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Uncatalyzed One-Pot Synthesis of Highly Substituted Pyridazines and Pyrazoline-Spirooxindoles via Domino SN/Condensation/Aza-ene Addition Cyclization Reaction Sequence

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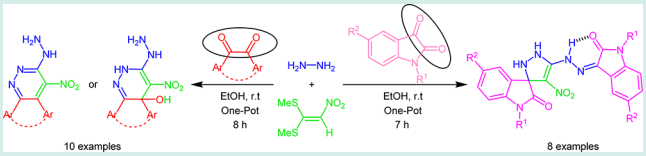
Supporting Information

ABSTRACT: A previously unknown class of highly substituted pyridazines and pyrazoline-spirooxinoles are easily prepared by an uncatalyzed one-pot three-component approach incorporating a domino SN/condensation/aza-ene addition cyclization reaction sequence. 1,1-Dihydrazino-2-nitroethylene (DHNE) which is generated in situ from the nucleophilic substitution (SN) reaction of hydrazine and 1,1-bis(methylthio)-2-nitroethylene (BMTNE), allowed to be condensed with active 1,2-dicarbonyl compounds followed by an intramolecular aza-ene addition cyclization to obtain the titled products depending on the type of 1,2-dicarbonyl. All reactions are easily performed and proceed with high efficiency under very simple and mild conditions without any catalyst and give good yields avoiding time-consuming, costly syntheses, and tedious workup and purification of products.



KEYWORDS: *1,2-diaza heterocycles, spirooxindole, pyrazoline, pyridazine, one-pot reactions, domino reactions, nitro ketene dithioacetal, isatin, benzil, 1,2-dicarbonyls, aza-ene reaction*

INTRODUCTION

Among the currently used strategies to find the new biologically active heterocyclic compounds, one-pot multicomponent reactions (MCRs) are used to increase the molecular complexity and diversity with minimum time, labor, cost, and waste production.[1−5] These benefits are highlights for multicomponent domino reactions, which involve in situ production of an intermediate with a strategic reactive site for subsequent transformations.[6,7]

Spiroheterocycles are of considerable interest because the conformational restriction associated to the structural rigidity affects considerably their biological activity.[8] Among them, spirooxindoles,[9−14] are the central structural frameworks which are present in numerous bioactive natural products and alkaloids with biological and clinical activities such as spirotryprostatin A, pteropodine,[15] gelsemine,[16] and horsfiline.[17]

Spirooxindole-pyrazolines are one of the interesting classes of spirooxindoles on which significantly less research has been done compared to the spirooxindole-pyrrolidine. Surprisingly, to the best of our knowledge there are three[18−20] procedures for the synthesis of spirooxindole-pyrazolines, and all of them require at least two steps, starting from the condensation of isatin and a reactive methylene nucleophile. In a very recent work, one-pot synthesis of pyrazolophthalazinyl-spirooxindoles has been reported in the presence of nickel chloride in polyethylene glycol 600 as catalyst.[21]

Pyridazines and fused pyridazines with their reduced derivatives are important subclasses of diaza-six-membered heterocycles that possess synthetic utility[22−26] and important pharmacological activities.[27,28] Several biologically active natural and unnatural compounds consist of heterocycles containing an N−N bond in six membered rings such as well-known piperazic acid and 1-Azafagomine.[29−35] In this class of compounds, 1,4-dihydropyridazines are of particular interest because of their activities as cardiovascular and spasmolytic agents that can be correlated with those of 1,4-dihydropyridine.[36,37] Conventional methods for pyridazine synthesis are based on the reaction of hydrazine or its derivatives with 1,4-dicarbonyls[38−44] and different types of [2 + 4] hetero Diels−Alder reaction.[45−50] Synthetic methods based on Ugi four-component reaction[51] and electrophilic hydrazination of enolates[52−57] are most interesting recent methods for the preparation of 1,4-dihydropyridines.

In view of the above introduction and prompted by our ongoing investigations on the construction of diaza-heterocycles,[58−62] we tried to design a practical and efficient multicomponent domino protocol for the preparation of two new classes of highly functionalized previously unknown 1,2-diazaheterocycles, pyrazoline-spirooxindoles and pyridazines, using 1,1-dihydrazino-2-nitroethylene (DHNE) as intermediate.

RESULTS AND DISCUSSION

Recently, we have become interested in the application of ketene aminal intermediates resulting from the reaction of 1,1-bis(methylthio)-2-nitroethylene (BMTNE) and nitrogen

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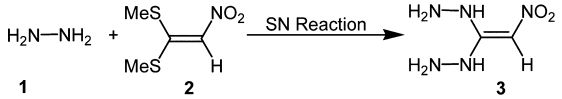
nucleophiles such as diamines or ammonia for the synthesis of interesting heterocycles in one-pot processes.[63−66] Following this lead and to achieve a diaza-intermediate to employ in one-pot synthesis of diaza heterocycles, we first evaluated the reaction of hydrazine and BMTNE under different conditions. The maximum yield of 1,1-dihydrazino-2-nitroethylene (DHNE) **3** was obtained when the reaction was performed in EtOH at room temperature for 7 h with 2.6:1 ratio of hydrazine:BMTNE (Table 1).

Table 1. Optimization Conditions for the Formation of Intermediate 1,1-Dihydrazino-2-nitroethylene (DHNE)



1 2 3

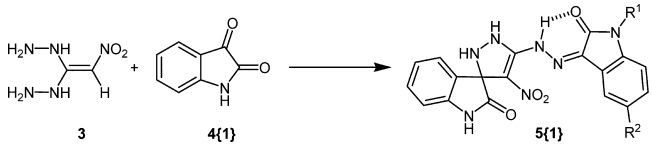
entry	solvent	T (°C)	t (h)	molar ratio **1**:**2**	yield (%)[a]
1	MeCN	r.t	5	2:1	51
2	MeCN	reflux	5	2:1	39
3	MeCN	r.t	7	2:1	65
4	MeCN	r.t	9	2:1	65
5	MeCN	r.t	14	2:1	15
7	H_2O	r.t	9	2:1	70
8	H_2O	r.t	7	2.2:1	73
9	EtOH	r.t	7	2.2:1	78
10	EtOH	r.t	7	2.6:1	80
11	EtOH	r.t	7	3:1	80
12	CH_2Cl_2	r.t	7	3:1	trace

[a]Isolated yields.

In the next stage, we decided to perform the reaction of isatin and the resulting 1,1-dihydrazino-2-nitroethylene **3** to evaluate the formation of pyrazoline-spirooxindoles. Thus, a mixture of isatin **4{1}** and 1,1-dihydrazino-2-nitroethylene **3** underwent a bis-condensation/aza-ene addition cyclization reaction through different conditions. The best result and maximum 85% yield of pyrazoline-spirooxindole **5{1}** was obtained when the reaction proceeded in EtOH at room temperature for 1.5 h (Table 2). Notably, performing the above reaction using equivalent ratio of reactants gave the corresponding pyrazoline-spirooxindole **5{1}** in nearly 45% and roughly half of unreacted 1,1-dihydrazino-2-nitroethylene **3** was recovered at the end of the reaction while no pyrazoline-spirooxindole **6** was obtained based on NMR investigation of reaction mixture (Scheme 1).

Despite the success in the synthesis of pyrazoline-spirooxindoles **5** using the above two-components per reaction, two step procedure (Procedure 1), we decided to evaluate a one-pot pseudo five-component reaction procedure (Procedure 2) for the synthesis

Table 2. Optimization Conditions for the Formation of Pyrazoline-Spirooxindole 5{1}[a]



3 4{1} 5{1}

entry	solvent	T (°C)	t (h)	**5a** yield (%)[b]
1	EtOH	r.t	0.5	52
2	EtOH	r.t	1	77
3	EtOH	r.t	1.5	85
4	EtOH	r.t	2	85
5	EtOH	reflux	1.5	70
6	H_2O	r.t	1.5	51
7	H_2O	reflux	1.5	25
8	H_2O	r.t	4	58
9	CH_2Cl_2	r.t	8	24
10	MeCN	r.t	7	66
11	MeCN	reflux	7	66

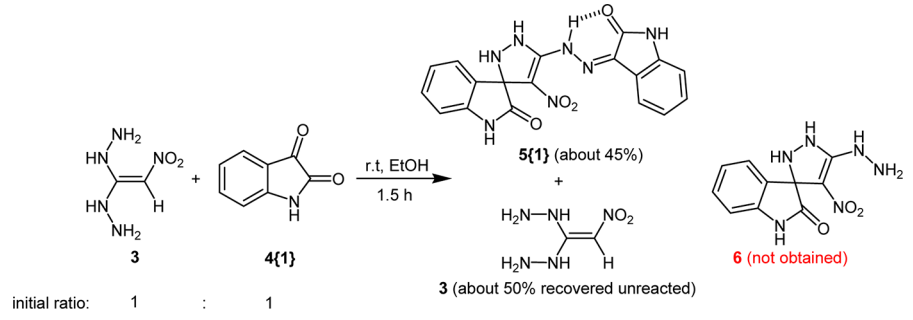
[a]1:2 ratio of DHNE **3**:isatin **4{1}**. [b]Isolated yield.

of **5**. Procedure 2 avoids the isolation of the intermediate BHNE (**3**) and should save time of execution and solvent amounts, and afford better yields.[67] These two procedures are summarized in Scheme 2. With the optimized conditions in hand, we performed a one-pot pseudofive component reaction with 2.6 equiv of hydrazine hydrate, 1 equiv of BMTNE **2**, and 2 equiv of isatin **4{1}**. As expected, the reaction proceeds smoothly in EtOH at room temperature after 7 h to produce spirooxindole-pyrazoline **5{1}** in 67% yield (Table 3, Entry 1).

Subsequently, we examined the scope and limitation of both of strategies by varying the isatin component. Different types of isatin such as 5-bromo, 5-nitro, and *N*-alkylisatins were used. As depicted in Table 3, both of procedures are general toward the isatin component. In addition, the yield of the one-pot, multicomponent reaction (Procedure 2) is higher than the total yield of procedure 1 in all examples (Table 3).

After this successful endeavor with the synthesis of pyrazoline-spirooxindole **5** using the DHNE intermediate **3** and isatin **4**, our attention turned to the use of 1,2-diarylethanediones (benzils) in both procedures. Comparing to the isatins, benzyls have two reactive ketonic carbonyls in 1,2 positions. Taking this difference between isatin and benzil into account and considering the behavior of DHNE and ketene aminal intermediates that show nucleophilicity on two sites, we performed the reaction of DHNE and benzil **6{1}** to obtain pyridazines. As expected, under optimum condition (Table 4, Entry 4), the reaction of

Scheme 1. Outcome of the Equimolecular Reaction of DHNE (3) and Isatin 4{1}



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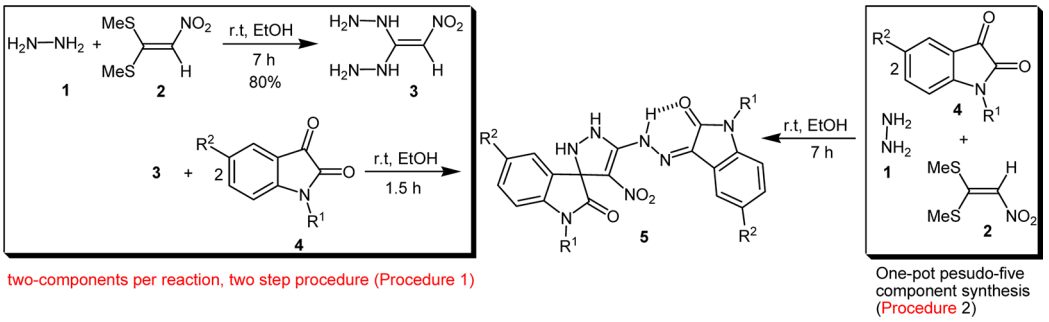
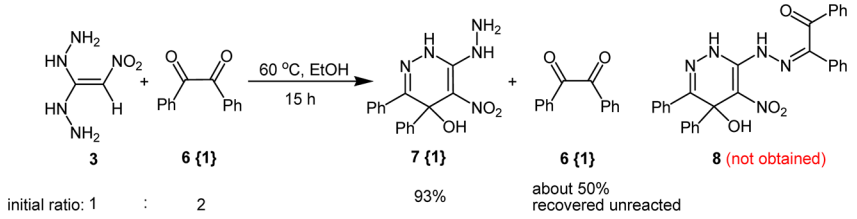
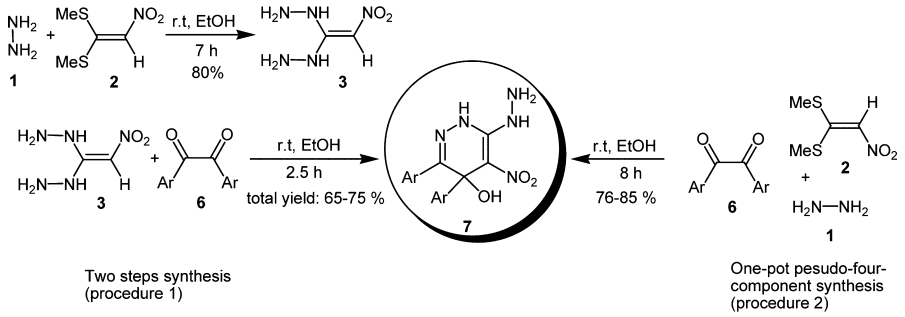
Scheme 2. Two- and One-Step Procedures for the Synthesis of Pyrazoline-Spirooxindoles 5



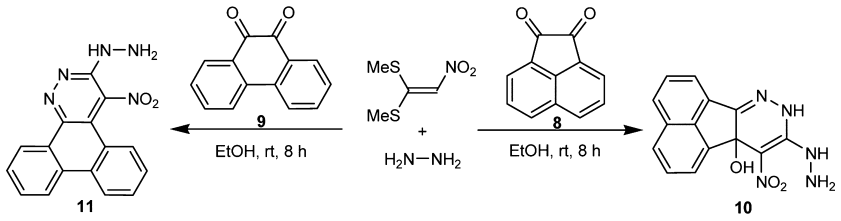
Scheme 3. Outcome of the Reaction of DHNE (3) and Benzil 6{1} with a Ratio 1:2



Scheme 4. Two- and One-Step Procedures for the Synthesis of Hydrazino-1,4-dihydropyridazinole 7



Scheme 5. One-Pot Synthesis of Hydrazinopyridazines Fused Phenathrenequinone 10 or Acenaphthoquinone 11 via Domino SN/Condensation/Addition Cyclization Reaction



DHNE **3** and 1,2-diphenylethanedione **6{1}** (benzil) produced hydrazino-1,4-dihydropyridazinole **7{1}** in 82% yield.

Interestingly, the reaction with 1:2 ratio of DHNE and benzil **6{1}** did not produce pyridazine **8** unlike the case of isatin even at high temperature and extended reaction times. Half of the benzil was recovered at the end of the reaction while the yield of pyridazine **7{1}** did not change (Scheme 3).

Then, we explored a one-pot, pseudo four-component domino SN/condensation/addition cyclization reaction (Scheme 4, procedure 2) for the synthesis of hydrazino-1,4-dihydropyridazinole **7**. With the optimized conditions for the two reactions of procedure 1 in hand, we performed a one-pot pseudo four-component reaction of 2.6:1:1 ratio of hydrazine **1**, BMTNE **2**, and benzil **6{1}**. The reaction mixture underwent a domino SN/condensation/addition cyclization processes in EtOH at room temperature to afford the hydrazino-1,4-dihydropyridazinole **7{1}** in 78% yield after 8 h (Table 5, Entry 1). Both of procedures are summarized in Scheme 4. It must be noted again that obviously, the one-pot synthesis of hydrazine-1,4-dihydropyridazinol is the preferred procedure.

Then, various benzils with different substituents were utilized under the same one-pot reaction conditions to examine the scope and limitations of both procedures. It was found that only benzils carrying electron-withdrawing groups (such as F, Cl, and NO_2, entries 3−8) or weak electron-donating groups (such as Me, entry 2) show similar reactivity and react efficiently to yield the desired products in both procedures (Table 5). Application of substituted benzils with an electron-donating

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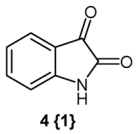
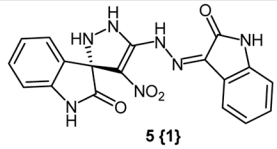
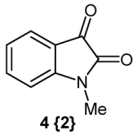
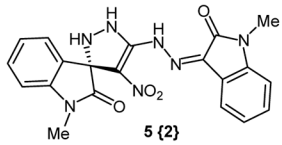
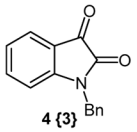
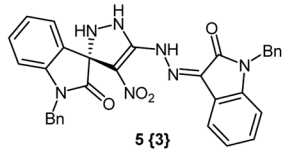
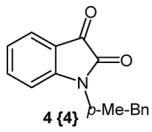
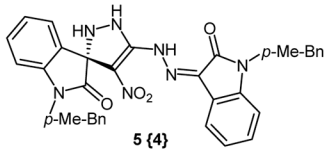
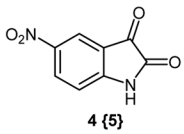
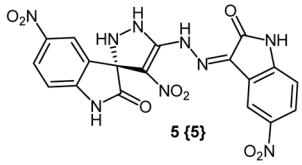
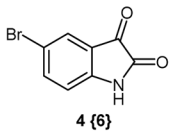
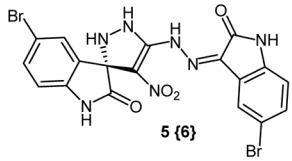
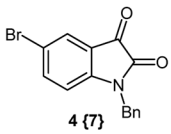
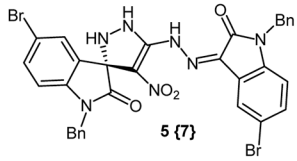
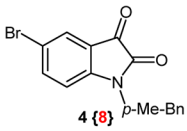
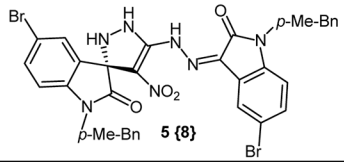
Table 3. Pyrazoline-Spirooxindoles 5 Synthesized by the Procedures Shown in Scheme 2[a]

Entry	Isatin **4**	Product	Total yield[b] (Yield of **5** in step 2[c])	Yield of **5**[d]
1	 **4 {1}**	 **5 {1}**	64 (80)	67
2	 **4 {2}**	 **5 {2}**	66 (83)	70
3	 **4 {3}**	 **5 {3}**	59 (74)	65
4	 **4 {4}**	 **5 {4}**	56 (70)	65
5	 **4 {5}**	 **5 {5}**	56 (70)	64
6	 **4 {6}**	 **5 {6}**	62 (77)	68
7	 **4 {7}**	 **5 {7}**	55 (69)	60
8	 **4 {8}**	 **5 {8}**	60 (76)	63

[a]Conditions for procedure 1: ratio of DHNE:isatin is 1:2/EtOH/1.5 h in all entries; conditions for procedure 2: ratio of hydrazine:BMTNE:isatin is 2.6:1:2/EtOH/7 h in all entries. [b]total yield of **5** obtained by procedure 1. [c]Isolated yield obtained by DHNE-isatin reaction in procedure 1 (step 2). [d]Isolated yield obtained by one-pot domino SN/condensation/addition cyclization reaction (procedure 2).

group such as OMe or Br (Entries 9,10) even in the presence of a NO_2 group (entries 11−13) did not lead to the desired product at all. In these cases, after appropriate time, 1,1-dihydrazino-2-nitroethylene intermediate and all of the related benzil were recovered unchanged.

We subsequently changed the 1,2-diketone component from substituted benzils **6** to reactive quinones. Interestingly, the one-pot reaction of hydrazine **1**, 1,1-bis(methylthio)-2-nitroethylene and acenaphthoquinone **8** or phenanthrenequinone **9** produces polycyclic 3,4-acenaphthoquino-6-hydrazino-5-nitro-1,4-dihydro-4-pyridazinol **10** or aromatic 3,4-([9,10]-phenanthrene)-6-hydrazino-5-nitro-pyridazine **11** under the same reaction conditions (Scheme 5).

The molecular structure of all synthetic compounds **5{1−8}**, **7{1−8}**, **10**, and **11** were elucidated from their mass spectrometric analyses, IR, and high-field ^{1}H NMR and ^{13}C NMR. The mass spectrum of **5{1}** displayed the molecular ion peak at m/z = 319 with low intensity. In the IR spectrum, stretching frequencies of five NH groups appear as two broad bands in the region of 3100−3500 cm^{-1}. Absorption bands at 1715, 1616, 1558, and 1340 cm^{-1} are related to NC═O, C═N, C═C, and NO_2 groups, respectively, and indicate the most important functional groups of the product. The ^{1}H NMR spectrum of **5{1}** exhibited four singlets at δ = 6.13, 10.79, 11.21, and 13.37 ppm and were assigned as NH protons, as all were exchangeable

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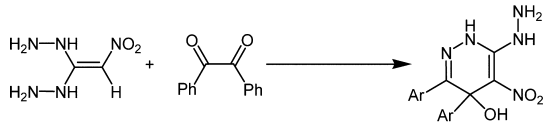
Table 4. Optimization Conditions for the Formation of Hydrazino-1,4-dihydropyridazinole 7{1}[a]



3 6 {1} 7 {1}

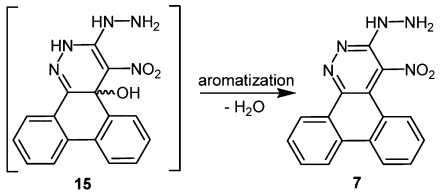
Entry	Solvent	T (°C)	t (h)	Yield of 7{1}(%)[b]
1	EtOH	r.t	1	70
2	EtOH	r.t	1.5	79
3	EtOH	r.t	2	87
4	EtOH	r.t	2.5	93
5	EtOH	35	2.5	93
6	EtOH	45	2.5	93
7	H_2O	r.t	2.5	76
8	MeCN	r.t	2.5	64
9	CH_2Cl_2	r.t	2.5	10
10	MeOH	r.t	2.5	47

[a]1:1 ratio of DHNE **3**:benzil **6**{**1**}. [b]Isolated yield.

with D_2O. The first signal is due to the two NH protons of the pyrazoline ring. The second and third signals are attributed to the two NH groups of isatins and are not present when *N*-alkyl isatins are used. The latter is related to the NHN=C which resonates downfield because of intramolecular hydrogen bonding with the NO_2 group, in addition of conjugation with C=CNO_2. Observation of 18 distinct signals in the ^{1}H-decoupled ^{13}C NMR spectrum of **5**{**1**} is in agreement with the proposed structure. In the aliphatic region there is one characteristic signal at δ = 74.3 ppm corresponding to the C-3 spiro carbon. Signals of two amidic carbonyls appear at δ = 162.5 and 164.2 ppm. It is proposed that intramolecular hydrogen bonding results in the formation of the *Z*-isomer around the C=N bond in the products **5**.

The mass spectrum of 7{**1**} displayed the molecular ion peak at m/z = 325 with low intensity. Ion peaks at m/z = 308 and 279 are related to the loss of OH and NO_2 fragments. In the IR

Scheme 7

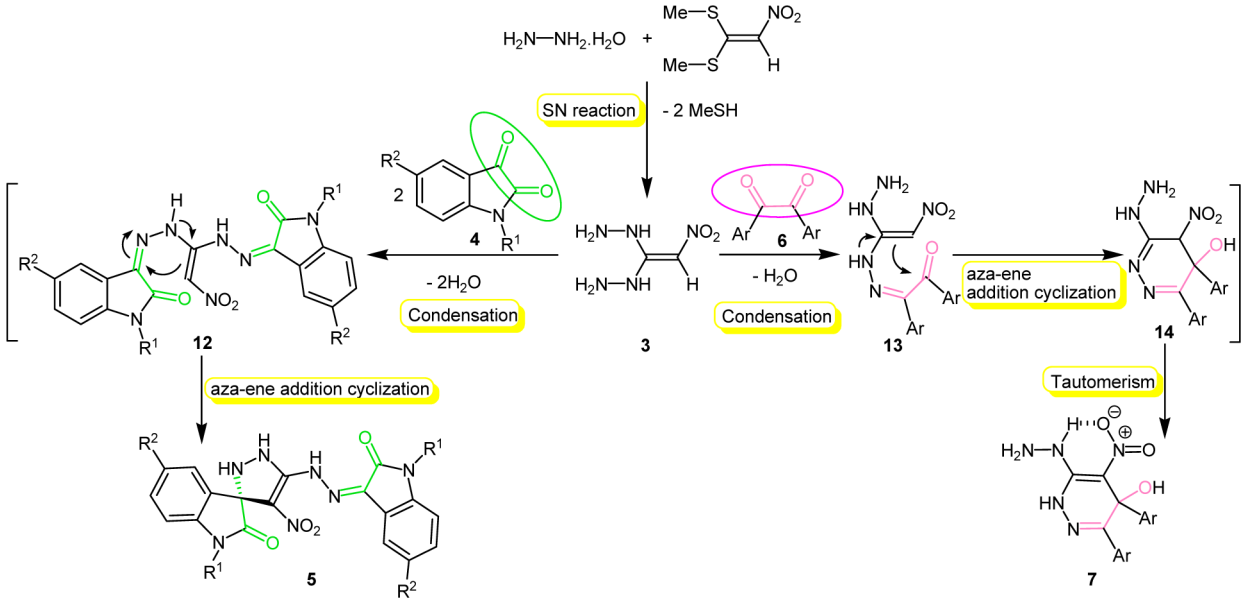


15 7

spectrum, stretching frequencies of OH, NH_2, and two NH groups appear as broad bands in 3471, 3348, 3170, 3066 cm^{-1}. Absorption bands at 1620, 1532, and 1404 cm^{-1} are clearly attributed to C=C, and NO_2 groups, respectively, and indicate the most important functional groups of the product. The ^{1}H NMR spectrum of 7{**1**} exhibited four singlets at δ = 4.52, 7.03, 8.33, and 12.73 ppm and were assigned as NH_2, two NH and OH protons, respectively, as all were exchangeable with D_2O. The OH and second NH resonate downfield because of intramolecular hydrogen bonding with the NO_2 group. Observation of 12 distinct signals in the ^{1}H-decoupled ^{13}C NMR spectrum of 7{**1**} is in agreement with the proposed structure. There are two characteristic signals at δ = 81.8 and 96.6 ppm corresponding to the C−OH and *C*-NO_2. In the ^{1}H NMR spectrum of **11** there are only two D_2O exchangeable singlets at δ = 6.82 and 15.95 ppm attributed to the NH and NH_2 (see Supporting Information for characterization data of all compounds).

Although no detailed mechanistic studies have been carried out at this point, a rationale mechanism for both of the one-pot procedures are outlined in Scheme 6. This mechanism is proposed knowing the chemical behavior of isatin,[68] 1,2-diketones such as benzils, and also ketene aminal intermediate **3**. Based on this mechanism, DHNE **3** readily prepared in situ from the addition of 2:1 ratio of hydrazine **1** and BMTNE **2** via a SN_2 reaction followed by loss of 2 equiv of MeSH. In the presence of isatin **4** which contained a highly active ketonic carbonyl, condensation reaction of DHNE **3** and 2 equiv of isatin followed by loss of 2 equiv of H_2O affords vinyl bis-hydrazone intermediate **12**. Finally, intermediate **12** converts to

Scheme 6. Proposed Mechanism for the Formation of Pyrazoline-Spirooxinoles 5 and Pyridazines 7



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the product **5** via an intramolecular aza-ene addition cyclization reaction.

On the other hand, in the presence of benzil with two active ketonic C═O, NH_2 of DHNE **3** condensed with one reactive carbonyl of benzil **6** followed by loss of 1 equiv of H_2O to afford vinyl hydrazone **13**. Since the other carbonyl of the benzil moiety is still highly reactive in intermediate **13**, an intramolecular aza-ene addition cyclization process followed by imine-enamine tautomerization leads to the formation of 6-hydrazino-5-nitro-3,4-diaryl-1,4-dihydropyridazin-4-ol product **7** (Scheme 7).

In the case of phenanthrenequinone, the pyridazinole intermediate **7** oxidized to hydrazinopyridazine **11** via an aromatization process (Scheme 7).

CONCLUSION

Overall, we have succeeded in developing a novel, convenient, and efficient synthesis of new spirooxindole-pyrazolines and

Table 5. Hydrazino-1,4-Dihydropyridazine 7 Synthesized by the Procedures Shown in Scheme 4[a]

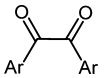
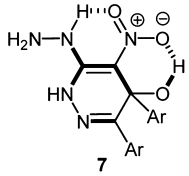
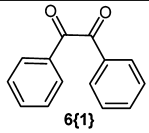
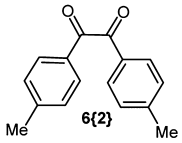
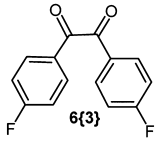
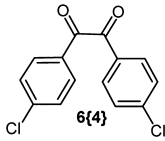
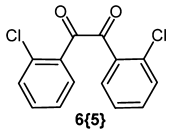
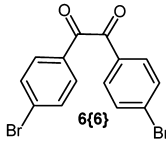
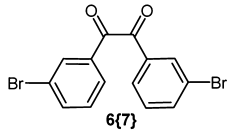
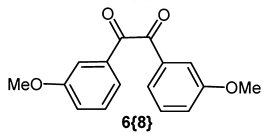
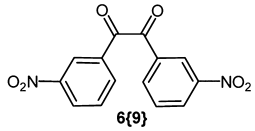
Entry	 6	[b]Product  7	Procedure 1 total yield of 7[c](Yield of 7[d])	Procedure 2 Yield of 7[e]
1	 6{1}	**7{1}**	66 (82)	78
2	 6{2}	**7{2}**	71 (89)	76
3	 6{3}	**7{3}**	65 (81)	81
4	 6{4}	**7{4}**	70 (87)	80
5	 6{5}	**7{5}**	73 (91)	80
[f]6	 6{6}	-	-	-
[f]7	 6{7}	-	-	-
[f]8	 6{8}	-	-	-
9	 6{9}	**7{6}**	74 (92)	83

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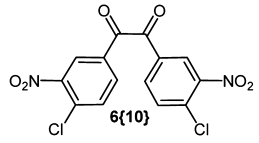
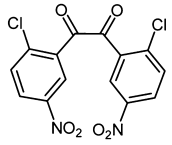
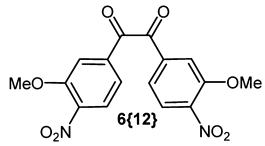
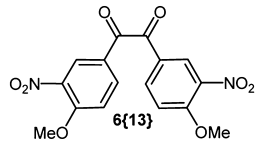
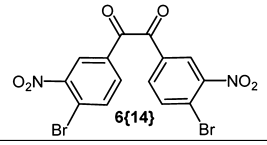
Table 5. continued

Entry	6	[b]Product 7	Procedure 1 total yield of 7[c](Yield of 7[d])	Procedure 2 Yield of 7[e]
10	 6{10}	7{7}	69 (86)	85
11	 6{11}	7{8}	94 (75)	84
[f]12	 6{12}	-	-	-
[f]13	 6{13}	-	-	
[f]14	 6{14}	-	-	-

[a]Conditions for procedure 1: ratio of DHNE and benzil is 1:1/EtOH/2.5 h in all entries; conditions for procedure 2: ratio of hydrazine, BMTNE and benzil is 2.6:1:1/EtOH/8 h in all entries. [b]The bold bonds refer to the bonds formed in the reaction. [c]Total yield of 7 in procedure 1. [d]Isolated yield of product 7 in DHNE-benzil reaction. [e]Isolated yield of one-pot domino SN/condensation/addition cyclization reaction (procedure 2). [f]Almost all benzil recovered unchanged in addition of DHNE **3**

1,4-dihydro pyridazinoles from readily available and inexpensive starting materials. Both one-pot procedures proceed through domino SN/condensation/aza-ene addition cyclization reactions. Our work presents a very simple reaction which is performed under neutral conditions without any catalyst that leads to the formation of four and five chemical bonds in 1,4-dihydropyridazines and spirooxindole-pyrazolines. All products were easily isolated (filtration or crystallization) and obtained in moderately good yields. The optimized one-pot procedure is noteworthy, when compared to the stepwise procedure, because of its ease of execution, flexibility, and substantial minimization of waste, labor, time, and cost. From the structural viewpoint, the products are polynitrogen and fully substituted compounds that will be suitable for further elaboration. Potential uses of the reaction in synthetic and medicinal chemistry might be quite significant.

EXPERIMENTAL PROCEDURES

General Information. Melting points measured on an Electrothermal 9100 apparatus. IR spectra were recorded as KBr pellets on a Shimadzu IR-460 spectrometer. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were obtained using a Bruker DRX-500 AVANCE spectrometer. All NMR spectra at room temperature were determined in DMSO-d_6. Chemical shifts are reported in parts per million (δ) downfield from an internal tetramethylsilane reference. Coupling constants (J values) are reported in hertz (Hz), and spin multiplicities are indicated by the following symbols: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet). Elemental analyses for C, H, and N performed using a Heraeus CHN-O-Rapid analyzer. Mass spectra were recorded on a FINNIGAN-MATT 8430 mass spectrometer operating at an ionization potential of 20 or 70 eV. All chemicals were purchased from Merck or Aldrich and were used without further purification.

General Procedure for the Preparation of 1,1-Dihydrazino-2-nitroethylene (DHNE) 3. To a magnetically stirred 50 mL flask containing 1,1-bis(thiomethyl)-2-nitroethylene (0.85 g, 5 mmol) in EtOH (10 mL) was added NH_2NH_2 (80% aq, 0.8 g, 13 mmol). After 7 h, the precipitated product **3** was filtered and washed with cold EtOH (2 mL) and dried under vacuum for 2 h.

General Procedure for the Preparation of Compounds 5{1−8} (for example 5{1}). *Procedure 1:* To a magnetically stirred 10 mL flask containing 1,1-dihydrazino-2-nitroethylene (0.16 g, 1 mmol) in EtOH (3 mL) was added isatin (0.30 g, 2 mmol). After 1.5 h, the precipitated product

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5{1} was filtered and washed with cold EtOH (2 mL). *Procedure 2*: To a magnetically stirred 10 mL flask containing 1,1-bis(thiomethyl)-2-nitroethylene (0.17 g, 1 mmol) in EtOH (3 mL) was added NH_2NH_2 (80% aq, 0.16 g, 2.6 mmol). After 6 h, isatin (0.30 g, 2 mmol) was added to the reaction mixture, and stirring was allowed to continue for 1 h. After the completion of the reaction, the precipitated product was filtered and washed with cold EtOH.

General Procedure for the Preparation of Compounds 7{1−8} (for example 7{1}). *Procedure 1*: To a magnetically stirred 10 mL flask containing 1,1- dihydrazino-2-nitroethylene (0.16 g, 1 mmol) in EtOH (3 mL) was added benzil (0.21 g, 1 mmol). After 2.5 h, the precipitated product **7{1}** was filtered and washed with cold EtOH (2 mL). *Procedure 2*: To a magnetically stirred 10 mL flask containing 1,1-bis(thiomethyl)-2-nitroethylene (0.17 g, 1 mmol) in EtOH (4 mL) was added $NH_2NH_2{\cdot}H_2O$ (80% aq, 0.16 g, 2.6 mmol). After 6 h, benzil (0.21 g, 1 mmol) was added to the reaction mixture, and stirring was allowed to continue for 2 h. After the completion of the reaction (monitoring by TLC), the precipitated product was filtered and washed with cold EtOH (1 mL)

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The experimental details and the spectroscopic data of all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

■ ABBREVIATIONS

SN, Nucleophilic substitution; BMTNE, 1,1-bis(methylthio)-2-nitroethylene; DHNE, 1,1-dihydrazino-2-nitroethylene

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