Journal of Applied Chemistry
JAC
http://chemistry.journals.semnan.ac.ir

Efficient synthesis of functionalized acenaphtho[1,2-*b*]indol-6b-ol derivatives

Nahale Kakavand[1], Mohammad Bayat[1,*] and Yadollah Bayat[2]
[1]*Department of Chemistry, Faculty of Science, Imam Khomeini International University, Qazvin, Iran*
[2]*Department of Chemistry and Chemical Engineering, Malek Ashtar University of Technology, Tehran, Iran*

Article history:
Received:17/July/2022
Received in revised form:15/Dec/2022
Accepted:17/Dec/2022

Abstract

An efficient method for the synthesis of functionalized acenaphtho[1,2-*b*]indol-6b-ol derivatives were developed by the three-component reaction of acenaphthoquinone, barbituric acid, or *N*,*N*-dimethyl barbituric acid and aryl amines through sequential Knoevenagel/Michael/intramolecular *N*-cyclization in ethanol. The reactions were carried out under catalyst-free and mild conditions. Advantages of this method include simple operation, catalyst-free, readily available starting materials, no column chromatographic purification and good to high yields (78 - 92 %). We confirmed the product by Fourier-transform infrared spectroscopy (FT-IR), Proton nuclear magnetic resonance (^{1}H NMR), ^{13}C nuclear magnetic resonance (^{13}C NMR), and Mass spectrometry.

Keywords: Acenaphthoquinone, barbituric acid, aryl amines, acenaphthoindolopyrimidine derivatives.

1. Introduction

One of the efficient and influencing methods in sustainable and diversity-oriented synthesis of compounds is multicomponent reactions (MCRs) [1]. Experts in biological, chemistry and modern organic synthesis have paid special attention to MCRs [2-5]. MCRs processes, in which three or more reactants are combined in a single chemical step to produce products that incorporate substantial portions of all the components [6].

MCRs demonstrate several benefits over classic methods in many ways such as synthetic efficiency, reduction of isolation and purification steps, ease of operation, minimization of costs, energy, time and waste production. In the past decade, a lot of multicomponent reactions have been reported, yet developing novel MCRs that meet almost all of the advantages above is still in the burgeoning phase [7-13].

* **.Corresponding author:** Mohammad Bayat, Department of Chemistry, Faculty of Science, Imam Khomeini International University, Qazvin, Iran. *E-mail Address: m.bayat@sci.ikiu.ac.ir*

Fused heterocyclic compounds are key structural scaffolds in a broad variety of natural products, drug molecules, and functional materials. Among them, fused pyrroles and their derivatives have been related to an extensive range of pharmacological activities, such as anti-asthmatic [14], antitumor [15], antibacterial [16], anti-inflammatory [17], antioxidant [18] and thus play a significant role in drug discovery [19]. These compounds can have intrinsic biological activity and also constitute the structural feature of many biologically active compounds. Some synthetic methodologies have been used for the construction of these important derivatives [20-24]. These approaches usually require catalysts [25] under harsh reaction conditions, multistep and tedious workup procedures. Consequently, it is desirable and important to develop simple, catalyst-free, mild conditions and environmentally friendly methods for the construction of acenaphtho[1,2-b]indolone derivatives. So the novelty of this work is the synthesis of new highly functionalized indole skeleton *via* one-pot catalyst-free reaction and potential biological activity of the products.

Some of the recent significant reactions for the synthesis of complex molecules from acenaphthoquinone has been shown (Fig. 1). Product (a) was synthesized from the reaction of 5,5-dimethylcyclohexane-1,3-dione, arylamines, active methylene compounds and acenaphthoquinone [26]. Product (b) was synthesized from the reaction of azomethine ylides and acenaphthoquinone [29]. Product (c) was synthesized from the reaction of cyclic enaminones, and acenaphthoquinone [28] in the presence of Et_3N. Product (d) was synthesized from the reaction of 3,5-bis[(*E*)-arylmethylene]tetrahydro-4(1*H*)-pyridinones, sarcosine and acenaphthoquinone [29].

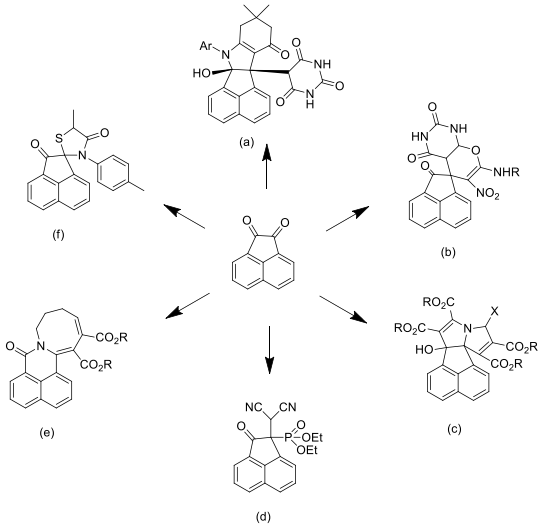
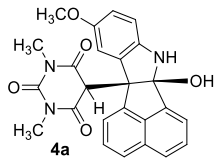


Fig. 1 Summary of previous studies of compounds based on acenaphthylene-1,2-dione

2. Experimental procedure

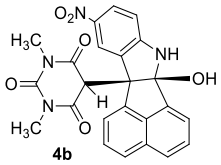
acenaphthoquinone, barbiturates, aniline derivatives and Ethanol were used to prepare the samples. All of the chemicals used in this work were purchased from Merck and Aldrich chemical companies. Melting points were measured on an Electrothermal 9100 apparatus. IR spectra were measured with Bruker Tensor 27 spectrometer; absorbencies are reported in cm^{-1}. ^1H and ^{13}C NMR spectra were measured with a Bruker DRX-300 AVANCE spectrometer at 300 MHz. NMR spectra were obtained in solutions of DMSO-d_6. Mass spectra were recorded on an Agilent Technologies 5975C VL MSD with Tripe-Axis Detector mass spectrometer operating at an ionization potential of 70 eV. The detailed synthesis procedure is as follows:

A mixture of acenaphthoquinone **1** (0.1822 g, mmol) 1,3-dimethyl barbituric acid **2** (0.1561 g, 1 mmol) and 4-methoxyaniline **3** (0.1232 g, 1 mmol) using EtOH (94%) as solvent under reflux condition for 2 h. After completion of the reaction, (monitored by TLC using *n*-hexane : EtOAc (1:1) as eluent), the reaction mixture was cooled to room temperature and the solid was washed with ethanol (10 mL) to obtain the product **4a**.



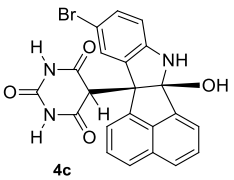
4a

5-((6bS,11bR)-6b-hydroxy-10-methoxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)-1,3-dimethylpyrimidine-2,4,6(1H,3H,5H)-trione **(4a)**: Gray solid, Yield 0.407 g (92%). Mp: 316-318 °C, IR (KBr) ($\bar{\upsilon}_{max}$/cm^{-1}): 3442, 3293, 2954, 1692, 1648, 1495, 1147. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 3.09 (s, 3 H, NCH_3), 3.15 (s, 3 H, NCH_3), 3.66 (s, 3 H, OCH_3), 6.53 (d, $^3J_{HH}$ = 8.4 Hz, 1 H, ArH), 6.55 (d, $^3J_{HH}$ = 8.4 Hz, 1 H, ArH), 7.43 (s, 1 H, ArH), 7.43-7.90 (m, 8 H, CH, OH, ArH), 7.96 (s, 1 H, NH). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 27.8, 29.9, 56.1, 71.0, 90.9, 110.8, 111.8, 114.1, 120.1, 120.6, 122.9, 124.4, 126.3, 128.9, 129.4, 131.2, 131.9, 136.6, 138.8, 142.4, 143.3, 151.1, 153.9, 159.4, 161.8 (C=O). MS (EI, 70 eV): *m/z* (%):= 443 (M^+, 0.2), 425 (M-18, 31), 368 (5), 312 (29), 283 (100), 240 (58), 201 (15), 141 (43), 106 (24), 56 (22). Anal. Calcd for $C_{25}H_{21}N_3O_5$ (443.45): C, 67.71; H, 4.77; N, 9.48. Found: C, 67.9; H, 4.5; N, 9.1.



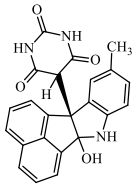
4b

5-((6bS,11bR)-6b-hydroxy-10-nitro-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)-1,3-dimethylpyrimidine-2,4,6(1H,3H,5H)-trione **(4b)**: Gray powder, Yield 0.357 g (78%). Mp: 244-245 °C, IR (KBr), ($\bar{\upsilon}_{max}$/cm^{-1}): 3422, 2955, 2861, 1676, 1437, 1368, 1130, 768 cm^{-1}. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 2.47 (s, 3 H, NCH_3), 2.77 (s, 3 H, NCH_3), 5.45 (s, 2 H, NH, OH), 7.60-8.04 (m, 9 H, Ar) ^{13}C NMR (75 MHz, DMSO-d_6) δ: 28.6, 53.2, 68.7, 101.0, 114.4, 120.4, 121.7, 128.9, 129.2, 130.7, 130.9, 132.7, 137.9, 144.4, 152.0, 168.2 (C=O). Anal. Calcd for $C_{24}H_{18}N_4O_6$ (458.12): C, 62.88; H, 3.96; N, 12.22. Found: C, 62.3; H, 3.6; N, 11.9.



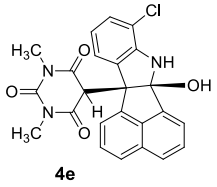
4c

5-((6bS,11bR)-10-bromo-6b-hydroxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)pyrimidine-2,4,6(1H,3H,5H)-trione **(4c):** Gray solid, Yield 0.366 g (79%). Mp: 247-248 °C, IR (KBr) ($\bar{\upsilon}_{max}$/cm^{-1}): 3423, 2992, 2864, 1769, 1443, 1374, 1264, 762 cm-1. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 5.33 (s, 2 H, NH, OH), 7.45-8.43 (m, 9 H, Ar), 11.10 (s, 1 H, NH), 11.18 (s, 1 H, NH). Anal. Calcd for $C_{22}H_{14}BrN_3O_4$ (464.27): C, 56.91; H, 3.04; N, 9.05. Found: C, 56.7; H, 3.5; N, 9.4.



4d

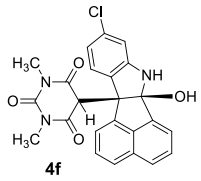
5-((11bR)-6b-hydroxy-10-methyl-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)pyrimidine-2,4,6(1H,3H,5H)-trione **(4d)**: Gray solid, Yield 0.315 g (79%). Mp: 312-314 °C, IR (KBr) ($\bar{\upsilon}_{max}$/cm^{-1}): 3376, 2928, 1709, 1597, 1148, 782, 675. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 1.90 (s, 3 H, CH_3), 6.48-7.95 (m, 9 H, Ar), 8.17 (s, 1 H, NH), 10.22 (s, 1 H, NH), 11.10 (s, 1 H, NH). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 18.08, 71.1, 91.7, 108.0, 114.2, 114.6, 116.8, 121.7, 122.9, 124.2, 126.2, 126.8, 128.9, 129.5, 130.2, 130.4, 130.7, 132.0, 135.9, 136.7, 138.8, 138.9, 143.2, 149.9, 150.6, 161.2, 163.8 (C=O). Anal. Calcd for $C_{23}H_{17}N_3O_4$ (399.40): C, 69.17; H, 4.29; N, 10.52. Found: C, 68.8; H, 4.1; N, 10.2.



4e

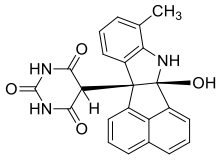
5-((6bS,11bR)-8-chloro-6b-hydroxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)-1,3-dimethylpyrimidine-2,4,6(1H,3H,5H)-trione **(4e)**: White powder, Yield 0.366 g (82%). Mp: 245-246 °C, IR (KBr) ($\bar{\upsilon}_{max}$/cm^{-1}): 3423, 2956, 2863, 1698, 1445, 1375, 1127, 777 cm-1. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 2.77 (s, 3 H, NCH_3), 2.92 (s, 3 H, NCH_3), 5.44 (s, 2 H, NH, OH), 7.53-8.17 (m, 9 H, Ar). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 28.2, 28.5, 53.1, 72.0, 91.8, 110.0, 111.7, 114.6, 121.4, 121.7, 128.4, 129.1, 130.5, 132.7, 136.5, 142.4, 152.3, 156.3, 166.3 (C=O). Anal. Calcd for $C_{24}H_{18}ClN_3O_4$ (447.87): C, 64.36; H, 4.05; N, 9.38. Found: C, 64.8; H,

4.5; N, 9.1.



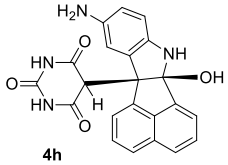
4f

5-((6bS,11bR)-9-chloro-6b-hydroxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)-1,3-dimethylpyrimidine-2,4,6(1H,3H,5H)-trione **(4f)**: White powder, Yield 0.367 g (82%). Mp: 265-266 °C, IR (KBr) ($\tilde{\upsilon}_{max}$/cm^{-1}): 2956, 2863, 1683, 1445, 1605, 1126, 756 cm-1. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 2.70 (s, 3 H, NCH_3), 2.92 (s, 3 H, NCH_3), 5.44 (s, 2 H, NH, OH), 7.53-8.18 (m, 9 H, Ar). Anal. Calcd for $C_{24}H_{18}ClN_3O_4$ (447.87): C, 64.36; H, 4.05; N, 9.38. Found: C, 64.0; H, 4.2; N, 9.6.



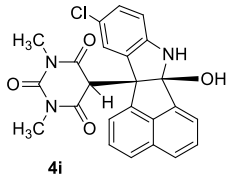
4g

5-((6bS,11bR)-6b-hydroxy-8-methyl-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)pyrimidine-2,4,6(1H,3H,5H)-trione **(4g)**: Gray powder, Yield 0.315 g (79%). Mp: 312-314 °C, IR (KBr) ($\tilde{\upsilon}_{max}$/cm^{-1}): 3376, 2928, 1709, 1597, 1148, 782, 675 cm^{-1}. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 1.90 (s, 3 H, CH_3), 6.48-7.95 (m, 9 H, Ar), 8.17 (s, 1 H, NH), 10.22 (s, 1 H, NH), 11.10 (s, 1 H, NH). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 18.08, 71.1, 91.7, 108.0, 114.2, 114.6, 116.8, 121.7, 122.9, 124.2, 126.2, 126.8, 128.9, 129.5, 130.2, 130.4, 130.7, 132.0, 135.9, 136.7, 138.8, 138.9, 143.2, 149.9, 150.6, 161.2, 163.8 (C=O). Anal. Calcd for $C_{23}H_{17}N_3O_4$ (399.40): C, 69.17; H, 4.29; N, 10.52. Found: C, 69.6; H, 4.7; N, 10.1.



4h

5-((6bS,11bR)-10-amino-6b-hydroxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)pyrimidine-2,4,6(1H,3H,5H)-trione **(4h)**: White powder, Yield 0.360 g (90%). Mp: 312-314 °C, IR (KBr) ($\tilde{\upsilon}_{max}$/cm^{-1}): 3428, 3285, 1649, 1628, 1495, 1148 cm^{-1}. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 4.37 (s, 1 H, OH), 6.27 (d, $^2J_{HH}$ = 7.4 Hz, 2 H, Ar), 7.58-7.96 (m, 7 H, Ar), 8.15 (s, 1 H, NH), 10.66 (s, 1 H, NH), 10.25 (s, 2 H, NH_2). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 27.5, 28.9, 53.6, 71.20, 91.9, 110.8, 111.8, 114.1, 120.1, 120.6, 122.9, 124.4, 126.3, 128.9, 129.4, 131.2, 131.9, 136.6, 138.8, 142.4, 143.3, 149.0, 152.9, 156.2, 165.3 (C=O). Anal. Calcd for $C_{22}H_{16}N_4O_4$ (400.39): C, 66.00; H, 4.03; N, 13.99. Found: C, 66.4; H, 4.5; N, 13.7.



4i

5-((6bS,11bR)-10-chloro-6b-hydroxy-7,11b-dihydro-6bH-acenaphtho[1,2-b]indol-11b-yl)-1,3-dimethylpyrimidine-2,4,6(1H,3H,5H)-trione **(4i)**: White powder, Yield 0.372 g (83%). Mp: 223-224 °C, IR (KBr) ($\tilde{\upsilon}_{max}$/cm^{-1}): 3425, 2954, 2861, 1678, 1440, 1131, 759 cm^{-1}. ^{1}H NMR (300 MHz, DMSO-d_6) δ: 2.78 (s, 3 H, NCH_3), 2.94 (s, 3 H, NCH_3), 5.46 (s, 2 H, NH, OH), 7.53-7.87 (m, 7 H, Ar), 8.18 (s, 1 H, Ar). ^{13}C NMR (75 MHz, DMSO-d_6) δ: 28.2, 28.5, 53.1, 72.0, 91.8, 110.0, 111.7, 114.6, 121.4, 121.7, 128.4, 129.1, 130.5, 132.7, 136.5, 142.4, 152.3, 156.3, 166.3 (C=O). Anal. Calcd for $C_{24}H_{18}ClN_3O_4$ (447.87): C, 64.36; H, 4.05; N, 9.38. Found: C, 64.7; H, 4.4; N, 9.0.

3. Results and discussion

The reaction of acenaphthoquinone **1**, barbituric acid **2**, and arylamines **3** in equimolar ratio in refluxing EtOH afford fused acenaphthoindolopyrimidine derivatives **4a-i** in high yield. (Scheme 1).

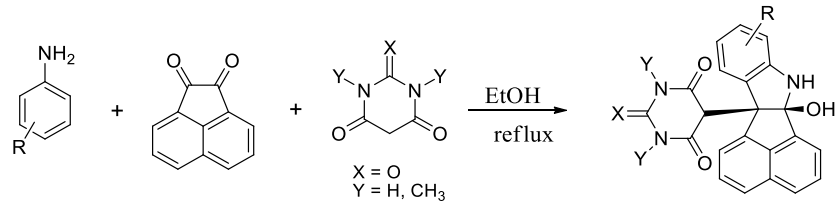
When the reaction was carried out in refluxing methanol, acetonitrile, or water, the products were obtained in lower yields. The effects of solvents were examined for this reaction, and the results are summarized in Table 1.

Initially, this reaction was carried out in EtOH at room temperature, In this case, target compound **4a** was observed but with low yield (Table 1, entry 1). The same reaction has also monitored at reflux. The result showed that reaction completed in 2 h with excellent yield as compared to another solvents (Table 1, entry 2). Next in different solvents such as MeOH, CH_3CN and H_2O were employed (Table 1, entries 3–7), and results show that all

were successful but with low yields. As a result, EtOH was determined to be the appropriate solvent.

In refluxing EtOH, reaction not only occurred over a shorter period of time but also provided a higher yield than that obtained by using any of the other examined solvents such as MeOH, CH_3CN, and H_2O (Table 1, entries 3-7).

In order to optimize the reaction condition of different solvents for the model product **4a**, using reaction mixture of acenaphthoquinone **1** (1 mmol), 1,3-dimethyle barbituric acid **2** (1 mmol) and 4-methoxyaniline **3** (1 mmol) under refluxing ethanol condition. Results are summarized in Table 2, showed that the best conversion was obtained using ethanol as solvent in reaction medium. The yields were excellent without formation of any side products, and products are obtained in very good purity. To the best of our knowledge, there is no report on the synthesis of these products (**4a-i**).



78-92%

Scheme 1. Synthesis of acenaphtho[1,2-*b*]indol-6b-ol derivatives **4a-i**

Table 1. Synthesis of acenaphtho[1,2-*b*]indol-6b-ol derivatives under different conditions[a]

Entry	Solvent	Temperature(°C)	Time(h)	Yield(%)[b]
1	EtOH	r.t.	15	50
2	EtOH[c]	80	2	92
3	MeOH	65	6	trace
4	CH_3CN	r.t.	12	51
5	CH_3CN	80	6	54
6	H_2O	r.t.	15	22
7	H_2O	80	12	54

[a]Conditions: 4-methoxyaniline (1 mmol), acenaphthoquinone (1 mmol), and *N*,*N*-dimethylbarbituric acid (1 mmol), solvent 5 mL.

[b]Yield of isolated **4i**.

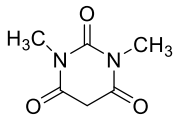
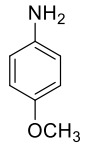
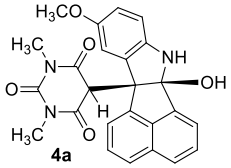
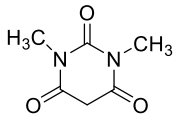
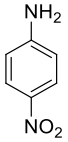
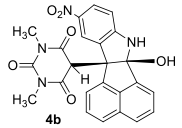
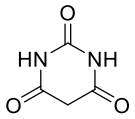
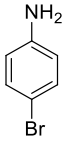
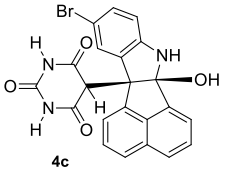
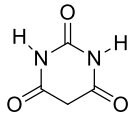
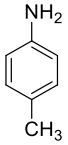
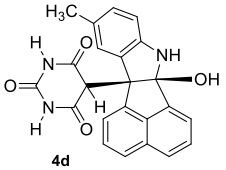
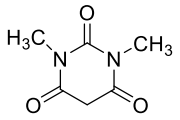
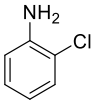
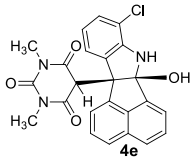
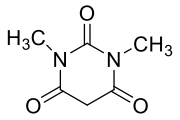
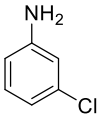
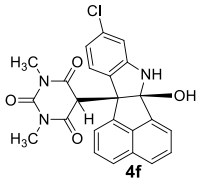
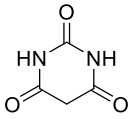
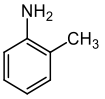
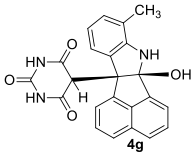
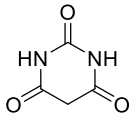
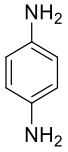
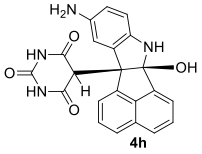
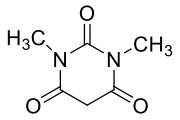
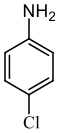
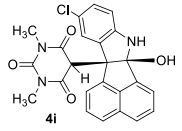
[c]The best condition.

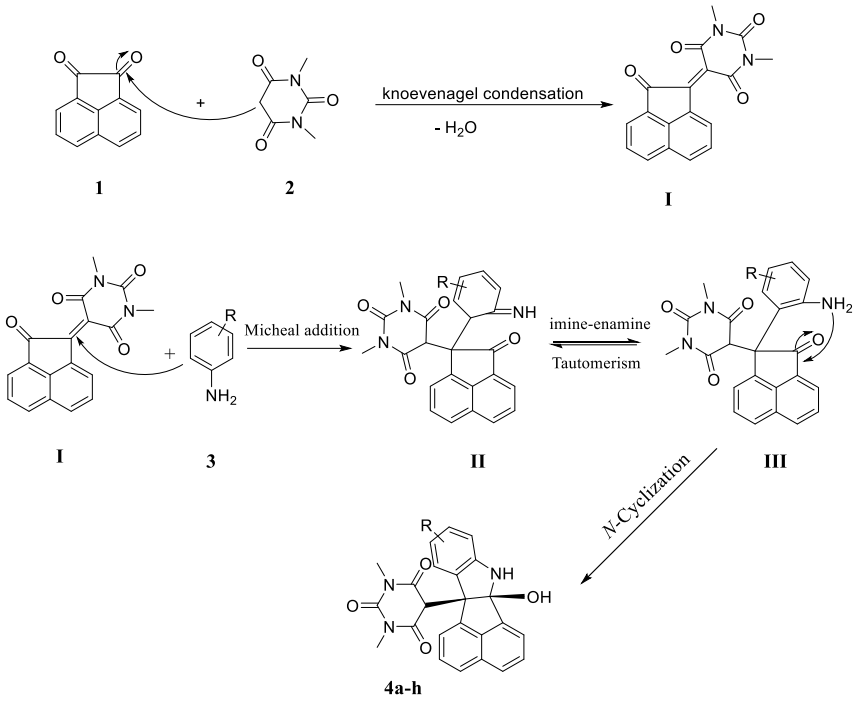
Mechanistically, the formation of the product is a sequence of reactions involving Knoevenagel condensation **I** of acenaphthoquinone with barbituric acid by loss of water molecule, followed by Michael addition **II** of arylamines on electron deficient C-atom, it produces open chain intermediate **II**. This intermediate is converted into **III** through the imine-enamine tautomerization, followed by *N*-cyclization via attack to the C=O of acenaphthoquinone produces **4**. A reasonable mechanism for the formation of targeted products is outlined in (Scheme 2).

The structures of model compound **4a** was confirmed by IR ,^{1}H ,^{13}C NMR and Mass spectra. The IR spectra of **4a** showed absorption bonds due to the NH and OH groups at 3442 and 3293 cm^{-1}. Stretching frequencies related to C=O, C=C, C-O functional groups appeared at 1692, 1648, 1495, 1147 cm^{-1}, respectively. The mass spectrum of **4a** did not show a molecular ion (M^+) at *m/z* = 443, but the presence of a *m/z* = 425 peak is confirmation of

product resulting in a [M – 18] peak from the loss of water. The ^{1}H NMR spectrum of **4a** exhibited two signals recognized as arising from the NCH_3 groups (δ= 3.09 and 3.15 ppm) and a singlet due to the OCH_3 group (δ= 3.66 ppm), and two doublet (δ= 6.53 and 6.65 ppm, $^{3}J_{HH}$ = 8.4 Hz, 2H, ArH_{ortho}), and aromatic region of the spectrum (δ = 7.43-7.90 ppm) for the methine proton and aromatic moieties. The sharp singlet due to the NH group (δ= 7.96 ppm), which were determined by D_2O exchange. The ^{1}H-decoupled ^{13}C NMR spectrum of **4a** showed 25 distinct resonances, which confirmed the proposed structure. Resonances due to the NCH_3, OCH_3, CH, OH-C-**C**, C-OH, and 3C=O appeared at δ = 27.8, 29.9, 56.1, 71.0, 90.9, and 153.9, 159.4, 161.8, respectively.

Table 2. Synthesis acenaphtho[1,2-*b*]indol-6b-ol derivatives **4a-i**

Entry	CH acid	Aryl amine	Product	Yield (%)	Time (h)
1			 **4a**	92	2
2			 **4b**	78	8
3			 **4c**	79	3
4			 **4d**	79	3
5			 **4e**	82	3
6			 **4f**	82	3
7			 **4g**	79	2
8			 **4h**	90	2
9			 **4i**	83	3



Scheme 2. Proposed mechanism for the synthesis of acenaphtho[1,2-*b*]indol-6b-ol derivatives.

4. Conclusion

In this paper, we have developed a simple methodology for the synthesis of acenaphthoindolopyrimidine derivatives *via* three component reaction between aniline derivatives, acenaphthoquinone, and barbiturates through sequential Knoevenagel/Michael/intramolecular *N*-cyclization sequences in EtOH media. The advantages of this route include catalyst-free reaction conditions, higher yields, short reaction time and simple workup.

Acknowledgments

Financial support of this research from Imam Khomeini International University, Iran is gratefully acknowledged.

References

[1] L. Saher, M. Makhloufi-Chebli, L. Dermeche, S. Dermeche, B. Boutemeur-Khedis, C.H. Rabia, M. Hamdi, A. Silva, *Tetrahedron* **74** (2018) 872.

[2] M. Dabiri, Z. N. Tisseh, M. Bahramnejad, A. Bazgir, *Ultrason Sonochem* **18** (2011) 1153.

[3] A. Hasaninejad, A. Zare, M. Shekouhy, *Tetrahedron* **67** (2011) 390.

[4] B. Maleki, G. Esmailian, R. Tayebee, *Org. Prep. Proc. Int* **47** (2015) 461.

[5] M. Beyrati, M. Forutan, A. Hasaninejad, E. Rakovský, S. Babaei, A. Maryamabadi, G.H. Mohebbi, *Tetrahedron* **73** (2017) 5144.

[6] J. Zhu, *Multicomponent reactions*, 2nd ed, (2005)

[7] G. Harichandran, S. Amalraj, P. Shanmugam, *J. Saudi Chem. Soc.* **22** (2018) 208.

[8] G. Zhu, D. Huang, W. Cao, H. Song, A. You, *Comput. Theor. Chem.* **1145** (2018) 22.

[9] J. Wiemann, L. Heller, R. Csuk, *Eur. J. Med. Chem* **150** (2018) 176.

[10] M. Bayat, F. Hosseini, B. Notash, *Tetrahedron* **73** (2018) 1196.

[11] K. Rabiei, H. Naeimi *J. Appl. Chem.* **17** (2022) 9.

[12] N. Inanlo, M. Bayat, M. Rezaei, *J. Appl. Chem.* **14** (2019) 311.

[13] Z. Lasemi; B. Sadeghi, *J. Appl. Chem.* **15** (2020) 149.

[14] S. Lazareno, A. Popham, N.J. Birdsall, *Comput. Theor. Chem.* **62** (2002) 1492.

[15] M. R. Shaaban, T. S. Saleh, A. S. Mayhoub, A M. Farag, *Eur. J. Med. Chem* **46** (2011) 3690.

[16] M. Palkar, M. Noolvi, R. Sankangoud, V. Maddi, A. Maddi, L. V. Nargund, *Arch. Pharm* **343** (2010) 353.

[17] O. Algul, A. Meric, S. Polat, Y.N. Didem, M.S. Serin, *Cent. Eur. J. Chem* **7** (2009) 337.

[18] G. Murineddu, G. Loriga, E. Gavini, A. T. Peanna, A. C. Mule, G. A. Pinna, *Arch. Pharm* **334** (2001) 393.

[19] J. Lehuede, B. Fauconneau, L. Barrier, M. Ourakow, A. Piriou, J. M. Vierfond, *Eur. J. Med. Chem* **34** (1999) 991.

[20] Y. Zi, Z.J. Cai, S.Y. Wang, S.J. Ji, *Org. Lett.* **16** (2014) 3094.

[21] J. Wu, H. Luo, T. Wang, H. Sun, Q. Zhang, Y. Chai, *Tetrahedron* **75** (2019) 1052.

[22] N. Gupta, K. Singh, J. Singh, *J. Mol. Liq.* **199** (2014) 470.

[23] A. Alizadeh, R. Hosseinpour, S. Rostamnia, *J. Mol. Liq.* **15** (2008) 2462.

[24] R. Mishra, A. Jana, A. Kumar Panday, L.H. Choudhury, *Org. Biomol. Chem.* **16** (2018) 3289.

[25] J. J. Zhang, X. Feng, X. C. Liu, Z.B. Huang, D. Q. Shi, *Mol. Divers*. **18** (2014) 727.

[26] M. Bayat, Z. Amiri, *J. Heterocycl. Chem.* **55** (2018) 1346.

[27] I. Yavari, L. Baoosi, M.R. Halvagar, *Mol. Divers.* **21** (2017) 257.

[28] X .B. Chen, T. B. Luo, G. Z. Gou, J. Wang, W. Liu, J. Lin, *Asian J. Org. Chem.* **4** (2015) 921.

[29] R. S. Kumar, H. Osman, S. Perumal, C. Menéndez, A. Afshar Ali, R. Ismail, T. S. Choon, *Tetrahedron* **67** (2011) 3132.