J IRAN CHEM SOC
DOI 10.1007/s13738-016-0876-0

ORIGINAL PAPER

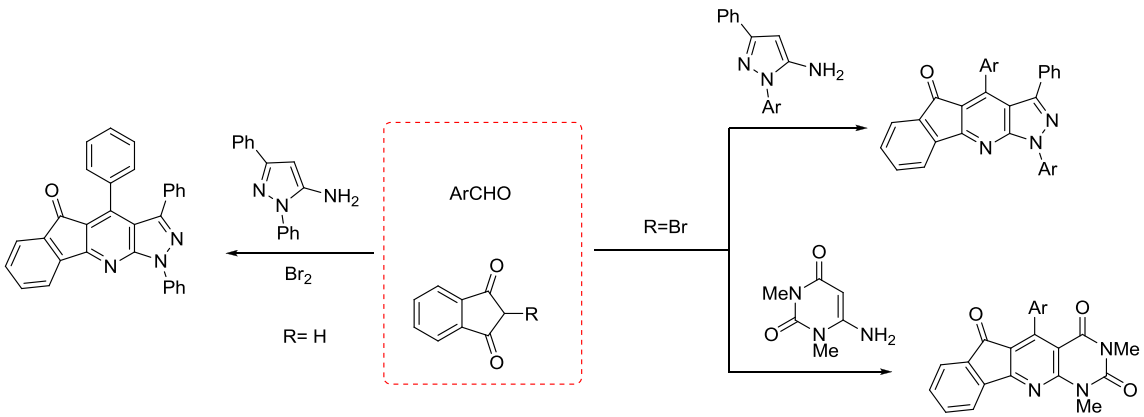
Three-component synthesis of fused indenopyridines from aromatic aldehydes, 2-bromo-2*H*-indene-1,3-dione and aminouracil or aminopyrazole

Somayeh Ahadi[1] · **Ayoob Bazgir**[1]

Received: 14 March 2016 / Accepted: 27 April 2016

Abstract Three-component synthesis of fused indenopyridines containing pyrazole or uracil moiety by the reaction of benzaldehydes, 2-bromo-1*H*-indene-1,3(2*H*)-dione, and pyrazoles or uracil, catalyzed by ammonium acetate is reported.

Graphical Abstract



Keywords Indenopyridine · Pyrazole · Uracil · 2-Bromo-1*H*-indene-1,3(2*H*)-dione

Introduction

Pyrazoles have gained more attention in recent years for biological [1, 2], medicinal [3, 4], and agricultural [5] applications. These compounds have been reported to possess a wide spectrum of biologic activities such as anti-hyperglycemic, analgesic, anti-inflammatory, antipyretic, antibacterial, hypoglycemic, sedative-hypnotic properties [6–11]. In particular among heterocycle-fused pyrazoles, pyrazolopyridines are an important class of heterocycles with broad pharmacological activities such as possible antiviral agent [12, 13], potent p38 kinase inhibitors [14], HIV reverse transcriptase inhibitors [15].

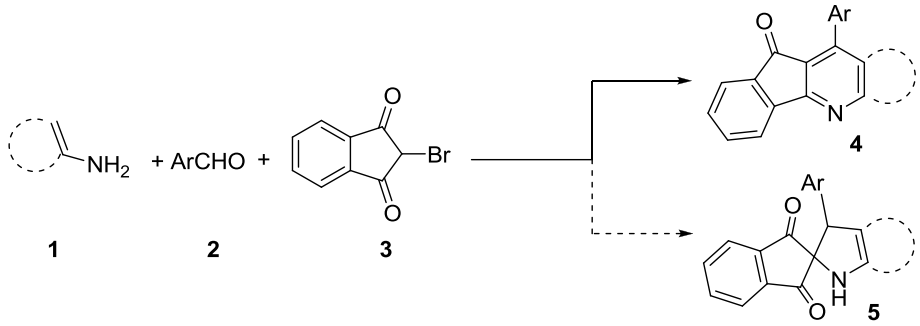
As a privileged scaffold, pyridine is a ubiquitous subunit in various products with remarkable biological activities such as antimicrobial [16–18], anticancer [19] anticonvulsant [20], antiviral [21], anti-HIV [22], antifungal, and antimycobacterial [23]. Particularly, among of this category, indenopyridines are attractive due to showing a wide range of biological activities such as calcium antagonistic [24], antioxidant [25], antihistamine, and antidepressant [26–28], and also act as phosphodiesterase (PDE) inhibitors [29], NK-1, and dopamine receptor ligands [30, 31].

✉ Ayoob Bazgir
a_bazgir@sbu.ac.ir

[1] Department of Chemistry, Shahid Beheshti University, General Campus, Tehran 1983963113, Iran

Published online: 04 May 2016

Scheme 1 Synthesis of indenopyridines containing pyrazole or uracil **4**



Very recently, we described a modified reaction for the synthesis of spiro indenofuran-triones by the reaction of 1,3-dicarbonyl compounds, aldehydes, and cyclic α-halo ketones [32–35]. As a continuation of our previous work for heterocycles synthesis using cyclic α-halo ketones [32–35], we herein investigate replacement of enamine compounds instead of 1,3-dicarbonyl compounds in the reaction. Notably, the expected product **5** was not obtained, while indenopyridines containing pyrazole or uracil moiety **4** was isolated in good yields (Scheme 1).

Experimental

Melting points were measured on an Electrothermal 9100 apparatus and are uncorrected. NMR spectra were recorded on a BRUKER DRX-300 AVANCE spectrometer. NMR spectra were obtained on solutions in DMSO-d_6. IR spectra were recorded using a BOMEM MB-Series. Elemental analyses were performed using a Herecus CHN-O-Rapid analyzer. The chemicals used in this work were obtained from Fluka and Merck and were used without purification.

Due to very low solubility of the products **4**, we cannot report the ^{13}C NMR date for these products.

General procedure for preparation of 1,3-diphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-ones **(4)** A mixture of pyrazoles (1 mmol), aldehydes (1 mmol), 2-bromo-1*H*-indene-1,3(2*H*)-dione (1 mmol) and NH_4OAc (30 mol%) in refluxing acetic acid (2 mL) was stirred for 24 h. After completion of the reaction (confirmed by TLC), the reaction mixture was cooled to room temperature. Then, the precipitate was filtered and washed with methanol (5 mL) to afford the pure product **4**.

1,3,4-Triphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4a)** Yellow powder (71 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1703, 1615, 1562. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 7.03 (4H, m, H-Ar), 7.12–7.28 (6H, m, H-Ar), 7.45–7.48 (1H, m, H-Ar), 7.59–7.74 (5H, m, H-Ar), 7.98–8.01 (1H, m, H-Ar), 8.33 (2H, d, J = 7.6 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 449 (M^+). Anal. Calcd. for $C_{31}H_{19}N_3O$: C, 82.83; H, 4.26; N, 9.35. Found: C, 82.76; H, 4.22; N, 9.26.

4-(4-Nitrophenyl)-1,3-diphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4b)** Cream powder (77 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1709, 1600, 1559. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 7.06–7.11 (4H, m, H-Ar), 7.21–7.23 (1H, m, H-Ar), 7.46–7.70 (7H, m, H-Ar), 7.77–7.82 (1H, m, H-Ar), 7.97–8.08 (3H, m, H-Ar), 8.34 (2H, d, J = 8.1 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 494 (M^+). Anal. Calcd. for $C_{31}H_{18}N_4O_3$: C, 75.29; H, 3.67; N, 11.33. Found: C, 75.34; H, 3.59; N, 11.24.

4-(4-Bromophenyl)-1,3-diphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4c)** Yellow powder (65 %); mp 245–247 °C. IR (KBr) (ν_{max}/cm^{-1}): 1709, 1603, 1554. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 7.01–7.07 (6H, m, H-Ar), 7.18–7.27 (3H, m, H-Ar), 7.31–7.44 (2H, m, H-Ar), 7.50–7.61 (5H, m, H-Ar), 7.96–798 (1H, m, H-Ar), 8.31 (2H, d, J = 6.9 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 529 (M^+ + 2), 527 (M^+). Anal. Calcd. for $C_{31}H_{18}BrN_3O$: C, 70.46; H, 3.43; N, 7.95. Found: C, 70.38; H, 3.37; N, 7.90.

4-(4-Methoxyphenyl)-1,3-diphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4d)** Yellow powder (73 %); mp 205–207 °C. IR (KBr) (ν_{max}/cm^{-1}): 1710, 1607, 1558. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.71 (3H, s, CH_3), 6.62 (2H, d, J = 8.1 Hz, H-Ar), 6.98–7.22 (7H, m, H-Ar), 7.44–7.70 (7H, m, H-Ar), 7.95 (1H, d, J = 6.9 Hz, H-Ar), 7. (1H, m, H-Ar), 8.31 (2H, d, J = 7.8 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 479 (M^+). Anal. Calcd. for $C_{32}H_{21}N_3O_2$: C, 80.15; H, 4.41; N, 8.76. Found: C, 80.24; H, 4.47; N, 8.38.

1-(4-Methoxyphenyl)-3,4-diphenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4e)** Yellow powder (68 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1704. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.86 (3H, s, CH_3), 7.03–7.32 (12H, m, H-Ar), 7.56–7.61 (2H, m, H-Ar), 7.66–7.77 (1H, m, H-Ar), 7.98 (1H, d, J = 7.5 Hz, H-Ar), 8.17 (2H, d, J = 8.8 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 449 (M^+). Anal. Calcd. for $C_{32}H_{21}N_3O_2$: C, 80.15; H, 4.41; N, 8.76. Found: C, 80.08; H, 4.36; N, 8.70.

1-(4-Methoxyphenyl)-4-(4-nitrophenyl)-3-phenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4f)** Yellow powder (69 %); mp 262–264 °C. IR (KBr) (ν_{max}/cm^{-1}): 1708, 1561, 1510. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.85 (3H, s, CH_3), 6.97–7.08 (4H, m, H-Ar), 7.17–7.22 (3H, m, H-Ar), 7.47–7.61 (4H, m, H-Ar), 7.71–7.76 (1H, m, H-Ar), 7.93–7.98 (3H, m, H-Ar), 8.15 (2H, d, J = 8.8 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 524 (M^+). Anal. Calcd. for $C_{32}H_{20}N_4O_4$: C, 73.27; H, 3.84; N, 10.68. Found: C, 73.18; H, 3.93; N, 10.72.

4-(4-Chlorophenyl)-1-(4-methoxyphenyl)-3-phenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4g)** Yellow powder (66 %); mp 243–245 °C. IR (KBr) (ν_{max}/cm^{-1}): 1705, 1563, 1505. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.86 (3H, s, CH_3), 6.92 (1H, bs, H-Ar), 7.01–7.26 (10H, m, H-Ar), 7.56–7.61 (2H, m, H-Ar), 7.71–7.75 (1H, m, H-Ar), 7.95 (1H, d, J = 7.4 Hz, H-Ar), 8.15 (1H, d, J = 8.9 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 513 (M^+). Anal. Calcd. for $C_{32}H_{20}ClN_3O_2$: C, 74.78; H, 3.92; N, 8.18. Found: C, 74.73; H, 3.85; N, 8.27.

1-(4-Bromophenyl)-4-(4-nitrophenyl)-3-phenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4h)** Yellow powder (80 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1711, 1561, 1498. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 7.04–7.09 (4H, m, H-Ar), 7.20–7.22 (1H, m, H-Ar), 7.48–7.61 (4H, m, H-Ar), 7.74–7.83 (3H, m, H-Ar), 7.93–8.04 (3H, m, H-Ar), 8.34 (2H, d, J = 8.3 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 574 (M^+ + 2), 572 (M^+). Anal. Calcd. for $C_{32}H_{20}ClN_3O_2$: C, 64.93; H, 2.99; N, 9.77. Found: C, 64.83; H, 3.07; N, 9.72.

1-(4-Bromophenyl)-4-(4-chlorophenyl)-3-phenylindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4i)** Yellow powder (50 %); mp 252–253 °C. IR (KBr) (ν_{max}/cm^{-1}): 1706, 1561, 1491. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 6.95–7.17 (9H, m, H-Ar), 7.44–7.64 (6H, m, H-Ar), 7.95 (1H, d, J = 7.5 Hz, H-Ar), 8.27 (2H, d, J = 8.1 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 563 (M^+ + 2), 561 (M^+). Anal. Calcd. for $C_{31}H_{17}BrClN_3O$: C, 66.15; H, 3.04; N, 7.47. Found: C, 66.09; H, 3.10; N, 7.40.

1-(4-Bromophenyl)-3-phenyl-4-(p-tolyl)indeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4j)** Yellow powder (70 %); mp 245–247 °C. IR (KBr) (ν_{max}/cm^{-1}): 1711, 1577, 1492. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 2.26 (3H, s, CH_3), 6.91–7.21 (8H, m, H-Ar), 7.58 (2H, bs, H-Ar), 7.80 (3H, m, H-Ar), 7.98 (1H, bs, H-Ar), 8.32 (2H, bs, H-Ar). MS (EI, 70 eV) *m/z*: 543 (M^+ + 2), 541 (M^+). Anal. Calcd. for $C_{32}H_{20}BrN_3O$: C, 70.86; H, 3.72; N, 7.75. Found: C, 70.78; H, 3.78; N, 7.84.

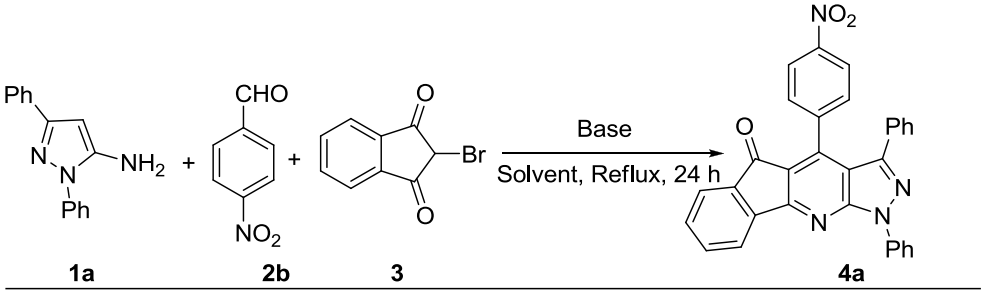
1-(4-Bromophenyl)-3-phenyl-4-(thiophen-2-yl)indeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **(4k)** Yellow powder (73 %); mp 267–269 °C. IR (KBr) (ν_{max}/cm^{-1}): 1706, 1558, 1492. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 6.84–6.97 (2H, m, H-Ar), 7.12–7.28 (5H, m, H-Ar), 7.54–7.77 (7H, m, H-Ar), 7.87–7.91 (1H, m, H-Ar). MS (EI, 70 eV) *m/z*: 535 (M^+ + 2), 533 (M^+). Anal. Calcd. for $C_{29}H_{16}BrN_3OS$: C, 65.17; H, 3.02; N, 7.86. Found: C, 65.08; H, 3.10; N, 7.81.

1,3-Dimethyl-5-phenyl-1H-indeno[2′,1′:5,6]pyrido[2,3-d]pyrimidine-2,4,6(3H)-trione **(4m)** Cream powder (95 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1701, 1685, 1604. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.14 (3H, s, CH_3), 3.75 (3H, s, CH_3), 7.22–7.39 (4H, m, H-Ar), 7.49–7.66 (3H, m, H-Ar), 7.75–7.80 (1H, m, H-Ar), 7.98 (1H, d, J = 7.1 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 369 (M^+). Anal. Calcd. for $C_{22}H_{15}N_3O_3$: C, 71.54; H, 4.09; N, 11.38. Found: C, 71.44; H, 4.01; N, 11.30.

1,3-Dimethyl-5-(4-nitrophenyl)-1H-indeno[2′,1′:5,6]pyrido[2,3-d]pyrimidine-2,4,6(3H)-trione **(4n)** Yellow powder (92 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1705, 1689, 1611. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.15 (3H, s, CH_3), 3.73 (3H, s, CH_3), 7.53–7.66 (4H, m, H-Ar), 7.75–7.80 (1H, m, H-Ar), 7.98 (1H, d, J = 7.3 Hz, H-Ar), 8.29 (2H, d, J = 8.5 Hz, H-Ar). MS (EI, 70 eV) *m/z*: 414 (M^+). Anal. Calcd. for $C_{22}H_{14}N_3O_5$: C, 63.77; H, 3.41; N, 13.52. Found: C, 63.68; H, 3.33; N, 13.63.

5-(4-Methoxyphenyl)-1,3-dimethyl-1H-indeno[2′,1′:5,6]pyrido[2,3-d]pyrimidine-2,4,6(3H)-trione **(4o)** Cream powder (87 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1706. ^{1}H NMR (300 MHz, DMSO-d_6): δ_H 3.14 (3H, s, CH_3), 3.74 (3H, s, CH_3), 3.83 (3H, s, CH_3), 6.93 (2H, d, J = 8.5 Hz,

Table 1 Optimization of the reaction



1a **2b** **3** **4a**

Entry	Solvent, reflux	Base (mol%)	Yield (%)[a]
1	CH_3CN	NH_4OAc (30)	45
2	EtOH	NH_4OAc (30)	40
3	H_2O	NH_4OAc (30)	43
4	HOAc	DBU (30)	70
5	HOAc	K_2CO_3 (30)	65
6	HOAc	$CsCO_3$ (30)	71
7	HOAc	NaOAc (30)	70
8	HOAc	NH_4OAc (30)	77
9	HOAc	NH_4OAc (20)	69
10	HOAc	NH_4OAc (40)	76
11	HOAc	–	<30

Pyrazol-5-amine **1a** (1 mmol), 4-nitrobenzaldehyde **2b** (1 mmol) and indene-1,3(2H)-dione **3** (1 mmol)

[a] Isolated yield

H-Ar), 7.17 (2H, d, $J = 8.5$ Hz, H-Ar), 7.61–7.79 (3H, m, H-Ar), 7.97 (1H, d, $J = 7.7$ Hz, H-Ar). MS (EI, 70 eV) *m/z*: 399 (M^+). Anal. Calcd. for $C_{23}H_{17}N_3O_4$: C, 69.17; H, 4.29; N, 10.52. Found: C, 69.10; H, 4.23; N, 10.61.

1,3,4-Triphenyl-4,10-dihydroindeno[1,2-b]pyrazolo[4,3-e] pyridin-5(1H)-one **(7)** White powder (66 %); mp > 270 °C. IR (KBr) (ν_{max}/cm^{-1}): 1704, 1601, 1543. ^1H NMR (300 MHz, DMSO-d_6): δ_H 5.67(1H, s, CH), 7.09 (1H, m, H-Ar), 7.24–7.43 (5H, m, H-Ar), 7.52–7.65 (7H, m, H-Ar),), 7.77 (3H, m, H-Ar),), 7.99–8.01 (3H, m, H-Ar), 11.05 (1H, s, NH). MS (EI, 70 eV) *m/z*: 451 (M^+). Anal. Calcd. for $C_{31}H_{21}N_3O$: C, 82.46; H, 4.69; N, 9.31. Found: C, 82.40; H, 4.62; N, 9.25.

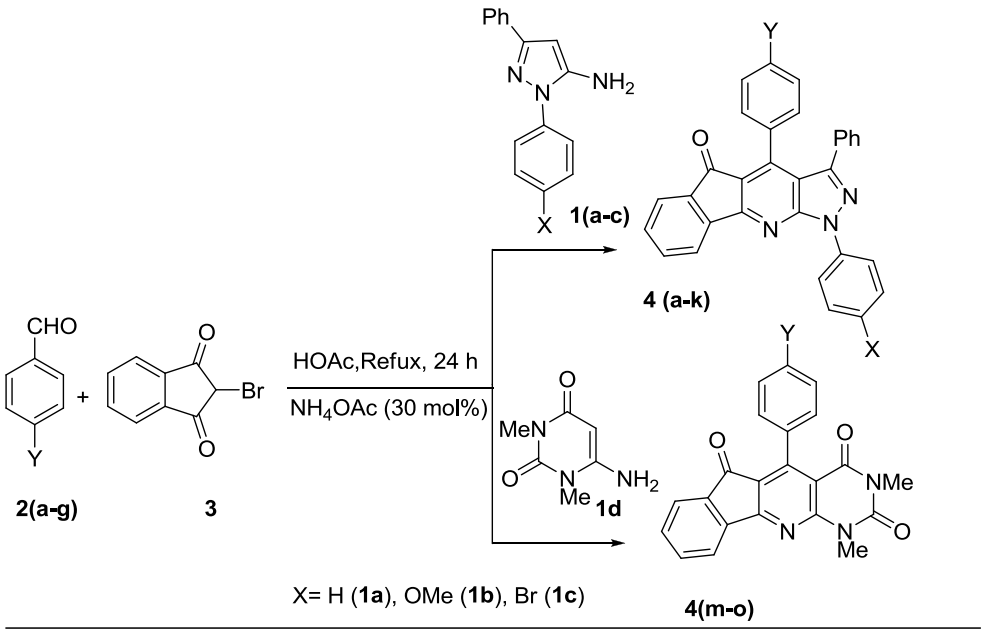
Results and discussion

To achieve suitable conditions for the synthesis of indenopyridines **4**, various reaction conditions and bases have been investigated in the reaction of pyrazol-5-amine **1a**, 4-nitrobenzaldehyde **2b**, and indene-1,3(2*H*)-dione **3** as a model reaction (Table 1). Screening of the solvent revealed that acetic acid is the most suitable reaction media, providing indeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **4b** in 77 % yield in the presence of 30 mol % of NH_4OAc (entry 8). It was found that when increasing the amount of NH_4OAc from 20 to 30 mol%, the isolated yield increased from 69 to 77 %, respectively (entries 8 and 9), and more amounts of the NH_4OAc did not improve the yield (entry 10). It should be mentioned that when the reaction was carried out in the absence of NH_4OAc, the yield of the product was low (entry 11). When this reaction was carried out with other bases such as DBU, NaOAc, $CsCO_3$, or K_2CO_3, the yield of the expected product was reduced.

According to the optimized conditions, the three-component condensation reaction of 1,3-diphenyl-1*H*-pyrazol-5-amines **1a–c** or uracil **1d**, aldehydes **2**, and 2-bromo-1*H*-indene-1,3(2*H*)-dione **3** in the presence of NH_4OAc (30 mol%) proceeded in HOAc under reflux conditions to afford indenopyridines containing pyrazole or uracil moiety diones **4**, in good yields after 24 h (Table 2). This protocol followed the GAP chemistry [36–39], which can avoid traditional chromatography and recrystallization purification methods. According GAP chemistry, pure products were obtained simply by filtration and washing off the solid with methanol.

To demonstrate the key role of 2-bromo-1*H*-indene-1,3(2*H*)-dione **3** in the reaction, we investigated the reaction of 1,3-indandion **6** with 1*H*-pyrazol-5-amine **1a** and

Table 2 Indenopyridines consist of pyrazole or uracil **4**



Product	*X*	*y*	Yield (%)
4a	H	H	71
4b	H	NO_2	77
4c	H	Br	65
4d	H	OMe	73
4e	OMe	H	68
4f	OMe	NO_2	69
4g	OMe	Cl	66
4h	Br	NO_2	80
4i	Br	Cl	50
4g	Br	Me	70
4k	Br	Thiophene	73
4m	_	H	95
4n	_	NO_2	92
4o	_	OMe	87

4-nitrobenzaldehyde **2b** in the same reaction conditions (Scheme 2). The indenopyrazolopyridin-5(1*H*)-one **4a** was not detected at all, while 4-(4-nitrophenyl)-1,3-diphenyl-4,10-dihydroindeno[1,2-b]pyrazolo[4,3-e]pyridin-5(1H)-one **7** was obtained in 66 % yield. In the HNMR spectrum of **7**, the benzylic proton is observed as a singlet at 5.67 ppm which confirms the proposed structure of **7**.

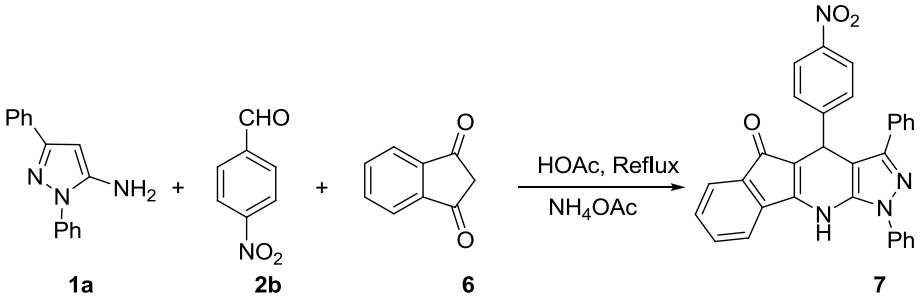
Although the exact mechanism of the reaction is not very clear, a plausible mechanism for the formation of product 4 is proposed in Scheme 3. Initially, nulleophilic reaction of aminopyrazole 1 to iminium salt **8** (formed in situ by the reaction of amine and aldehyde), followd by acid–base reaction produced intermediate **9**. Then, nucleophilic reaction of 2-bromo-1*H*-indene-1,3(2*H*)-dione **3** to intermediate **9** followed by intracyclization afforded intermediate **10**. Eventually, elimination of HBr and H_2O from **10** produced the corresponding product **4**.

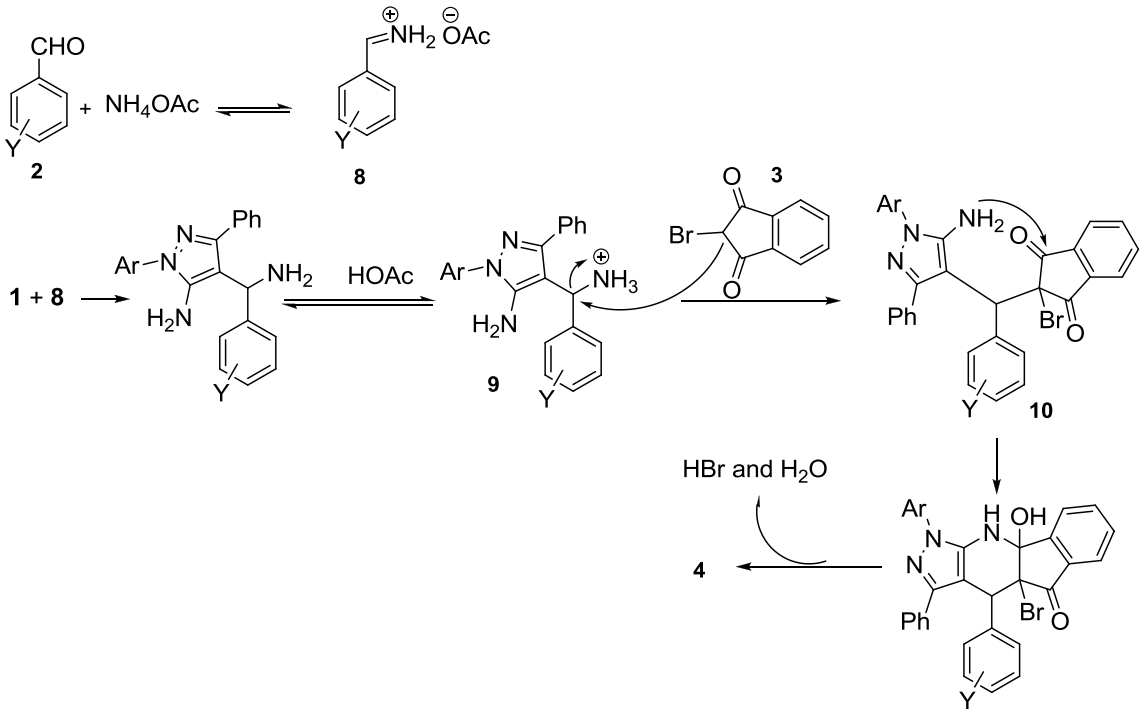
Finally, in situ generation of 2-bromo-1*H*-indene-1,3(2*H*)-dione **3** by the reaction of 1,3-indandion **6** and bromine was investigated in the reaction. Therefore, the reaction of 1,3-diphenyl-1*H*-pyrazol-5-amine **1a**, 4-nitro aldehyde **2b**, 1,3-indandion **6** and bromine under same reaction conditions afforded the same product **4** in 65 % yield after 24 h (Scheme 4).

Conclusion

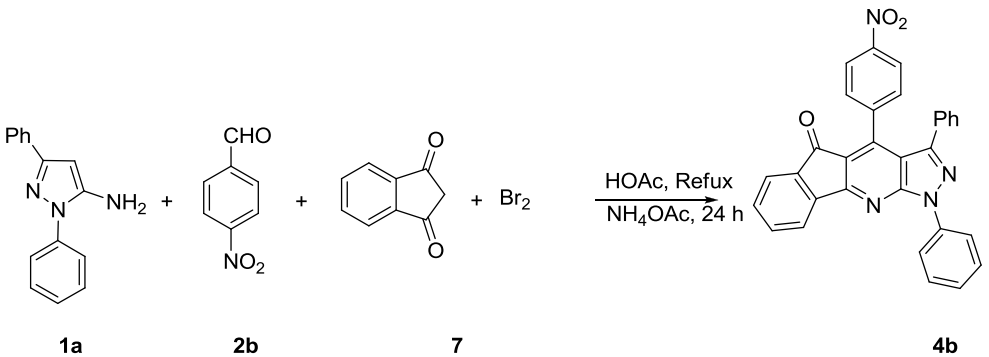
In this paper, 2-bromo-1*H*-indene-1,3(2*H*)-dione as a cyclic α-halo compound was used for the synthesis of

Scheme 2 Reaction of 1,3-indandion, aldehyde and aminopyrazole





Scheme 3 Proposed mechanism



Scheme 4 In situ generation of 2-bromoindene-dione **3** in the reaction

indenopyridines containing densely pyrazole or uracil in good yields via multi-component coupling reactions. Prominent among the advantages of this new method are novelty, operational simplicity, good yields, and easy work-up procedures employed.

Acknowledgments We gratefully acknowledge financial support from the Research Council of Shahid Beheshti University.

References

1. R. Katoch-Rouse, A.G. Horti, J. Label. Compd. Radiopharm. **46**, 93 (2003)
2. J.P. Meschler, D.M. Kraichely, G.H. Wilken, A.C. Howlett, Biochem. Pharmacol. **60**, 1315–1323 (2000)
3. A.B. Adnan, T.Y.F. Hesham, A.F.R. Sherif, A. Baraka, Eur. J. Med. Chem. **38**, 27 (2003)
4. P.C. Wong, D.J.P. Pinto, R.M. Knabb, Cardiovasc. Drug Rev. **20**, 137 (2002)
5. M. Ge, E. Cline, L. Yang, Tetrahedron Lett. **47**, 5797 (2006)
6. M.J. Genin, C. Biles, B.J. Keiser, S.M. Poppe, S.M. Swaney, W.G. Tarpley, Y. Yagi, D.L. Romero, J. Med. Chem. **43**, 1034 (2000)
7. A. Lévai, A.M.S. Silva, J.A.S. Cavaleiro, I. Alkorta, J. Elguero, J. Jekö, Eur. J. Org. Chem. **71**, 2825 (2016)
8. N. Almirante, A. Cerri, G. Fedrizzi, G. Marazzi, M. Santagostino, Tetrahedron Lett. **39**, 3287 (1998)
9. S. Peruncheralathan, T.A. Khan, H. Ila, H. Junjappa, J. Org. Chem. **70**, 10030 (2005)
10. H.M. Aly, J. Iran. Chem. Soc. **13**, 999 (2016)
11. M.G. Dekamin, M. Alikhani, A. Emami, S. Ghafuri, S. Javanshir, J. Iran. Chem. Soc. **13**, 591 (2016)
12. R.R. Crenshaw, G.M. Luke, P. Smirnoff, J. Med. Chem. **19**, 262 (1976)
13. R. Crenshaw, G.M. Luke, P. Smirnoff, Canadian Patent 10, 32, 538; Chem. Abstr. 1978, 89, 179995r
14. M. Cheung, P.A. Harris, J.G. Badiang, G.E. Peckham, S.D. Chamberlain, M.J. Alberti, D.K. Jung, S.S. Harris, N.H. Bramson, A.H. Epperly, S.A. Stimpson, M.R. Peel, Bioorg. Med. Chem. Lett. **18**, 5428 (2008)
15. S.A. Saggar, J.T. Sisko, T.J. Tucker, R.M. Tynebor, D.S. Su, N.J. Anthony, US Patent Appl.US 2,007,021,442 (2007)
16. N.B. Patel, S.N. Agravat, F.M. Shaikh, Med. Chem. Res. **20**, 1033 (2011)
17. M. Shekarchi, M. Pirali-Hamedani, L.N. Abid, A. Shafiee, J. Iran. Chem. Soc. **5**, 150 (2008)
18. N.B. Patel, S.N. Agravat, Chem. Heterocycl. Compd. **45**, 1343 (2009)
19. S.N.J. Srivastava, Pandeya. Curr. Pharm. Rev. Res. **4**, 5 (2011)
20. E.G. Paronikyan, A.S. Noravyan, I.A. Dzhagatspany, I.M. Nazaryan, R.G. Paronikyan, Pharm. Chem. J. **36**, 465 (2002)
21. A.M.R. Bernardino, A.R. De Azevedo, L.C.D. Pinheiro, J.C. Borges, V.L. Carvalho, M.D. Miranda, M.D.F. De Meneses, M. Nascimento, D. Ferreira, M.A. Rebello, Med. Chem. Res. **16**, 352 (2007)
22. T.J. Tucker, J.T. Sisko, R.M. Tynebor, T.M. Williams, P.J. Felock, J.A. Flynn, M. Lai, Y. Liang, G. McGaughey, M.J. Liu, Med. Chem. **51**, 6503 (2008)
23. M.G. Mamolo, D. Zampieri, V. Falagiani, L. Vio, M. Fermeglia, M. Ferrone, S. Pricl, E. Banfi, G. Scialino, Arkivoc **5**, 231 (2004)
24. C. Safak, R. Simsek, Y. Altas, S. Boydag, K. Erol, Boll. Chim. Farm. **136**, 665 (1997)
25. E. Bisenieks, J. Uldrikis, I. Kirule, G. Tirzite, G. Dubur, Khim. Geterotsikl. Soedin. **27**, 1528 (1982)
26. J. Augstein, A.L. Ham, P.R. Leeming, J. Med. Chem. **15**, 466 (1972)
27. R. Kunstmann, U. Lerch, H. Gerhards, M. Leven, U. Schacht, J. Med. Chem. **27**, 432 (1984)
28. R. Kunstmann, G. Fischer, J. Med. Chem. **27**, 1312 (1984)
29. C. Rentzea, N. Meyer, J. Kast, P. Plath, H. Koenig, A. Harreus, U. Kardorff, M. Gerber, H. Walter, Ger. Offen. DE 4301426 A1 21, Chem. Abstr. **1994**(121), 133986 (1994)
30. T. De Wit, K. Van Emelen, F. Maertens, G.J. Hoornaert, F. Compernolle, Tetrahedron Lett. **42**, 4919 (2001)
31. K. Van Emelen, T. De Wit, G.J. Hoornaert, F. Compernolle, Tetrahedron **58**, 4225 (2002)
32. S. Ahadi, M. Abaszadeh, A. Bazgir, Mol. Divers. **16**, 299 (2012)
33. S. Ahadi, P. Mirzaei, A. Bazgir, Comb. Chem. High Throughput Screen. **16**, 435 (2013)
34. S. Ahadi, M. Zolghadr, H.R. Khavasi, A. Bazgir, Org. Biomol. Chem. **11**, 279 (2013)
35. S. Ahadi, H.R. Khavasi, A. Bazgir, Chem. Eur. J. **19**, 12553 (2013)
36. P. Kaur, S. Pindi, W. Wever, T. Rajale, G. Li, Chem. Commun. **46**, 4330 (2010)
37. P. Kaur, S. Pindi, W. Wever, T. Rajale, G. Li, J. Org. Chem. **75**, 5144 (2010)
38. P. Kaur, W. Wever, S. Pindi, R. Milles, P. Gu, M. Shi, G. Li, Green Chem. **13**, 1288 (2011)
39. G. An, C. Seifert, G. Li, Org. Biomol. Chem. **13**, 1600 (2015)