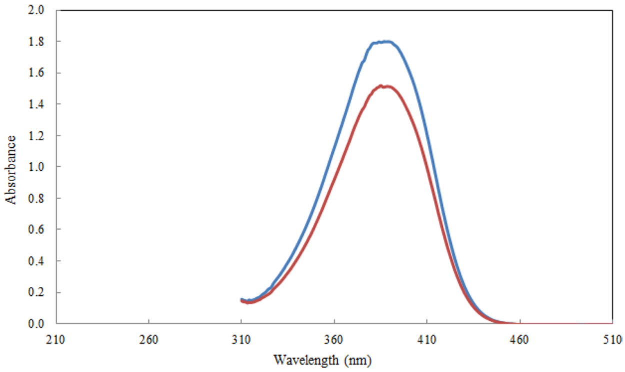


Fig. 6 Diagram of the Hammett acidity for [DB-18-C-6K$^+$][OH$^-$] nIL

Table 1 Calculation of the Hammett acidity function H_0 for [DB-18-C-6K$^+$][OH$^-$] nIL

Catalyst	A_{max}	[I]%	[HI]%	H_0
–	1.8177	100	0	–
[DB-18-C-6K$^+$][OH$^-$] nIL	1.5096	83.2	16.8	1.68

Condition for UV–Vis spectrum measurement solvent DMSO, indicator: 4-nitroaniline ($pKI_{aq}=0.99$, 1×10^{-5} mol/l, 2.5 mL); catalyst: [DB-18-C-6K$^+$][OH$^-$] nIL (0.345 mg, 25 °C)

neighbor carbonyl group, ruptured by basic part of the nIL (OH^-) and converted into its enol form (**B**) It must be mentioned that the neighbor carbonyl moiety of this proton has been more electrophilic through its coordination by cationic center of the nIL (K^+). It means that the reaction could be promoted due to the synergistic effect (aid) of the cation and also the anion parts of the [DB-18-C-6K$^+$][OH$^-$] nIL [20]. Nucleophlic attack of **B** to dialkylacetylenendicarboxylate **3** produced intermediate **C** that absorbed proton from ethanol to form **D**. Deporotonation of **D** by means of EtO^- from solvent yielded **E** that condensed with intermediate **A** to obtain F. Cycloaddition of **F** give **G** which followed by dehydration afford the corresponding spiro[indoline-3,2′-quinoline] derivatives **5**.

Table 2 Screening the reaction conditions in the synthesis of spiro[indoline-3,2′-quinoline] **5d**

Entry	Conditions [DB-18-C-6K$^+$][OH$^-$] nIL (g)/solvent (8 mL)/temperature (°C)	Time (min)	Yield^a (%)
1	0.004/EtOH/rt	90	50
2	0.008/EtOH/rt	60	90
3	0.012/EtOH/rt	60	80
4	0.008/–/rt	19 h	90
5	0.008/H_2O/rt	24 h	–
6	0.008/EtOH/H_2O 11/rt	120	80
7	0.008/EtOH/50	60	70
8	0.008/EtOH/reflux	90	30

^{a}Isolated yield

3 Conclusion

In conclusion, crown ether-based nano ionic liquid ([DB-18-C-6K$^+$][OH$^-$] nIL) has been prepared via easily-available precursors simply, and characterized by FT-IR, EDAX, ^{1}H NMR, HR-SEM, UV–Vis techniques. It catalytic efficiency has been examined to produce spiro[indoline-3,2′-quinoline] heterocycles from isatin derivatives, arylamines, dialkylacetylenendicarboxylates, and dimedone in ethanol via the one-pot four-component reaction at room temperature. In general, the reported protocol has several advantages such as (a) short reaction times, (b) green reaction media because of no requirement to hazardous solvents, (c) easily-handle, inexpensive, and non-toxic nano reagent usage.

4 Experimental

All chemicals were purchased from Merck, Aldrich, and *Alfa Aesar and were used without further purification*. FT-IR spectra were recorded on FT-IR Bruker Tensor 27 instrument from KBr disk. Melting points were determined on an Electrothermal 9200 analyzer and are uncorrected. ^{1}H NMR spectra were obtained with a Bruker drx 300 MHz machine. Elemental analyses were determined using a Thermo-Finnigan Flash EA 1112 Series. Mass spectroscopy has been achieved by Gc-Mass 5973 network mass selective detector, Gc 6690 Agilent device. The scanning electron

Scheme 2 One-pot synthesis of spiro[indoline-3,2′-quinoline] derivatives using [DB-18-C-6K$^+$][OH$^-$] nIL

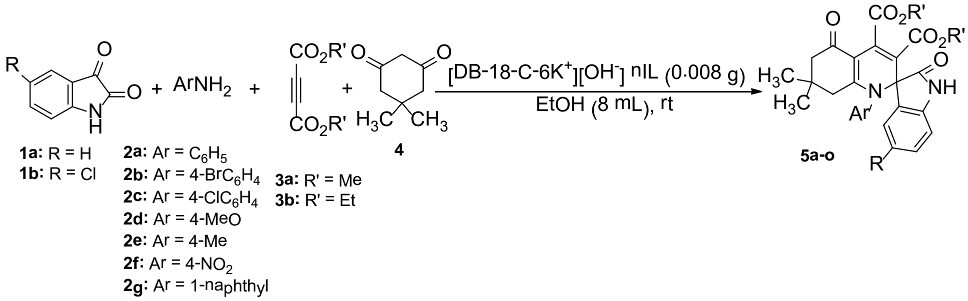


Table 3 Synthesis of spiro[indoline-3,2′-quinoline] derivatives in the presence of [DB-18-C-6K$^+$][OH$^-$] nIL

Entry	R	Ar	R′	Product	Time (min)	Yield (%)[a]	Mp (°C)[b]
1	H	C_6H_5	CH_3	**5a**	75	92	162–164 [15]
2	H	4-BrC_6H_4	CH_3	**5b**	80	81	310–312 [14]
3	H	4-ClC_6H_4	CH_3	**5c**	135	91	286–287 [15]
4	H	4-$OCH_3C_6H_4$	CH_3	**5d**	60	94	270–271 [15]
5	H	4-$CH_3C_6H_4$	CH_3	**5e**	100	90	290–292 [14]
6	Cl	C_6H_5	CH_3	**5f**	120	80	252–254 [15]
7	Cl	4-BrC_6H_4	CH_3	**5g**	135	90	310–312 [14]
8	Cl	4-ClC_6H_4	CH_3	**5h**	135	90	247–249 [14]
9	Cl	4-$NO_2C_6H_4$	CH_3	**5i**	60	90	114–117
10	Cl	4-$OCH_3C_6H_4$	CH_3	**5j**	120	90	248–250 [15]
11	Cl	1-Naphthyl	CH_3	**5k**	200	80	332–335
12	H	4-BrC_6H_4	C_2H_5	**5l**	135	90	288–290 [14]
13	H	4-ClC_6H_4	C_2H_5	**5m**	45	80	292–293 [15]
14	H	4-$OCH_3C_6H_4$	C_2H_5	**5n**	85	80	240–242 [14]
15	H	4-$CH_3C_6H_4$	C_2H_5	**5o**	45	90	231–233 [15]

[a] Isolated yield

[b] Refrence of known compounds

microscope (HR-SEM, model ZEISS AMA) used to characterize the nanostructures. Thermogravimetric analysis were determined PYRIS DIAMOND apparatus. UV–Vis spectra were recorded with Perkin-Elmer 45 LAMBADA quartz cell, 1 cm machine. Progress of the reaction was monitored by thin layer chromatography (TLC) technique using commercially available silica gel sheets. Preparative layer chromatography (PLC) carried out on 20 × 20 cm^2 plates, coated with a 1 mm thick layer of Merck silica gel PF_{254}, prepared by applying the silica as slurry and drying in air.

4.1 Synthesis of Crown Ether-Based nIL ([DB-18-C-6K$^+$][OH$^-$] nIL)

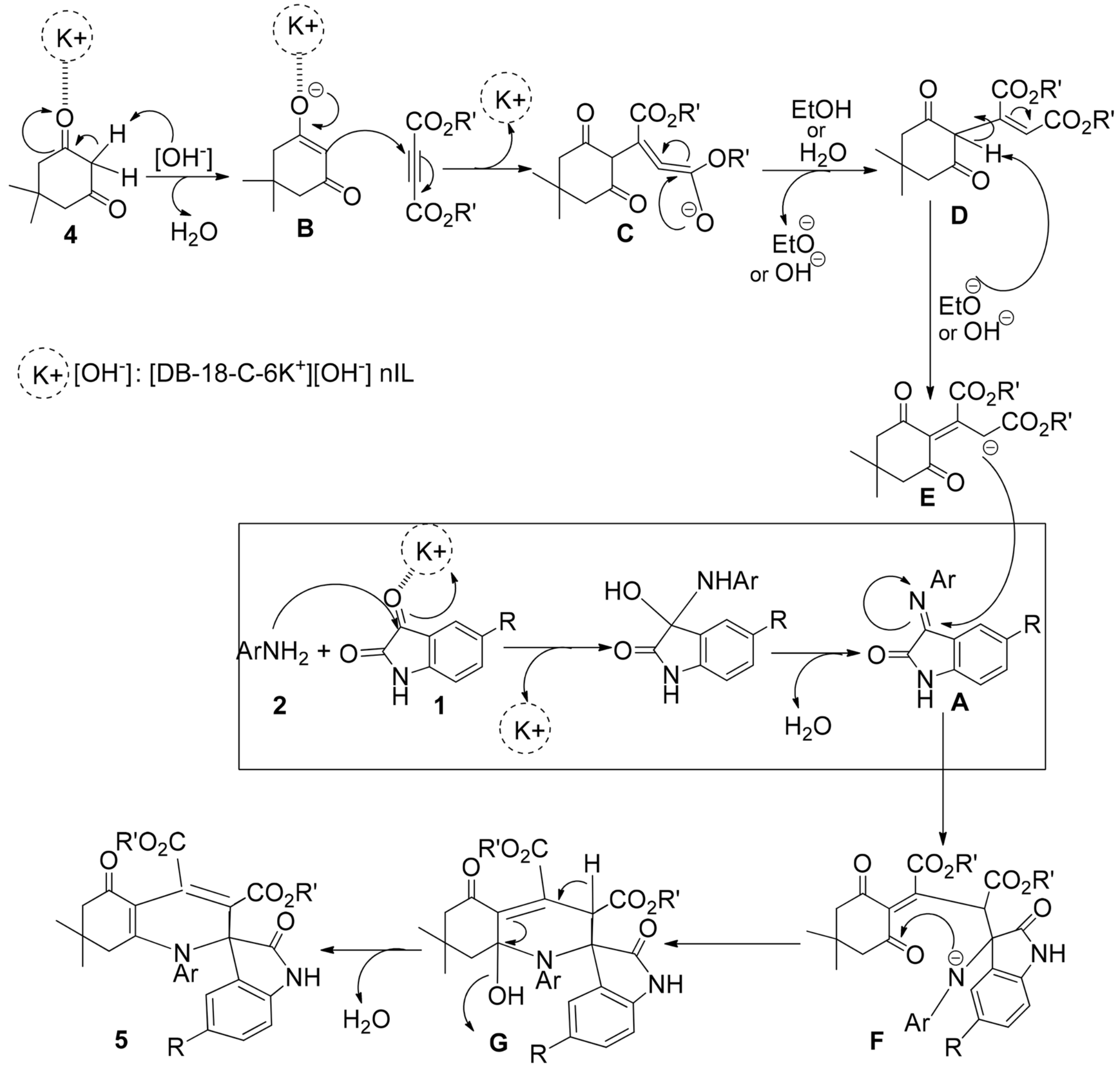
A mixture of dibenzo-18-crown-6 (2 mmol, 0.36 g) and potassium hydroxide (2 mmol, 0.056 g) in methanol (5 mL) was stirred at 70 °C for 19 h. Then, the solvent was evaporated to give a yellow powder which was centrifuged with CCl_4 (2 mL) within 5 min followed with drying in 70 °C oven for 30 min.

4.2 General Procedure for the Synthesis of Spiro[indoline-3,2′-quinoline] Derivatives 5a–o

A mixture of isatins **1a–b** (1 mmol), arylamines **2a-g** (1 mmol), dialkylacetylenendicarboxylates **3a-b** (1 mmol), and dimedone **4** (1 mmol) in the presence of [DB-18-C-6K$^+$][OH$^-$] nIL (0.008 g) in ethanol (8 mL) was magnetically stirred at room temperature for the desired reaction time monitored by TLC (*n*-hexane/ethylacetate eluent). After completion, purification of the products was performed through plate chromatography to give the corresponding solid products **5a-o** in high yields. The characterization data of the new compounds are given below.

4.2.1 Dimethyl 5-chloro-7′,7′-dimethyl-1′-(4-nitrophenyl)-2,5′-dioxo-5′,6′,7′,8′-tetrahydro-1′H-spiro[indoline-3,2′-quinoline]-3′,4′-dicarboxylate (5i)

Mp decomp. 114–117 °C. IR (KBr, cm^{-1}) υ 3420, 2957, 1716, 1648, 1617, 1510, 1474, 1368, 1248, 1183, 670. ^{1}H



Scheme 3 Proposed route for the synthesis of spiro[indoline-3,2′-quinoline]s using [DB-18-C-6K$^+$][OH$^-$] nIL

NMR DMSO-d_6 (δ, ppm) 0.96 (s, 6H, $2CH_3$), 2.03–2.10 (m, 2H, CH_2), 2.53 (s, 2H, CH_2), 3. 32 (br s, 6H, $2OCH_3$), 6.66 (d, $J = 8.17$, 2H, -ArH), 6.71–6.90 (m, 2H, -ArH), 6.93 (s, 1H, -ArH), 7.09 (d, $J = 8.17$, 2H, -ArH), 9.93 (br s, 1H, NH). m/z 346 ([M$^+$]- *p*-nitrophenyl-cyclohexenyl), 331 ([M$^+$]- *p*-nitrophenyl- 5-methylcyclohexenyl), 281 ([M$^+$]- $CO_2MeCHCHCO_2Me$- *p*-nitrophenyl -Me), 254 ([M$^+$]- $CO_2MeCHCHCO_2Me$- *p*-nitrophenyl -isopropyl), 221 ([M$^+$]- *p*-nitrophenyl -5-chlorooxindolyl- CMe_3), 163 ([5-chlorooxindolyl]$^+$), 125 ([nitrophenyl]$^+$). Anal Calcd for $C_{28}H_{24}N_3O_8Cl$: C 59.42, H 4.27, N 7.42%, Found C 59.40, H 4.22, N 7.39%.

4.2.2 Dimethyl 5-chloro-7′,7′-dimethyl-1′-(naphthalen-1-yl)-2,5′-dioxo-5′,6′,7′,8′-tetrahydro-1′H-spiro[indoline-3,2′-quinoline]-3′,4′-dicarboxylate (5k)

Mp decomp. 330–335 °C. IR (KBr, cm^{-1}) υ 3396, 2955, 1714, 1617, 1436–1569, 1222, 1183, 669. ^{1}H NMR DMSO-d_6 (δ, ppm) 0.91 (s, 6H, $2CH_3$), 1.83–1.97 (m, 1H, CH_2), 2.03–2.26 (m, 1H CH_2), 2.53 (s, 2H, CH_2), 3.35 (s, 3H, OCH_3), 3.54 (s, 3H OCH_3), 6.31–7.14 (m, 10H, -ArH), 7.14 (s, 1H, NH). m/z 282 ([M$^+$]-naphthyl-5-chlorooxindolyl), 217 ([M$^+$]-naphthyl-5-chlorooxindolyl-CMe_3), 185 ([3-nitro-5-chlorooxindolyl]$^+$), 163 ([5-chlorooxindolyl]$^+$), 141 ([$CO_2MeCHCHCO_2Me$]$^+$), 126 ([naphthyl]$^+$). Anal Calcd for $C_{32}H_{26}N_2O_6Cl$: C 67.43, H 4.60, N 4.91% Found C 67.40, H 4.64, N 4.87%.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Parvulescu VI, Hardacre C (2007) Catalysis in ionic liquids. Chem Rev 107(6):2615–2665
2. Cole AC, Jensen JL, Ntai I, Tran KLT, Weaver KJ, Forbes DC et al (2002) Novel brønsted acidic ionic liquids and their use as dual solvent-catalysts. J Am Chem Soc 124(21):5962–5963
3. Amarasekara AS (2016) Acidic ionic liquids. Chem Rev 116(10):6133–6183
4. Vafaeezadeh M, Alinezhad H (2016) Brønsted acidic ionic liquids: green catalysts for essential organic reactions. J Mol Liq 218:95–105
5. Davis JH Jr (2004) Task-specific ionic liquids. Chem Lett 33(9):1072–1077
6. Yue C, Fang D, Liu L, Yi TF (2011) Synthesis and application of task-specific ionic liquids used as catalysts and/or solvents in organic unit reactions. J Mol Liq 163(3):99–121
7. Singh H, Sindhu J, Khurana JM, Sharma C, Aneja KR (2014) Ultrasound promoted one pot synthesis of novel fluorescent triazolyl spirocyclic oxindoles using DBU based task specific ionic liquids and their antimicrobial activity. Eur J Med Chem 77:145–154
8. Galliford CV, Scheidt KA (2007) Pyrrolidinyl-spirooxindole natural products as inspirations for the development of potential therapeutic agents. Angew Chem 46:8748–8758
9. Satyamaheshwar P (2009) 3-Substituted-3-hydroxyl-2-oxindole, an emerging new scaffold for drug discovery with potential anticancer and other biological activities. Curr Bioact Compd 5(1):20–38
10. Yeung BKS, Zou B, Rottmann M, Lakshminarayana SB, Ang SH, Leong SY et al (2010) Spirotetrahydro β-carbolines (spiroindolones): a new class of potent and orally efficacious compounds for the treatment of malaria. J Med Chem 53(14):5155–5164
11. Bhaskar G, Arun Y, Balachandran C, Saikumar C, Perumal PT (2012) Synthesis of novel spirooxindole derivatives by one pot multicomponent reaction and their antimicrobial activity. Eur J Med Chem 51:79–91
12. Liu J, Sun Y, Zhang X, Liang X, Wu Y, Wang Y, Jiang X (2014) Spirooxindoles, a potential novel class of anti-inflammatory agent. Inflamm Cell Signal 1(4):372–375
13. Girgis AS, Mabied AF, Stawinski J, Hegazy L, George RF, Farag H, Shalaby EM (2015) Farag ISA synthesis and DFT studies of an antitumor active spiro-oxindole. New J Chem 39:8017–8027
14. Sun J, Sun Y, Gao H, Yan C-G (2012) Synthesis of spiro [indoline-3, 2′-quinoline] derivatives through a four-component reaction. Eur J Org Chem 2012(10):1976–1983
15. Debnath K, Pramanik A (2015) Heterogeneous bimetallic $ZnFe_2O_4$ nanopowder catalysed facile four component reaction for the synthesis of spiro[indoline-3,2′-quinoline] derivatives from isatins in water medium. Tetrahedron Lett 56(13):1654–1660
16. Song Y, Jing H, Li B, Bai D (2011) Crown ether complex cation ionic liquids: preparation and applications in organic reactions. Chem Eur J 17:8731–8738
17. Abaszadeh M, Seifi M (2017) Crown ether complex cation ionic liquids: synthesis and catalytic applications for the synthesis of tetrahydro-4H-chromene and 1,4-dihydropyridine derivatives. J Sulfur Chem 38(4):440–449
18. Shirini F, Langarudi MSN, Seddighi M, Jolodar OG (2015) Bi-SO_3H functionalized ionic liquid based on DABCO as a mild and efficient catalyst for the synthesis of 1,8-dioxo-octahydroxanthene and 5-arylmethylene-pyrimidine-2,4,6-trione derivatives. Res Chem Intermed 41(11):8483–8497
19. Xing H, Wang T, Zhou Z, Dai Y (2007) The sulfonic acid-functionalized ionic liquids with pyridinium cations: acidities and their acidity–catalytic activity relationships. J Mol Catal A 264(1–2):53–59
20. Wang J, Liang Y, Zhou D, Ma J, Jing H (2018) New crown ether complex cation ionic liquids with N-heterocycle anions: preparation and application in CO_2 fixation. Org Chem Front 5:741–748

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