GREEN ASPECT FOR MULTICOMPONENT SYNTHESIS OF SPIRO[4H-INDENO[1,2-b]PYRIDINE-4,3'-[3H]INDOLES]

Nilam C. Dige and Dattaprasad M. Pore
Department of Chemistry, Shivaji University, Kolhapur, India

GRAPHICAL ABSTRACT

Abstract An efficient, four-component reaction of isatin, 1,3-indanedione, ethyl acetoacetate, and ammonium acetate in ethanol/water (9:1) system furnished spiro[4H-indenol[1,2-b]pyridine-4,3'-[3H]indoles] at room temperature. Merits of the method are mild reaction conditions, simple workup procedure, and ambient temperature. The synthesized compounds exhibit excellent fluorescence properties.

Keywords Ambient temperature; ammonium acetate; 1,3-indanedione; multicomponent; spiro[4H-indenol[1,2-b]pyridine-4,3'-[3H]indoles]

INTRODUCTION

Designing and developing an efficient, simple, and economic protocol under the umbrella of green chemistry for organic transformations is an attractive research area from both academic and industrial point of view. In this vein, multicomponent reactions (MCRs) are promising tools, permitted a rapid access to large number of structurally related, druglike compounds and thereby facilitating lead

Received June 7, 2015.
Address correspondence to Dattaprasad M. Pore, Department of Chemistry, Shivaji University, Kolhapur 416 004, India. E-mail: p_dattaprasad@rediffmail.com
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/lsyc.
generation of “privileged medicinal scaffolds.”[5–7] Thus they become a crucial part of today’s arsenal of methods in combinatorial chemistry because of their valued features such as atom-economy, energy economy, straightforward reaction design, economic route, and the opportunity to construct target compounds by the introduction of several diversity elements in a single chemical event.[8] Environmental aspects triggered scientists to focus on the modification of known MCRs with green characteristics, such as development of catalyst-free and solvent-free methods, and avoidance of organic solvents and auxiliary chemicals paraphrased by the concept “the best catalyst is no catalyst,” reported by Maggi.[9]

Indenone is ambitious nucleus of several bioactive heterocycles, for example, alkaloids like onychnine of 4-azafluorenone group involve the indenopyridine skeleton (Fig. 1).[10] Indenopyrazoles (A) and indenopyridazines (B) have been investigated as cyclin-dependent kinase[11] and selective monoamine oxidase B (MAO-B)[12] inhibitors, respectively. Further, indenopyridines (C) exhibit cytotoxic,[13a] phosphodiesterase inhibitory,[13b] adenosine A2a receptor antagonistic,[13c] anti-inflammatory/antiallergic,[13d] coronary dilating,[13e] and calcium modulating activities.[13f] These compounds have also been investigated for the treatment of hyperlipoproteinemia and arteriosclerosis,[13g] as well as neurodegenerative diseases.[13h] Indenopyridone NSC 314622 is serving as a lead compound for the development of anticancer agents targeting topoisomerase I. Its polycyclic planar structure allows for DNA intercalation and inhibition of DNA relegation by topoisomerase I in a manner similar to the polycyclic natural product camptothecin and its clinically useful derivative topotecan.[14]

Furthermore, indole moiety is also embedded in the most well-known heterocycles, a variety of natural products and medicinal agents.[15] Furthermore, it has been reported that sharing of the indole-3-carbon atom in the formation of spiroindoline derivatives can highly enhance biological activity.[16] The spirooxindole system is the core structure of many pharmacological agents and natural alkaloids.[17]

Figure 1. Representative examples of natural products and bioactive molecules containing indenones and spirooxindoles.
For example, spirotryprostatin A and B, two natural alkaloids isolated from the fermentation broth of *Aspergillus fumigatus*, have been identified as novel inhibitors of microtubule assembly,[17d] and pteropodine and isopteropodine have been shown to modulate the function of muscarinic serotonin receptors (Fig. 1).[17a] Owing to the importance of indenones and spiroindoles, their presence in the spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles] may confer important properties.

To the best of our knowledge, there are sporadic reports for the synthesis of spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles].[18] The authors employed pyridine as a catalyst for a one-pot, four-component reaction of indane-1,3-dione, isatins, 1,3-dicarbonyl compounds, and AcONH₄ in toluene at reflux conditions for 24 h. In their second report, they carried out the reaction of isatin, indane-1,3-dione, and enamine for the synthesis of spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles][18b] using *L*-proline as a catalyst in 1-propanol at reflux condition for 10 h. Therefore an environmentally benign, energy efficient, economical method for synthesis of spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles] operable under mild conditions in a short time is highly desirable.

**RESULTS AND DISCUSSION**

As a part of our endeavor to develop methodologies for the synthesis of bioactive heterocycles,[19] we report herein the synthesis of spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles] from isatin, 1,3-indanedione, ethyl acetoacetate, and ammonium acetate at ambient temperature (Scheme 1).

In continuation of our earlier experience with catalyst-free synthesis of polyhydroquinolines,[19a] we have foreseen that NH₄OAc, one of the reactant upon hydrolysis leads to in situ formation of acetic acid, may act as a catalyst for the present transformation without need for an external catalyst. In this context, in a pilot experiment as a model reaction, a mixture of isatin, 1,3-indanedione, ethyl acetoacetate, and ammonium acetate was stirred in ethanol at ambient temperature. The corresponding spiro[4H-indeno[1,2-b]pyridine-4,3′-[3H]indole] was formed in

![Scheme 1](image-url)
good yield. The precipitated solid was filtered and washed with ethanol to furnish the desired product in high purity, thus avoiding tedious workup procedure and chromatographic separation for isolation and purification of product, respectively.

The formation of product was confirmed by spectral techniques including infrared (IR), $^1$H and $^{13}$C NMR, mass spectrometry (MS), high-resolution MS (HRMS), and elemental analysis. The IR spectrum (entry F, Table 2) exhibited bands at $3426, 3322$ cm$^{-1}$ for NH stretching, while band detected at $1700, 1674, 1648$ cm$^{-1}$ are due to stretching of $>\text{C}=\text{O}$. In $^1$H NMR spectrum, two significant singlets at $\delta$ 10.35, 10.31 ppm confirmed the presence of two $-\text{NH}$ protons, and a multiplet depicted at $\delta$ 3.76–3.80 highlighted the presence of $-\text{OCH}_2$, singlet at $\delta$ 2.43 ppm is due to $-\text{CH}_3$ protons, while another $\text{CH}_3$ adjacent to $-\text{OCH}_2$ displayed a triplet for three proton at $\delta$ 0.86–0.90 ppm. In $^{13}$C NMR three carbonyl carbons appeared at $\delta$ 189.97, 179.81, 166.07 ppm while the spiro carbon and $\text{OCH}_2$ appeared at 60.29 and 49.98 ppm, respectively. Mass spectrum displayed peaks at 512 (M$^+$), 484, 456, 439, 411 ($m/z$), which is also in good agreement with the proposed structure.

For optimization of reaction conditions, keeping in mind principles of green chemistry, initially we carried out model reaction in water; however, no desired product was observed even after 12 h stirring (Table 1, entry 1). With our earlier experience in a mixed solvent system, we focused our attention on screening of ethanol: water system for a model reaction (Table 1, entries 2–10). Satisfyingly, we observed formation of the desired product in excellent yield in 90% ethanol.

To obtain a library of spiroindenopyridineindoles employing the optimized reaction conditions, we used a wide diversity of substituted isatins. Electron-rich, electron-deficient, and $N$-substituted isatins reacted smoothly without any remarkable reactivity difference (Table 2).

A plausible mechanism is suggested in Scheme 2. The electronegative counteranion of ammonium acetate abstracts the acidic proton of 1,3-indanedione (b), generating carbanion, which subsequently attacks the carbonyl carbon of isatin (a), furnishing Knoevenagel products. Then Michael addition of in situ-formed enamine 2 by the reaction of ethyl acetoacetate (c) and ammonium acetate (d) on 1 led to

| Entry | Solvent, water/alcohol (v/v) | Time (h) | Yield (%) |
|-------|-------------------------------|----------|-----------|
| 1     | (10/0)                        | 12       | —         |
| 2     | (9/1)                         | 12       | —         |
| 3     | (8/2)                         | 12       | 48        |
| 4     | (7/3)                         | 12       | 52        |
| 5     | (6/4)                         | 12       | 54        |
| 6     | (5/5)                         | 10       | 60        |
| 7     | (4/6)                         | 10       | 61        |
| 8     | (3/7)                         | 8.5      | 59        |
| 9     | (2/8)                         | 8        | 62        |
| **10**| (1/9)                         | **6**    | **78**    |
| 11    | (0/10)                        | 6        | 72        |
| 12    | DMSO                          | 16–17    | 70        |

Notes. Reaction conditions: isatin (1 mmol); indane 1,3 dione (1 mmol); ethyl acetoacetate (1 mmol); ammonium acetate (1 mmol); temperature: rt.
| No. | Sample code (entry) | Isatin | Product | Time (h) | Yield (%) |
|-----|---------------------|--------|---------|---------|-----------|
| 1   | A                   | ![Isatin A](image) | ![Product A](image) | 5.3     | 79        |
| 2   | B                   | ![Isatin B](image) | ![Product B](image) | 3.5     | 70        |
| 3   | C                   | ![Isatin C](image) | ![Product C](image) | 5       | 86        |
| 4   | D                   | ![Isatin D](image) | ![Product D](image) | 4       | 78        |
| 5   | E                   | ![Isatin E](image) | ![Product E](image) | 6       | 75        |

(Continued)
Table 2. Continued

| No. | Sample code (entry) | Isatin | Product | Time (h) | Yield (%) |
|-----|---------------------|--------|---------|---------|----------|
| 6   | F                   | ![Image](image1.png) | ![Image](image2.png) | 5       | 78       |
| 7   | G                   | ![Image](image3.png) | ![Image](image4.png) | 5       | 83       |
| 8   | H                   | ![Image](image5.png) | ![Image](image6.png) | 6       | 72       |
| 9   | I                   | ![Image](image7.png) | ![Image](image8.png) | 4.3     | 73       |
| 10  | J                   | ![Image](image9.png) | ![Image](image10.png) | 6       | 73       |
| 11  | K                   | ![Image](image11.png) | ![Image](image12.png) | 6       | 82       |

Notes. Reaction conditions: Substituted isatins (1 mmol); indane-1,3-dione (1 mmol); ethyl acetoacetate (1 mmol); ammonium acetate (1 mmol); solvent: ethanol:water (9:1); temperature: rt.
intermediate 3, followed by intramolecular cyclocondensation, furnished the desired product (S).

Organic compounds exhibiting fluorescence properties have attracted attention in the field of chemosensor applications. Multifunctional organic compounds possessing conjugated $\pi$-system exhibit excellent fluorescence properties, which could have use in the pharmaceutical or environmental areas for sensing applications.\textsuperscript{20,21} Hence synthesized compounds were analyzed for the photophysical studies.

**Scheme 2.** A plausible mechanism for the synthesis of spiro[4H-indeno[1,2-b]pyridine-4,3'-[3H]indoles].
Photophysical Properties of Synthesized Compounds

The absorption and fluorescent spectra of spiro[4H-indeno[1,2-b]pyridine-4,3’-[3H]indoles] (SIPI) and its substituted derivatives were studied. The solubility of synthesized compounds was checked in different solvents such as dichloromethane (DCM), toluene, CCl₄, acetonitrile, methanol, ethanol, chloroform, acetone, dimethylformamide (DMF), and dimethylsulfoxide (DMSO). Excellent solubility was observed in DMSO solvent, which was used for absorption and fluorescence emission studies of synthesized compounds.

Absorption Study

Figure 2 illustrates the absorption spectra of SIPI (G) and its derivatives A to F and H to K in DMSO. The absorption spectra display no significant spectral shift in absorption maxima but an increase in absorption was observed. The absorption spectra of SIPI and its derivatives were composed of structured broad bands at 343 and 470 nm. However, the structured, broad absorption spectrum of dilute solution of compound G and its derivatives indicates that the indole-pyridine rings and substituents are coplanar and exhibit wider spectral separation in their maxima. The absorption transition $S_0 \rightarrow S_1$ is $\pi \rightarrow \pi^*$ because of conjugated indole-pyridine rings and greater number of delocalized $\pi$ electrons. The values of molar extinction coefficient for synthesized compounds A to K in DMSO were estimated from absorption data, indicating that substitution by electron-donating moiety enhances the photoabsorption and substitution by electron-withdrawing moiety decreases the photoabsorption.[22]

Fluorescence Study

Figure 3 depicts the fluorescence emission spectra of SIPI (G) and its derivatives (A to F, H to K). The compound G in DMSO exhibits a moderate broad fluorescence band at 560 nm with shoulder peak at 597 nm attributed to most
probable \( p^* \rightarrow \pi \) and \( p^* \rightarrow n \) transitions, respectively. The shoulder peak appeared in almost all compounds in the region 590–600 nm assigned to the less probable \( p^* \rightarrow n \) transition.

The compound G has fluorescence emission maximum at 560 nm. The compounds A, B, E, J, and K are derivatives of compound G having electron-donating substituents on the indole ring and show enhanced fluorescence emission along with a remarkable red shift (∼14–18 nm) in fluorescence emission maxima. These compounds show enhanced emission and bathochromic shift of ∼14–18 nm with respect to the fluorescence emission spectra of compound G in DMSO (560 nm).

It is well known that electron-donating and electron-withdrawing groups and solvent polarity may change the photophysical properties of organic molecules.[22,23] The electron-donating groups that are capable to extend \( \pi \) conjugation in the molecule should lead to great highest occupied molecular orbital (HOMO) levels and smaller HOMO–lowest unoccupied molecular orbital (LUMO) gaps, thus resulting in a red shift.[24] The enhanced fluorescence emission and red shift in fluorescence emission maxima observed is because of the presence of an electron-donating group and polar aprotic solvent DMSO. Further compounds C, D, F, H, and I bearing electron-withdrawing groups on the indole ring of SIPI show decrease in fluorescence intensity and slight hypsochromical (blue) shift in fluorescence maxima as compared to compound G. The blue shift and observed fluorescence quenching for compounds bearing electron-withdrawing groups is due to the ability of the electron-withdrawing group to pull the electron toward itself and disturb the conjugated structure of compound in its excited state. Thus, the disruption occurs in the excited state, restricts the rotation of fluorescent compound, and favors the nonradiative pathways, resulting in a decrease in fluorescence emission and fluorescence maxima. The decrease in the absorption and fluorescence intensity owing to the disturbance in conjugated effect leads to an increase in the energy loss in the excited-state vibration.[24]

A larger Stokes shift was observed for the derivatives of compound G bearing electron-donating groups while the smaller Stokes shift was observed for compounds with electron-withdrawing groups. This was also confirmed by calculating the Stokes shift of synthesized compounds. The photophysical properties of all synthesized compounds A to K are shown in Table 3.
CONCLUSION

We developed a facile method for multicomponent synthesis of spiro-[4H-indeno[1,2-b]pyridine-4,3′-[3H]indoles] by carrying out reaction of isatin, ammonium acetate, indane-1,3-dione, and ethylacetoacetate in ethanol:water (9:1) at ambient temperature. Noticeable advantages of the present method are employment of mild conditions along with ambient temperature, operational simplicity, good yield of products in short time, easy isolation and purification of products by simple filtration followed by washing with ethanol. Significant changes in the absorption spectra and fluorescence emission of compound G and its derivatives (compounds A to F, H to K) discussed on the basis of electron-donating and electron-withdrawing power of a substituted group on indole ring of compound G. Overall, the substituent effects appear to exert a more pronounced effect on fluorescence emission and on absorption spectra. The fluorescence studies of synthesized compounds open new windows in the field of chemosensing technique.

EXPERIMENTAL

Various substituted isatins (Alfa Aesar), ethyl acetoacetate (spectrochem) indane-1,3-dione, and ammonium acetate (Sigma-Aldrich) were used as received without further
puriﬁcation. Melting points were measured by open capillary. IR spectra were recorded on a Perkin–Elmer FT-IR 783 spectrophotometer. NMR spectra were recorded on a Bruker AC-300 spectrometer in DMSO-d$_6$ using tetramethylsilane (TMS) as an internal standard. Mass spectra were recorded on a Shimadzu QP2010 GCMS. HRMS were performed on Thermo Scientiﬁc Q–Exactive, Accela 1250 pump, instrument. Elemental analyses were done using EURO EA3000 vector model. UV–visible spectra and ﬂuorescence spectra were recorded on a Shimadzu spectrophotometer and on a Jasco (FP-750) spectroﬂuorometer in respective solvents. The concentration of each sample was maintained in the range of $\sim 10^{-5}$ M for absorption and ﬂuorescence study.

**General Procedure for Multicomponent Synthesis of Spiro[4H-indeno[1,2-b]pyridine-4,3'-[3H]indoles]**

Isatin (1 mmol), 1,3-indanedione (1 mmol), ethyl acetoacetate (1 mmol), and NH$_4$OAc (1 mmol) were placed in a 25-mL round-bottomed ﬂask in ethanol:water (9:1) (5 mL). The resulting mixture was stirred at room temperature for time mentioned in Table 2, until completion of the reaction as monitored by thin-layer chromatography (TLC). After completion of the reaction, the mixture was ﬁltered and washed with a small quantity of ethanol to furnish pure spiro[4H-indeno-[1,2-b]pyridine-4,3'-[3H]indoles]. The structure of products was conﬁrmed by IR, $^1$H and $^{13}$C NMR, GCMS, HRMS, and elemental analysis.

**ACKNOWLEDGMENTS**

We are grateful to Prof. S. R. Patil and Mr. P. G. Mahajan, Department of Chemistry, Shivaji University, Kolhapur, for ﬂuorescence study of synthesized compounds and fruitful discussion on it.

**FUNDING**

D. M. P. is thankful to the University Grants Commission, New Delhi, for ﬁnancial assistance [F. No. 42- 394/2013(SR)].

**SUPPLEMENTAL MATERIAL**

Supplemental data for this article can be accessed on the publisher’s website.

**REFERENCES**

1. (a) Lindström, U. M. (Ed.); *Organic Reactions in Water: Principles, Strategies, and Applications*; Blackwell: Oxford, UK, 2007; (b) Weber, L. *Drug Discov. Today* **2002**, 7, 143; (c) Hulme, C.; Gore, V. *Curr. Med. Chem.* **2003**, 10, 51; (d) Dömling, A. *Chem. Rev.* **2006**, 106, 17; (e) Kanizsai, I.; Gyárfás, S.; Szadonyi, Z.; Sillanpää, R.; Fülöp, F. *Green Chem.* **2007**, 9, 357.

2. (a) Ramon, D. J.; Miguel, Y. *Angew. Chem., Int. Ed.* **2005**, 44, 1602; (b) Li, G.; Wei, H.-X.; Kim, S.-H.; Carducci, M. D. *Angew. Chem., Int. Ed.* **2001**, 40, 4277; (c) Tu, S.;
Jiang, B.; Zhang, Y.; Jia, R.; Zhang, J.; Yao, C.; Feng, S. Org. Biomol. Chem. 2007, 5, 355.
3. Patchett, A. A.; Nargund, R. Annu. P. Rep. Med. Chem. 2000, 35, 289.
4. Dömling, A. Chem. Rev. 2006, 106, 17.
5. Cui, S. L.; Lin, X. F.; Wang, Y. G. J. Org. Chem. 2005, 70, 2866.
6. Huang, Y. J.; Yang, F. Y.; Zhu, C. J. J. Am. Chem. Soc. 2005, 127, 16386.
7. (a) Tietze, L. F. Chem. Rev. 1996, 96, 115; (b) Dömling, A.; Ugi, I. Angew. Chem., Int. Ed. 2000, 39, 3169.
8. (a) Zhu, J., Bienaymé, H. (Eds.); Multicomponent Reactions; Wiley-VCH: Weinheim, Germany, 2005. For recent reviews, see (b) Dömling, A. Chem. Rev. 2006, 106, 17; (c) Zhu, J. Eur. J. Org. Chem. 2003, 1133; (d) Ramón, D. J.; Yus, M. Angew. Chem. Int. Ed. 2005, 44, 1602; (e) Simon, C.; Constantieux, T.; Rodriguez. J. Eur. J. Org. Chem. 2004, 4957.
9. Maggi, R.; Bigi, F.; Carloni, S.; Mazzacani, A.; Sartori, G. Green Chem. 2001, 3, 173.
10. Zhang, J.; El-Shabrawy, A.-R.O.; El-Shanawany, M. A.; Schiff, P. L.; Slatkin, D. J. Nat. Prod. 1987, 50, 800.
11. Nugiöl, D. A.; Etkzorn, A.-M.; Vidwans, A.; Benfield, P. A.; Boisclair, M.; Burton, C. R.; Cox, S.; Czerniak, P. M.; Doleniak, D.; Seitz, S. P. J. Med. Chem. 2001, 44, 1334.
12. Fáderléck, R.; Dumont, W.; Ooms, F.; Aschenbach, L.; Van der Schyf, C.J.; Castagnoli, N.; Wouters, J.; Krief. A. J. Med. Chem. 2006, 49, 3743.
13. (a) Míri, R.; Javidnia, K.; Hemmateenejad, B.; Azarpíra, A.; Amirhöfran, Z. Bioorg. Med. Chem. 2004, 12, 2529; (b) Heintzelman, G. R.; Averill, K. M.; Dodd, J. H. PCT Int. Appl. WO 2002085894 A1 20021031, 2002; (c) Heintzelman, G. R.; Averill, K. M.; Dodd, J. H.; Demarest, K. T.; Tang, Y.; Jackson, P. F. US Pat. Appl. Publ. 2004082578 A1 20040429, 2004; (d) Cooper, K.; Fray, M. J.; Cross, P. E.; Richardson, K. Eur. Pat. Appl. EP 299727 A1 19890118, 1989; (e) Vigante, B.; Ozols, J.; Sileniece, G.; Kimenis, A.; Duburs, G. USSR SU 794006 19810107, 1989; (f) Safak, C.; Simsek, R.; Altas, Y.; Boydag, S.; Erol, K. Boll. Chim. Farm. 1997, 136, 665; (g) Brandes, A.; Loeppers, M.; Schmidt, G.; Angerbauer, R.; Schmeck, C.; Bremm, K.-D.; Bischoff, H.; Schmidt, D.; Schuhmacher. J. Ger. Offen. DE 19627430 A1 19980115, 1998; (h) Heintzelman, G. R.; Averill, K. M.; Dodd, J. H.; Demarest, K. T.; Tang, Y.; Jackson, P. F. WO PCT Int. Appl. 2003088963 A1 20031030, 2003.
14. Nagarajan, M.; Morrell, A.; Fort, B.C.; Meckely, M. R.; Antony, S.; Kohlhaan, G.; Pommier, Y.; Cushman, M. J. Med. Chem. 2004, 47, 5651.
15. Sundberg, R. J. The Chemistry of Indoles; Academic: New York, 1996.
16. (a) Joshi, K. C.; Chand, P. Pharmazie 1982, 37, 1; (b) Da Silva, J. F. M.; Garden, S. J.; Pinto, A. C. J. Braz. Chem. Soc. 2001, 12, 273 (c) Abdel-Rahman, A. H.; Keshk, E. M.; Hanna, M. A.; El-Bady, Sh. M. Bioorg. Med. Chem. 2004, 12, 2483; (d) Zhu, S.-L.; Ji, S.-J.; Yong, Z. Tetrahedron 2007, 63, 9365.
17. (a) Kang, T.-H.; Matsumoto, K.; Murakami, Y.; Takayama, H.; Kitajima, M.; Aimi, N.; Watanabe, H. Eur. J. Pharmacol. 2002, 444, 39 (b) Ma, J.; Hecht, S. M. Chem. Commun. 2004, 1190; (c) Usui, T.; Kondo, M.; Cui, C.-B.; Mayumi, T.; Osada, H. Biochem. J. 1998, 333, 543; (d) Khafagy, M. M.; El-Wahas, A. H. F. A.; Eid, F. A.; El-Agrody, A. M. Farmaco 2002, 57, 715.
18. (a) Feiz, A.; Shakibaei, G. I.; Yasaei, Z.; Khavasi, H. R.; Bazgir A. Hely. Chim. Acta 2011, 94, 1628; (b) Khorrami, A. R.; Kiani P.; Bazgir A. Monatsh. Chem. 2011, 142, 287.
19. (a) Undale, K. A.; Shaikh, T. S.; Gaikwad, D. S.; Pore D. M. C. R. Chim. 2011, 4, 511; (b) Pore, D. M.; Shaikh, T. S.; Undale, K. A.; Gaikwad D. S. C. R. Chim. 2010, 13, 1429; (c) Pore, D. M.; Patil, P. B.; Gaikwad, D. S.; Hegade, P. G.; Patil, J. D.; Undale, K. A. Tetrahedron Lett. 2013, 54, 5876; (d) Pore, D. M.; Hegade, P. G.; Gaikwad, D. S.; Patil, P. B.; Patil J. D. Lett. Org. Chem. 2014, 11, 131.
20. Lee, Y. J.; Lim, C.; Suh, H.; Song, E. J.; Kim, C. *Sensor Actuat. B* 2014, 201, 535.
21. Wang, Y.; Yu, M.; Yu, Y.; Bai, Z.; Shen, Z.; Li, F.; You, X. *Tetrahedron Lett.* 2009, 50, 6169.
22. Maeda, H.; Maeda, T.; Mizuno, K. *Molecules* 2012, 17, 5108.
23. (a) Mahajan, P. G.; Bhopate, D. P.; Kolekar G. B.; Patil, S. R. *Sensor Actuat. B* 2015, 220, 864; (b) Albert, K. J.; Walt, D. R. *Anal. Chem.* 2000, 72, 1947.
24. Duvenhage, M. M.; Visser, H. G.; Ntwaeaborwa, O. M.; Swart, H. C. *Phys. B* 2014, 439, 46.