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One-Pot Synthesis of Spirocyclic or Fused Pyrazoles from Cyclic Ketones: Calcium Carbide as the Carbon Source in Ring Expansion

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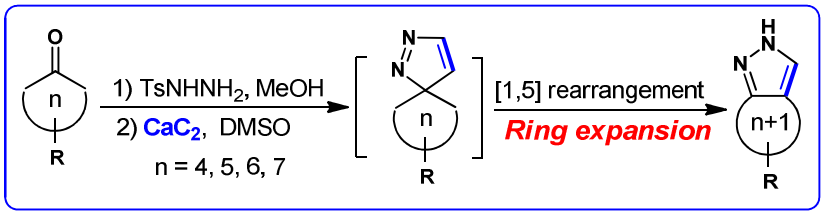


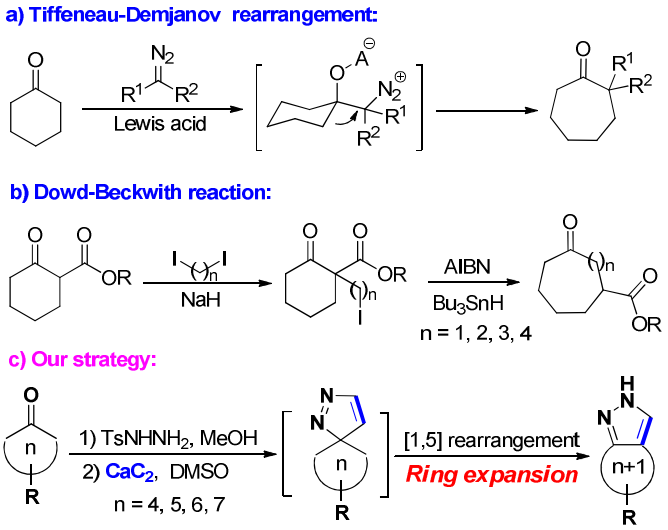
Abstract: *N*-Tosylhydrazones generated *in situ* from cyclic ketones smoothly underwent a [3+2] cycloaddition to afford saturated spirocyclic pyrazoles and further transformed to the fused analogues via a ring expansion in certain cases. An inexpensive and renewable resource, calcium carbide, was utilized as the carbon source in the ring expansion. The salient features of this reaction include widely available starting materials, convenient one-pot/two-step procedure, great efficiency and high regioselectivity. Remarkably, this reaction underwent [1,5]-sigmatropic rearrangement process, which was supported by deuterium-labeling experiments.

INTRODUCTION

Owing to their convenient accessibility and structural diversity, cycloalkanone derivatives have been widely used as raw materials for many total syntheses of natural products or bioactive molecules.[1-2] Ring expansion reactions of cycloalkanones rank among the most strategically useful in the steps of these syntheses, since many natural products consist of unavailable polycyclic networks. To date, there have been various methods developed for the ring expansion of cycloalkanones,[3] some of which have even become name reactions. For examples, the Lewis acid-catalyzed addition of α-diazoacetates or diazoalkanes to cyclohexanones has been known for more than half a century as a practical strategy to synthesize seven-membered carbocyclic ketones through the Tiffeneau-Demjanov rearrangement intermediates (Scheme 1a).[4] Another well-known and efficient method is the Dowd-Beckwith ring expansion reaction, in which the 2-oxocyclohexanecarboxylate compounds are transformed to medium-sized ring cyclic ketones. However, this process requires the addition of toxic or explosive reagents such as AIBN and Bu_3SnH, and environmentally unfriendly haloalkane substrates are used as the carbon source (Scheme 1b).[5]

In order to expand the richness of green ring expansion reactions, we tried to hunt for other atom-economical and easy-to-obtain carbon sources. It is known that calcium carbide (CaC_2) is thought to be a promising candidate for a safer and more inexpensive alternative to acetylene gas that has become an important basic organic chemical raw material.[6] Therefore, the conversions of CaC_2 to acetylene-derived compounds have received continuing attention in these years owing to their potential to the preparation of 3-substituted or 3,4-disubstituted 1*H*-pyrazoles in industry field

Scheme 1. Transition-metal free ring expansion reactions of cyclic ketones

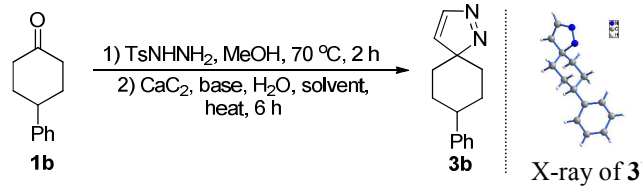


by using CaC_2 as the source.[7] The reaction pathways have been clarified that the 3*H*-pyrazole intermediates were involved and spontaneously rearranged to the final products. On the basis of this work and Valdés's report[8], we envisaged that the 3*H*-pyrazole intermediate could be stably isolated as product by using symmetrical cyclic ketones as substrates. In addition, asymmetrical cyclic ketones would undergo the [3+2] cycloaddition/[1,5] rearrangement sequence to give the fused pyrazoles with expansion of the carbocyclic ring. In this context, we report herein a new method for utilizing CaC_2 as both an acetylide source in the [3+2] annulation and the carbon source in ring expansion to synthesize spirocyclic or fused pyrazoles (Scheme 1c). Such saturated polycyclic pyrazole motifs were prevalent structural elements in numerous compounds of significant biological/medicinal value for the applications in dyes, agrochemicals and pharmaceuticals.[8-11] However, their preparations were typically challenging to achieve directly by using conventional methods.

RESULTS AND DISCUSSION

At the outset of our studies, we investigated this reaction for the synthesis of spiro-heterocycles from 4-phenyl-cyclohexanone (**1b**) and calcium carbide. The condensation reaction between ketones and tosylhydrazide can easily afford *N*-tosylhydrazones *in situ* without the need for chromatographic purification.[12] Therefore, a mixture of **1b** and tosylhydrazide was first stirred at 70 ^{o}C for 2 h in methanol, followed by removal of the solvent. The remaining crude mixture was then treated with excessive amounts of CaC_2, H_2O and equivalent amounts of bases in appropriate solvents. To our delight, when the reaction was performed in DMSO at 80 ^{o}C for 6 h with the addition of Cs_2CO_3, the desired spirocyclic pyrazole **3b** was obtained in 51% isolated yield (Table 1, entry 1). Subsequent screening of other bases such as K_2CO_3, KOH, *t*-BuOLi or MeONa did not improve the yield (Table 1, entries 2-5). Significantly, increasing the reaction temperature had a positive effect on the yield. 110 ^{o}C was found to be optimal, affording the target product **3b** in 87% isolated yield (Table 1, entries 6-8). Different types of solvents were then investigated, while no superior results were obtained (Table 1, entries 9-13). Furthermore, the molecular structure of **3b** was unambiguously determined by X-ray crystallographic analysis (see Supporting Information for details).

Table 1. Optimization of Reaction Conditions [a]



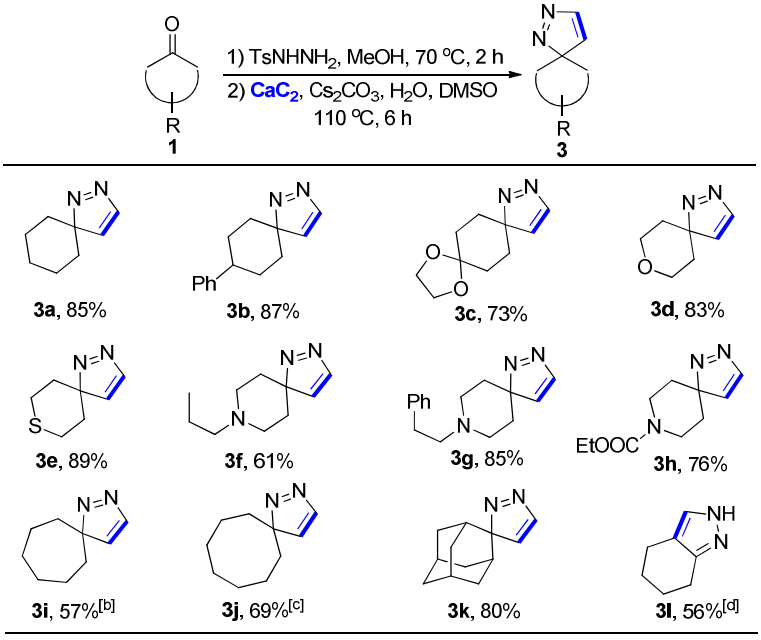
entry	base	solvent	T (^{o}C)	yield [b](%)
1	Cs_2CO_3	DMSO	80	54 (51)[c]
2	K_2CO_3	DMSO	80	35
3	KOH	DMSO	80	29
4	*t*-BuOLi	DMSO	80	11
5	MeONa	DMSO	80	46
6	Cs_2CO_3	DMSO	100	79
7	Cs_2CO_3	DMSO	110	92 (87)[c]
8	Cs_2CO_3	DMSO	120	90
9	Cs_2CO_3	DMF	110	63
10	Cs_2CO_3	1,4-Dioxane	110	86
11	Cs_2CO_3	DMA	110	65
12	Cs_2CO_3	CH_3CN	110	trace
13	Cs_2CO_3	Toluene	110	trace

[a] Reaction conditions: 1) **1** (0.5 mmol), $TsNHNH_2$ (0.5 mmol), MeOH (2 mL) at 70 ^{o}C for 2 h; 2) CaC_2 (2 mmol), base (0.5 mmol), H_2O (2.5 mmol) and 2.0 mL solvent heating for 6 h. [b] GC yield with *n*-dodecane as internal standard. [c] Number in parentheses is the yield of isolated product.

With the optimized reaction conditions in hand, we turned our attention to the generality of this transformation (Table 2). Initially, *N*-tosylhydrazones generated from cyclohexanone and 4-substituted cyclohexanones were found to undergo [3+2] annulations with CaC_2 to give the corresponding spiro-heterocycles **3a-3c** in 73-87% yields. Pleasingly, a series of 6-membered saturated oxygen-, sulfur- and nitrogen-containing heterocyclic ketones were also suitable substrates for this cyclization that the target products **3d-3h** were isolated in 61-89% yields. Concerning the cycloalkanone ring size, cycloheptanone, cyclooctanone and adamantanone were

next investigated, and the corresponding products (**3i-3k**) were obtained in moderate to good yields. Notably, when cyclopentanone **1l** was examined, a 6-membered fused pyrazole product **3l** was afforded in 56% yield while the spirocyclic one was not detected. We supposed that spontaneous rearrangement in this manner might occur, based on the angle strain in the spirocyclic intermediate. Moreover, the temperature of this transformation should not be more than 100 °C, otherwise **3l** would further react with another equivalent of acetylene via nucleophilic addition to form a *N*-vinyl pyrazole product instead. As for other cycloalkanones, cyclobutanone was found to be in similar situation with cyclopentanone, albeit with too low yield that we only detected the product by crude ^{1}H NMR.

Table 2. Substrate scope for the synthesis of spirocyclic pyrazoles [a]

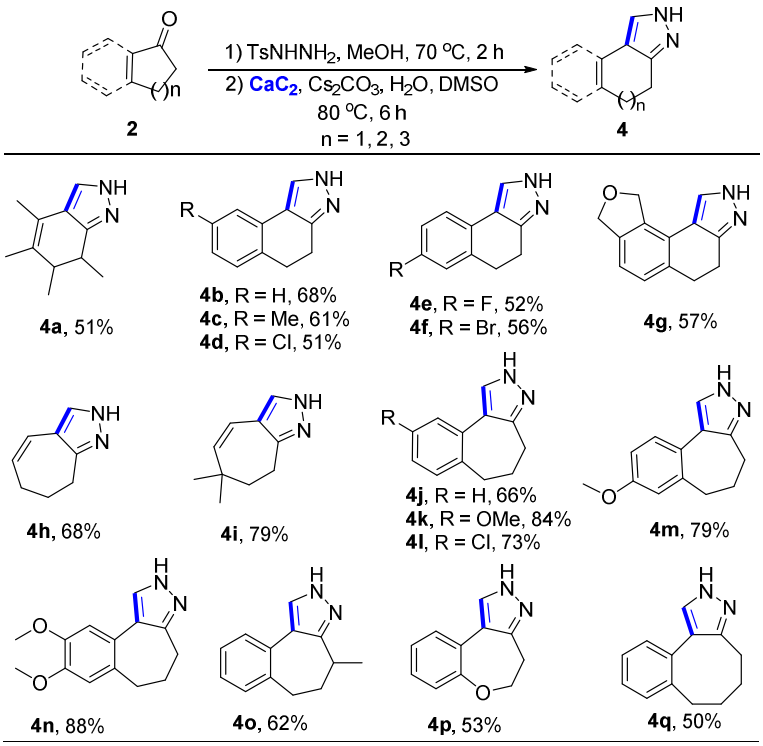


[a] Reaction conditions: 1) **1** (0.5 mmol), $TsNHNH_2$ (0.5 mmol), MeOH (2 mL) at 70 °C for 2 h; 2) CaC_2 (2 mmol), base (0.5 mmol), H_2O (2.5 mmol) and 2.0 mL DMSO at 110 °C for 6 h. [b] *N*-vinyl pyrazole product **3i'** was detected in 13% yield. [c] *N*-vinyl pyrazole product **3j'** was detected in

16% yield. [d] 90 °C.

The spirocyclic substrates that spontaneously rearranged to the fused analogues prompted us to examine the synthesis of fused pyrazoles **4** directly from their parent cyclic ketones. In addition to the angle strain, a rich electron density adjacent to the carbonyl moiety was also anticipated to be an important influence factor for the expansion of the carbocyclic ring in this reaction. Therefore, various examples were tested under similar reaction conditions with a lower temperature, as shown in Table 3. Indeed, [3+2] annulations between CaC_2 and a series of *N*-tosylhydrazones generated from 5-membered cyclic ketenes or benzo ketones proceeded smoothly to give the corresponding pyrazoles fused to a six-membered ring in moderate to good yields (**4a**-**4g**). Owing to the rich electron density of vinyl or aryl group, the [1,5]-sigmatropic rearrangement took place again in a regioselective manner, thus giving rise exclusively to the ring-expanded pyrazoles. Furthermore, a range of 6- and 7-membered saturated cyclic ketenes or benzo ketones were then investigated in the reaction as well, and the corresponding 7- or 8-membered products were generated in 50-88% yields (**4h**-**4q**). In general, ketones with electron-donating substituents on the phenyl ring furnished the desired products in higher yields than those with electron-neutral or electron-withdrawing groups.

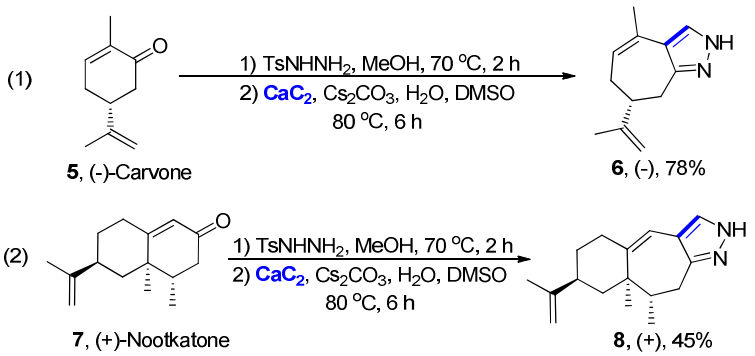
Table 3. Substrate scope of the cyclization/ring expansion [a]



[a] Reaction conditions: 1) **2** (0.5 mmol), $TsNHNH_2$ (0.5 mmol), MeOH (2 mL) at 70 °C for 2 h; 2) CaC_2 (2 mmol), base (0.5 mmol), H_2O (2.5 mmol) and 2.0 mL DMSO at 80 °C for 6 h.

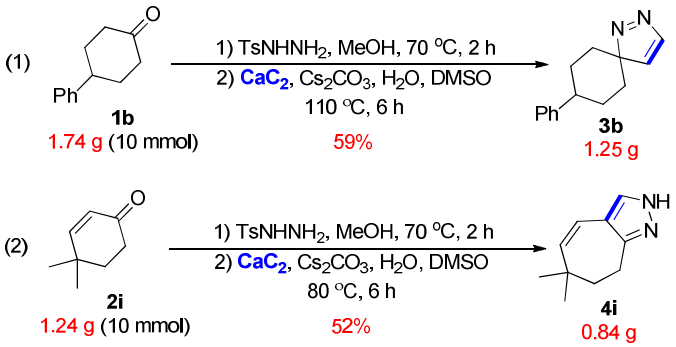
We then applied the present protocol to the functionalization of two biologically active molecules. Under the standard conditions, (-)-Carvone **5** and (+)-Nootkatone **7** could undergo further modification smoothly and the corresponding pyrazoles **6** and **8** were successfully obtained in moderate yields (Scheme 2). The practicality of this ring-expansion reaction using calcium carbide as a one-carbon unit should lead to potential utilities in the synthesis of valuable polycyclic pyrazole derivatives.

Scheme 2. Further modification on biologically active molecules



To validate the potential industrial applications of this strategy, two scale-up experiments were then carried out for 4-phenyl-cyclohexanone (**1b**) and 4,4-dimethylcyclohex-2-enone (**2i**) (Scheme 3). The two reactions afforded the corresponding spirocyclic pyrazole **3b** or fused pyrazole **4i** in gram scale, albeit in diminished yields as compared with the small-scale experiments (see Supporting Information for details).

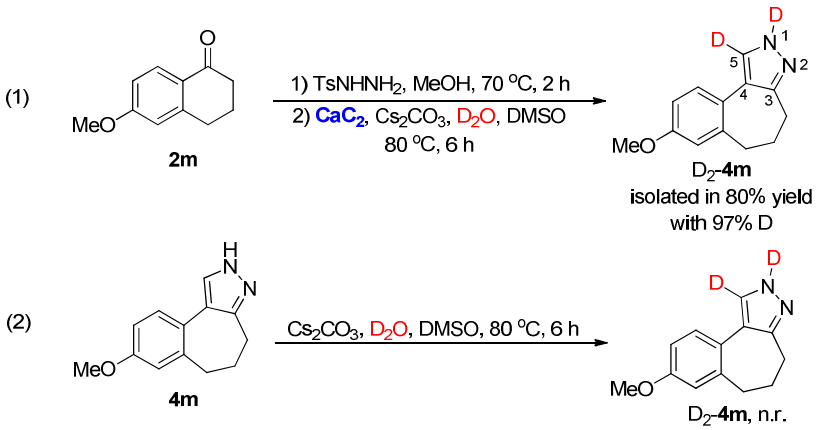
Scheme 3. Gram-scale experiments



To cast some light on the mechanism details for our reaction, deuterium-labeling experiments were conducted. Initially, the reaction of CaC_2 and *N*-tosylhydrazone generated *in situ* from **2m** was performed in dry DMSO at 80 °C for 6 h with the

addition of Cs_2CO_3 and D_2O. It was found that the reaction afforded the corresponding deuterated pyrazole [D_2]-**4m** in 80% yield with 97% D (Scheme 4, eq 1). In order to confirm whether the deuteration occurred before or after the cyclization, we tried to test the reaction of pyrazole **4m** under the standard conditions in the presence of Cs_2CO_3 and D_2O, and the deuterated product [D_2]-**4m** was not detected, which suggested that the deuteration occurred before the [3+2] cyclization (Scheme 4, eq 2). In view of the structure of [D_2]-**4m** and our previous works[7], we deduced that the deuterium atom on N1 was shifted from C4 of the pyrazole ring through multiple [1,5]-H shifts during the process of aromatic isomerization. Before that, a migration of phenyl group from C3 to C4 through [1,5]-sigmatropic rearrangement should occur. We also tried to cultivate single crystals of pyrazoles **4** while no direct experimental result was obtained. We supposed that due to the prototropic tautomerism of 1*H*-pyrazoles, the characters of **4** are either oils or amorphous powders. Since the migrational principles of [1,5]-sigmatropic rearrangement are clear, the structures of **4** are considered credible.

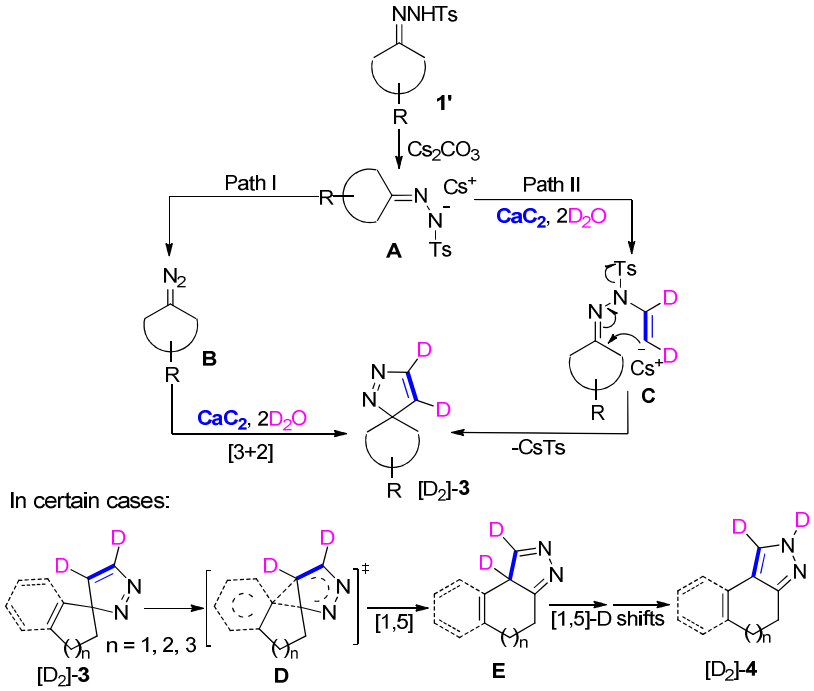
Scheme 4. Deuterium-labeling experiments



On the basis of the results of deuterium-labeling experiments and previous works[7, 8a], we tentatively proposed the reaction mechanism as outlined in Scheme 5. Initially, in the presence of Cs_2CO_3, the cesium salt **A** was afforded by the deprotonation of *N*-tosylhydrazone **1'**. In one possible way, reactive diazo compound **B** was rapidly formed under the action of the base, followed by a [3+2] cycloaddition with [D_2]-acetylene gas, affording deuterated spirocyclic pyrazole [D_2]-**3** (Path I). Another possibility is that nucleophilic addition of the counter *N*-anion of intermediate **A** to [D_2]-acetylene gas followed by the elimination of Ts anion and cesium ion led to the spirocyclic product [D_2]-**3** (Path II). The reactions of 6, 7 or 8-membered heterocyclic ketones resulted in spirocyclic products which would not spontaneously occur rearrangement. While for 4 or 5-membered cyclic ketones with strong angle strain, or substrates with rich electron density adjacent to the carbonyl moiety, the nonaromatic spirocyclic pyrazole [D_2]-**3** have a trend to isomerize to the aromatic fused analogues. Thus, a spontaneous [1,5]-sigmatropic rearrangement from [D_2]-**3** to **E** through the transition state **D** must be favored and the subsequent multiple

[1,5]-D shifts gave the final product [D_2]-**4**.

Scheme 5. Possible mechanism



In summary, we present a convenient one-pot/two-step procedure for transition metal-free coupling between calcium carbide and *N*-tosylhydrazones generated *in situ* from cyclic ketones, affording saturated spirocyclic pyrazoles via [3+2] cycloadditions. In certain cases, the spirocyclic pyrazoles could undergo a ring expansion to give the fused analogues, in which calcium carbide was used as the carbon source. In addition, deuterium-labeling experiments have been conducted to clarify the reaction pathway that multiple [1,5]-sigmatropic rearrangements were involved in the transformation. From a synthetic point of view, this ring-expanded reaction should lead to great utilities in formation of biologically active pyrazole

scaffolds.

EXPERIMENTAL SECTION

General Methods

^{1}H and ^{13}C NMR spectra were recorded using a Bruker DRX-400 spectrometer using $CDCl_3$ as solvent. The chemical shifts are referenced to signals at 7.26 and 77.0 ppm, respectively. Mass spectra were recorded on a Thermo Scientific ISQ gas chromatograph-mass spectrometer. The data of HRMS was carried out on a high-resolution mass spectrometer (LCMS-IT-TOF). IR spectra were obtained either as potassium bromide pellets or as liquid films between two potassium bromide pellets with a Bruker TENSOR 27 spectrometer. Melting points were determined with a Büchi Melting Point B-545 instrument.

General Procedure for the Preparation of 3 and 4

In a Schlenk tube, a mixture of cyclic ketone (0.5 mmol) and tosylhydrazide (0.5 mmol) was stirred at 70 ^{o}C for 2 h in methanol (3 mL), followed by removal of the solvent in vacuo. The remaining crude mixture was then treated with CaC_2 (2 mmol), Cs_2CO_3 (0.5 mmol), H_2O (2.5 mmol, added by using a microliter syringe) and DMSO (2 mL). The mixture was stirred at 110 ^{o}C or 80 ^{o}C for 6 h. After completion of the reaction (monitored by TLC), water (10 mL) was added to the reaction mixture, and the resulting mixture was extracted with ethyl acetate. The combined organic layers were then dried over $MgSO_4$, filtered, and then concentrated in vacuo. The residue was purified by flash chromatography on silica gel to give **3** or **4**.

Procedure for the Preparation of 3b or 4i on a gram scale

In a 200 mL round-bottom flask with a reflux condenser, a mixture of **1b** (1.74 g, 10 mmol)/**2i** (1.24 g, 10 mmol) and tosylhydrazide (1.86 g, 10 mmol) was first stirred at 70 ^{o}C for 2 h in methanol, followed by removal of the solvent. The remaining crude mixture was then treated with CaC_2 (2.56 g, 40 mmol), Cs_2CO_3 (3.26 g, 10 mmol) and H_2O (0.9 mL, 50 mmol) in DMSO (40 mL). The flask was then sealed with an uninflated balloon and the mixture was stirred at 110 ^{o}C/80 ^{o}C for 6 h. After completion of the reaction (monitored by TLC), water (3 × 100 mL) was added to the reaction mixture, and the resulting mixture was extracted with ethyl acetate for 3 times. The combined organic layers were then dried over $MgSO_4$, filtered, and then concentrated in vacuo. The residue was purified by flash chromatography on silica gel to give **3b** as a brown solid or **4i** as a yellow oil.

1,2-Diazaspiro[4.5]deca-1,3-diene (3a)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a black oil (57.9 mg, 85%); IR (KBr): 2930, 2858, 1670, 1444, 1048 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.56 (s, 1H), 7.13 (s, 1H), 2.08-2.01 (m, 2H), 1.92 (t, J = 11.2 Hz, 2H), 1.73-1.53 (m, 4H), 1.34-1.26 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.5, 142.6, 97.4, 30.5, 25.3, 24.5; MS (EI, 70 eV) m/z: 136.25, 108.22, 94.20, 84.04; HRMS ESI (m/z): calcd for $C_8H_{13}N_2$ $[M + H]^+$: 137.1073, found: 137.1074.

8-Phenyl-1,2-diazaspiro[4.5]deca-1,3-diene (3b)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a brown crystalline solid (92.3 mg, 87%), mp 110.5-111.9 ^{o}C; IR (KBr): 3081, 2929, 1700, 1438, 690 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.60 (s, 1H), 7.35 (t, J = 9.5 Hz, 4H), 7.22 (t, J = 6.9 Hz, 1H), 6.92 (s, 1H), 2.81 (t, J = 12.2 Hz, 1H), 2.54-2.42 (m, 2H), 2.06 (dd, J = 22.6, 12.3 Hz, 4H), 1.28 (d, J = 13.9 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 147.7, 146.5, 142.2, 128.3, 126.8, 126.1, 95.2, 43.5, 31.6, 31.4; MS (EI, 70 eV) *m*/*z*: 212.28, 134.25, 108.20, 94.21; HRMS ESI (m/z): calcd for $C_{14}H_{16}N_2Na$ $[M + Na]^+$: 235.1206, found: 235.1210.

9,12-Dioxaspiro-1,2-diazaspiro[4.5]deca-1,3-diene (3c)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown crystalline solid (70.9 mg, 73%), mp 127.8-128.9 ^{o}C; IR (KBr): 3740, 3087, 1739, 1259, 952 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.61 (s, 1H), 7.07 (s, 1H), 4.10-3.97 (m, 4H), 2.30 (t, J = 8.4 Hz, 2H), 1.88-1.70 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.5, 142.9, 108.0, 64.5, 64.5, 33.4, 28.6; MS (EI, 70 eV) *m*/*z*: 194.26, 149.22, 107.20, 87.17; HRMS ESI (m/z): calcd for $C_{10}H_{14}N_2NaO_2$ $[M + Na]^+$: 217.0947, found: 217.0950.

8-Oxa-1,2-diazaspiro[4.5]deca-1,3-diene (3d)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a brown oil (57.4 mg, 83%); IR (KBr): 3738, 2928, 1744, 1524, 1038, 883 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.72-7.59 (m, 1H), 7.14-7.00 (m, 1H), 4.34-4.23 (m, 2H), 3.94-3.85 (m, 2H), 1.79-1.65 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 144.6, 143.4, 93.8, 65.8, 30.0; MS (EI, 70 eV) *m*/*z*: 138.36, 109.22, 95.17, 79.17; HRMS ESI (m/z): calcd for $C_7H_{11}N_2O$ $[M + H]^+$: 139.0866, found: 139.0865.

8-Thia-1,2-diazaspiro[4.5]deca-1,3-diene (3e)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a brown amorphous solid (68.6 mg, 89%), mp 142.7-144.4 ^oC; IR (KBr): 3740, 3089, 2924, 1427, 1254, 913 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.65 (d, J = 3.2 Hz, 1H), 7.09 (d, J = 3.2 Hz, 1H), 3.33-3.23 (m, 2H), 2.79-2.71 (m, 2H), 2.01-1.94 (m, 2H), 1.82 (t, J = 11.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.1, 143.4, 95.4, 31.2, 26.5; MS (EI, 70 eV) *m*/*z*: 154.18, 111.15, 97.15, 79.19; HRMS ESI (m/z): calcd for $C_7H_{11}N_2S$ $[M + H]^+$: 155.0637, found: 155.0637.

8-Propyl-1,2,8-triazaspiro[4.5]deca-1,3-diene (3f)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (56.5 mg, 61%); IR (KBr): 2935, 1740, 1454, 1250, 780 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.62 (d, J = 3.3 Hz, 1H), 7.08 (d, J = 2.9 Hz, 1H), 3.08-2.99 (m, 2H), 2.66 (d, J = 4.8 Hz, 2H), 2.52-2.46 (m, 2H), 1.86-1.73 (m, 4H), 1.59 (dd, J = 15.2, 7.5 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.1, 143.0, 95.1, 60.7, 51.8, 30.1, 20.1, 12.0; MS (EI, 70 eV) *m*/*z*: 179.32, 150.25, 122.22, 98.23; HRMS ESI (m/z): calcd for $C_{10}H_{18}N_3$ $[M + H]^+$: 180.1495, found: 180.1494.

8-Phenethyl-1,2,8-triazaspiro[4.5]deca-1,3-diene (3g)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (102.6 mg, 85%); IR (KBr): 3080, 2935, 1500, 1128, 763 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.63 (s, 1H), 7.30 (t, J = 7.3 Hz, 2H), 7.25-7.19 (m, 3H), 7.09 (s, 1H), 3.11 (t, J = 10.7 Hz, 2H), 2.94-2.86 (m, 2H), 2.80-2.74 (m, 4H), 1.87-1.76 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.0, 143.0, 140.1, 128.6, 128.3, 126.0, 94.8, 60.4, 51.6, 33.6, 30.0; MS (EI, 70 eV) *m*/*z*: 241.32, 150.26, 121.21, 91.16; HRMS ESI (m/z): calcd for $C_{15}H_{20}N_3$ $[M + H]^+$: 242.1652, found: 242.1655.

Ethyl 1,2,8-Triazaspiro[4.5]deca-1,3-diene-8-carboxylate (3h)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a brown oil (79.5 mg, 76%); IR (KBr): 2936, 1692, 1435, 1246, 774 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.63 (s, 1H), 7.01 (s, 1H), 4.16 (q, J = 7.0 Hz, 2H), 3.95-3.79 (m, 4H), 1.73-1.65 (m, 2H), 1.57 (d, J = 13.5 Hz, 2H), 1.26 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 155.5, 144.5, 143.5, 94.5, 61.5, 42.3, 29.7, 14.6; MS (EI, 70 eV) *m/z*: 209.28, 180.24, 120.21, 108.20; HRMS ESI (m/z): calcd for $C_{10}H_{15}N_3NaO_2$ $[M + Na]^+$: 232.1056, found: 232.1055.

1,2-Diazaspiro[4.6]undeca-1,3-diene (3i)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a black oil (42.8 mg, 57%); IR (KBr): 2924, 2857, 1692, 1450, 1246 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.46 (s, 1H), 7.08 (s, 1H), 2.08-1.97 (m, 4H), 1.82-1.58 (m, 6H), 1.33 (dd, J = 14.5, 8.5 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 146.8, 142.0, 100.4, 32.1, 29.4, 25.6; MS (EI, 70 eV) *m/z*: 150.26, 121.20, 107.20, 94.21; HRMS ESI (m/z): calcd for $C_9H_{14}N_2Na$ $[M + Na]^+$: 173.1049, found: 173.1042.

1,2-Diazaspiro[4.7]dodeca-1,3-diene (3j)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was

isolated as a brown oil (56.7 mg, 69%); IR (KBr): 3095, 2924, 1598, 1454, 774 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.54 (d, J = 1.9 Hz, 1H), 7.10 (d, J = 1.7 Hz, 1H), 2.05 (dd, J = 13.6, 8.8 Hz, 2H), 1.96 (dd, J = 13.7, 11.6 Hz, 2H), 1.87-1.58 (m, 8H), 1.33 (dd, J = 14.8, 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 146.9, 142.6, 100.3, 28.3, 28.2, 25.0, 24.9; MS (EI, 70 eV) *m*/*z*: 164.28, 135.24, 121.21, 107.18; HRMS ESI (m/z): calcd for $C_{10}H_{16}N_2Na$ $[M + Na]^+$: 187.1206, found: 187.1205.

(1*r*,3*r*,5*r*,7*r*)-Spiro[adamantane-2,3'-pyrazole] (3k)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 20:1), the product was isolated as a yellow crystalline solid (75.3 mg, 80%), mp 104.0-105.2 ^oC; IR (KBr): 3093, 2901, 1738, 1446, 1241, 779 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.56 (s, 1H), 7.34 (s, 1H), 2.83 (d, J = 12.6 Hz, 2H), 2.10 (d, J = 45.4 Hz, 2H), 1.90 (dd, J = 36.2, 17.8 Hz, 8H), 1.33 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.6, 142.3, 102.0, 38.6, 37.7, 37.5, 35.7, 35.3, 35.2, 31.4, 27.3, 27.2; MS (EI, 70 eV) *m*/*z*: 188.28, 131.20, 117.23, 91.18; HRMS ESI (m/z): calcd for $C_{12}H_{16}N_2Na$ $[M + Na]^+$: 211.1206, found: 211.1210.

4,5,6,7-Tetrahydro-2*H*-indazole (3l)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a yellow oil (34.2 mg, 56%); IR (KBr): 3163, 2930, 1445, 1157, 960 cm^{-1};

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.61 (s, 1H), 7.29 (s, 1H), 2.66 (t, J = 6.0 Hz, 2H), 2.53 (t, J = 5.9 Hz, 2H), 1.84-1.70 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 143.2, 132.0, 115.0, 23.4, 23.1, 22.0, 20.4; MS (EI, 70 eV) *m*/*z*: 122.23, 119.20, 94.20, 67.18; HRMS ESI (m/z): calcd for $C_7H_{11}N_2$ $[M + H]^+$: 123.0917, found: 123.0914.

4,5,6,7-Tetramethyl-6,7-dihydro-2*H*-indazole (4a)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a yellow oil (45.0 mg, 51%); IR (KBr): 3217, 2963, 1728, 1376, 1058 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (s, 1H), 5.12 (dr, 1H), 2.81-2.68 (m, 1H), 2.12-1.81 (m, 1H), 1.91 (s, 3H), 1.81 (s, 3H), 1.10 (d, J = 7.1 Hz, 3H), 0.94 (d, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 150.5, 129.1, 123.8, 118.1, 117.6, 44.4, 34.2, 20.8, 18.6, 18.0, 14.7; MS (EI, 70 eV) *m*/*z*: 176.30, 161.27, 146.23, 131.20; HRMS ESI (m/z): calcd for $C_{11}H_{17}N_2$ $[M + H]^+$: 177.1386, found: 177.1379. Anal. Calcd for $C_{11}H_{16}N_2$: C, 74.96; H, 9.15; N, 15.89; Found: C, 75.10; H, 9.22; N, 15.68.

4,5-Dihydro-2*H*-benzo[*e*]indazole (4b)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a brown amorphous solid (57.8 mg, 68%), mp 127.1-128.0 ^{o}C; IR (KBr): 3172, 2931, 1592, 1176, 761 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.12 (dr, 1H), 7.78 (s, 1H), 7.39 (d, J = 7.4 Hz, 1H), 7.20 (t, J = 7.3 Hz, 2H), 7.10 (t, J = 7.3 Hz, 1H),

2.97 (dd, J = 19.7, 6.5 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 146.5, 134.1, 130.3, 128.4, 126.8, 126.6, 125.8, 122.8, 117.2, 29.5, 21.2; MS (EI, 70 eV) *m*/*z*: 170.10, 142.08, 115.06, 84.10; HRMS ESI (m/z): calcd for $C_{11}H_{11}N_2$ $[M + H]^+$: 171.0917, found: 171.0914.

8-Methyl-4,5-dihydro-2*H*-benzo[*e*]indazole (4c)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a brown amorphous solid (56.2 mg, 61%), mp 172.5-173.2 ^{o}C; IR (KBr): 3180, 2929, 1725, 1164, 810 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (s, 1H), 7.23 (s, 1H), 7.11 (d, J = 7.6 Hz, 1H), 6.93 (d, J = 7.6 Hz, 1H), 3.00-2.89 (m, 4H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 146.8, 136.3, 131.1, 130.0, 129.5, 128.2, 126.5, 123.5, 117.3, 29.1, 21.3, 21.1; MS (EI, 70 eV) *m*/*z*: 184.26, 169.24, 142.22, 115.20; HRMS ESI (m/z): calcd for $C_{12}H_{13}N_2$ $[M + H]^+$: 185.1073, found: 185.1075.

8-Chloro-4,5-dihydro-2*H*-benzo[*e*]indazole (4d)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a brown amorphous solid (52.1 mg, 51%), mp 144.1-145.6 ^{o}C; IR (KBr): 3164, 2930, 1595, 1170, 805 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (s, 1H), 7.37 (d, J = 2.0 Hz, 1H), 7.14 (d, J = 8.1 Hz, 1H), 7.10-6.90 (m, 2H), 3.06-2.84 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 147.1, 132.4, 132.4, 131.9, 129.6, 128.0, 125.6,

122.8, 116.6, 29.0, 21.1; MS (EI, 70 eV) *m*/*z*: 204.22, 169.25, 140.20, 115.21; HRMS ESI (m/z): calcd for $C_{11}H_{10}ClN_2$ $[M + H]^+$: 205.0527, found: 205.0525.

7-Fluoro-4,5-dihydro-2*H*-benzo[*e*]indazole (4e)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a brown amorphous solid (48.9 mg, 52%), mp 76.2-77.3 ^oC; IR (KBr): 3180, 2931, 1579, 1243, 812 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (s, 1H), 7.34 (dd, *J* = 8.3, 5.6 Hz, 1H), 6.96-6.89 (m, 2H), 4.58 (dr, 1H), 3.11-2.84 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 161.1 (*J* = 242.7 Hz), 146.3, 136.4 (*J* = 7.4 Hz), 126.4 (*J* = 2.8 Hz), 126.1, 124.0 (*J* = 8.1 Hz), 116.6, 115.4 (*J* = 21.5 Hz), 113.4 (*J* = 21.4 Hz), 29.7 (*J* = 1.2 Hz), 20.9; MS (EI, 70 eV) *m*/*z*: 188.24, 160.20, 133.20, 93.61; HRMS ESI (m/z): calcd for $C_{11}H_{10}FN_2$ $[M + H]^+$: 189.0823, found: 189.0822. Anal. Calcd for $C_{11}H_9FN_2$: C, 70.20; H, 4.82; N, 14.88; Found: C, 70.41; H, 4.92; N, 14.71.

7-Bromo-4,5-dihydro-2*H*-benzo[*e*]indazole (4f)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a white amorphous solid (69.5 mg, 56%), mp 103.4-105.1^oC; IR (KBr): 3181, 2933, 1726, 1066, 811 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 (s, 1H), 7.37-7.22 (m, 2H), 7.23-7.02 (m, 2H), 2.93-2.83 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* ppm 146.3, 136.1, 131.2, 129.7, 129.2, 126.7, 124.2, 118.9, 116.4, 29.3,

20.9; MS (EI, 70 eV) *m*/*z*: 248.17, 169.24, 140.19, 115.20; HRMS ESI (m/z): calcd for $C_{11}H_{10}BrN_2$ $[M + H]^+$: 249.0022, found: 249.0016. Anal. Calcd for $C_{11}H_9BrN_2$: C, 53.04; H, 3.64; N, 11.25; Found: C, 53.19; H, 3.70; N, 11.13.

4,5,8,10-Tetrahydro-2*H*-isobenzofuro[4,5-*e*]indazole (4g)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 3:1), the product was isolated as a brown amorphous solid (60.5 mg, 57%), mp 161.3-161.9 ^oC; IR (KBr): 3739, 2923, 1463, 1239, 807 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.66 (s, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 6.59 (d, *J* = 8.0 Hz, 1H), 5.89 (dr, 1H), 4.65 (t, *J* = 8.7 Hz, 2H), 3.28 (t, *J* = 8.6 Hz, 2H), 3.05-2.87 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 159.2, 147.6, 127.7, 127.7, 126.9, 126.2, 121.4, 116.3, 106.3, 30.0, 29.0, 21.8, 21.8; MS (EI, 70 eV) *m*/*z*: 212.28, 184.24, 156.23, 91.18; HRMS ESI (m/z): calcd for $C_{13}H_{13}N_2O$ $[M + H]^+$: 213.1022, found: 213.1024.

2,6,7,8-Tetrahydrocyclohepta[*c*]pyrazole (4h)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (45.6 mg, 68%); IR (KBr): 3217, 2930, 1713, 1437, 1144, 807 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.37 (s, 1H), 6.49 (dr, 1H), 6.22 (d, *J* = 11.5 Hz, 1H), 5.68-5.57 (m, 1H), 3.00-2.90 (m, 2H), 2.47-2.42 (m, 2H), 1.94 (dt, *J* = 11.4, 5.7 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 146.3, 129.9, 128.8, 127.2, 119.1, 31.2,

28.1, 22.8; MS (EI, 70 eV) *m*/*z*: 134.25, 119.20, 92.18, 79.18; HRMS ESI (m/z): calcd for $C_8H_{11}N_2$ $[M + H]^+$: 135.0917, found: 135.0910. Anal. Calcd for $C_8H_{10}N_2$: C, 71.61; H, 7.51; N, 20.88; Found: C, 71.87; H, 7.54; N, 20.59.

6,6-Dimethyl-2,6,7,8-tetrahydrocyclohepta[*c*]pyrazole (4i)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a yellow oil (64.1 mg, 79%); IR (KBr): 3649, 2934, 1727, 1457, 800 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 10.49 (dr, 1H), 7.38 (s, 1H), 6.08 (d, *J* = 11.7 Hz, 1H), 5.40 (d, *J* = 11.7 Hz, 1H), 2.97-2.87 (m, 2H), 1.79-1.69 (m, 2H), 1.09 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 145.6, 137.2, 134.7, 116.9, 115.8, 36.8, 35.8, 30.1, 22.7; MS (EI, 70 eV) *m*/*z*: 162.26, 147.24, 19.20, 92.20; HRMS ESI (m/z): calcd for $C_{10}H_{15}N_2$ $[M + H]^+$: 163.1230, found: 163.1230.

2,4,5,6-Tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4j)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a black oil (60.7 mg, 66%); IR (KBr): 3066, 2935, 1601, 1440, 759 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 3.3 Hz, 1H), 7.27-7.16 (m, 3H), 6.96 (t, *J* = 7.4 Hz, 1H), 6.20 (d, *J* = 7.8 Hz, 1H), 3.11-2.96 (m, 2H), 2.45 (dt, *J* = 7.4, 6.5 Hz, 1H), 2.00 (dd, *J* = 14.7, 9.0 Hz, 2H), 1.79 (t, *J* = 10.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 147.6, 143.2, 137.6, 130.3, 128.2, 126.6, 126.0, 125.4, 98.6, 29.5, 29.5,

21.9; MS (EI, 70 eV) *m*/*z*: 184.09, 169.06, 128.06, 115.07; HRMS ESI (m/z): calcd for $C_{12}H_{13}N_2$ $[M + H]^+$: 185.1073, found: 185.1070.

9-Methoxy-2,4,5,6-tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4k)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a black oil (90.0 mg, 84%); IR (KBr): 3096, 2936, 1605, 1497, 1244, 1036 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ppm 7.65 (d, *J* = 3.3 Hz, 1H), 7.16 (dd, *J* = 8.3, 5.9 Hz, 2H), 6.78 (dd, *J* = 8.5, 2.7 Hz, 1H), 5.71 (d, *J* = 2.6 Hz, 1H), 3.61 (s, 3H), 2.96 (tdd, *J* = 11.6, 9.2, 4.5 Hz, 2H), 2.46-2.37 (m, 1H), 2.05-1.94 (m, 2H), 1.77 (dd, *J* = 15.9, 5.9 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* ppm 157.6, 147.6, 143.1, 131.1, 129.6, 127.4, 114.8, 109.7, 98.7, 55.1, 29.4, 28.7, 22.1; MS (EI, 70 eV) *m*/*z*: 214.30, 199.26, 183.25, 156.22; HRMS ESI (m/z): calcd for $C_{13}H_{15}N_2O$ $[M + H]^+$: 215.1179, found: 215.1178.

9-Chloro-2,4,5,6-tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4l)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a black oil (79.7 mg, 73%); IR (KBr): 3094, 2939, 1590, 1479, 807 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 3.3 Hz, 1H), 7.15 (dd, *J* = 6.7, 3.2 Hz, 3H), 6.18 (s, 1H), 3.09-2.91 (m, 2H), 2.44 (dt, *J* = 17.6, 7.6 Hz, 1H), 2.03-1.96 (m, 2H), 1.80 (dd, *J* = 18.3, 8.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* ppm 147.0, 143.7,

136.0, 131.5, 131.5, 128.4, 128.4, 125.3, 98.1, 29.2, 29.0, 21.7; MS (EI, 70 eV) *m*/*z*: 218.24, 183.27, 156.25, 127.20; HRMS ESI (m/z): calcd for $C_{12}H_{12}ClN_2$ $[M + H]^+$: 219.0684, found: 219.0682.

8-Methoxy-2,4,5,6-tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4m)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was isolated as a black amorphous solid (84.6 mg, 79%), mp 150.3-151.2 ^oC; IR (KBr): 2934, 1602, 1254, 1038, 822 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 3.3 Hz, 1H), 7.13 (d, *J* = 3.3 Hz, 1H), 6.75 (d, *J* = 2.5 Hz, 1H), 6.54 (dd, *J* = 8.6, 2.6 Hz, 1H), 6.14 (d, *J* = 8.6 Hz, 1H), 3.75 (s, 3H), 3.09-2.94 (m, 2H), 2.50-2.37 (m, 1H), 2.04-1.93 (m, 2H), 1.85-1.76 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* ppm 159.3, 147.6, 142.9, 139.1, 123.6, 118.5, 114.6, 112.5, 98.2, 55.1, 29.9, 29.5, 21.9; MS (EI, 70 eV) *m*/*z*: 214.28, 199.25, 171.23, 130.22; HRMS ESI (m/z): calcd for $C_{13}H_{15}N_2O$ $[M + H]^+$: 215.1179, found: 215.1175.

8,9-Dimethoxy-2,4,5,6-tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4n)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 3:1), the product was isolated as a brown oil (107.5 mg, 88%); IR (KBr): 3337, 2934, 1737, 1513, 1253, 1034 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 3.3 Hz, 1H), 7.15 (d, *J* = 3.3 Hz, 1H), 6.69 (s, 1H), 5.62 (s, 1H), 3.84 (s, 3H), 3.62 (s, 3H), 3.04-2.88 (m, 2H),

2.45-2.36 (m, 1H), 2.04-1.93 (m, 2H), 1.74 (dd, J = 13.1, 6.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 149.0, 147.8, 147.3, 142.9, 130.2, 118.0, 112.4, 107.6, 98.4, 55.7, 55.7, 29.4, 29.2, 22.1; MS (EI, 70 eV) *m*/*z*: 244.30, 229.28, 201.27, 160.23; HRMS ESI (m/z): calcd for $C_{14}H_{17}N_2O_2$ $[M + H]^+$: 245.1285, found: 245.1290.

4-Methyl-2,4,5,6-tetrahydrobenzo[3,4]cyclohepta[1,2-*c*]pyrazole (4o)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a yellow oil (61.5 mg, 62%); IR (KBr): 3190, 2935, 1730, 1453, 949, 754 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, J = 7.1 Hz, 1H), 7.45 (s, 1H), 7.21-7.12 (m, 3H), 6.28 (dr, 1H), 3.09-2.86 (m, 1H), 2.81-2.62 (m, 2H), 2.19-2.01 (m, 1H), 1.70-1.56 (m, 1H), 1.22 (d, J = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 141.6, 136.0, 130.2, 129.5, 127.7, 127.0, 126.4, 125.9, 123.5, 36.3, 33.0, 30.3, 22.9; MS (EI, 70 eV) *m*/*z*: 198.28, 183.27, 168.24, 115.21; HRMS ESI (m/z): calcd for $C_{13}H_{15}N_2$ $[M + H]^+$: 199.1230, found: 199.1233.

4,5-Dihydro-2*H*-benzo[6,7]oxepino[4,5-*c*]pyrazole (4p)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a black oil (49.4 mg, 53%); IR (KBr): 3093, 2962, 1486, 1228, 761 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, J = 3.3 Hz, 1H), 7.20 (t, J = 7.7 Hz, 1H), 7.12 (d, J = 3.3 Hz, 1H), 6.98 (d, J = 8.3 Hz, 1H), 6.72 (t, J = 7.5 Hz, 1H), 6.25 (d, J = 7.8

Hz, 1H), 4.82 (td, *J* = 11.0, 2.4 Hz, 1H), 4.43 (ddd, *J* = 11.2, 4.9, 3.6 Hz, 1H), 2.23 (ddd, *J* = 13.8, 10.2, 3.4 Hz, 1H), 1.89 (ddd, *J* = 14.0, 5.1, 2.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 155.3, 145.4, 144.4, 130.1, 126.1, 120.6, 118.2, 112.8, 94.2, 61.5, 27.7; MS (EI, 70 eV) *m*/*z*: 186.26, 171.23, 128.21, 115.20; HRMS ESI (m/z): calcd for $C_{11}H_{11}N_2O$ $[M + H]^+$: 187.0866, found: 187.0866.

4,5,6,7-Tetrahydro-2*H*-benzo[3,4]cycloocta[1,2-*c*]pyrazole (4q)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (49.5 mg, 50%); IR (KBr): 3320, 2922, 2861, 1732, 754 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 3.3 Hz, 1H), 7.51 (d, *J* = 3.4 Hz, 1H), 7.21-7.13 (m, 2H), 7.01 (ddd, *J* = 19.0, 10.4, 5.1 Hz, 2H), 3.19 (ddd, *J* = 24.5, 14.5, 9.1 Hz, 2H), 2.41-2.18 (m, 2H), 2.01-1.42 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 144.0, 143.1, 142.1, 136.2, 130.9, 128.0, 126.4, 126.1, 102.5, 36.6, 34.4, 31.0, 27.8; MS (EI, 70 eV) *m*/*z*: 198.13, 183.12, 169.10, 142.10; HRMS ESI (m/z): calcd for $C_{13}H_{15}N_2$ $[M + H]^+$: 199.1230, found: 199.1228.

(*R*)-8-Methyl-5-(prop-1-en-2-yl)-2,4,5,6-tetrahydrocyclohepta[*c*]pyrazole (6)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (73.4 mg, 78%); IR (KBr): 2908, 1730, 1657, 1047 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.81 (dr, 1H), 7.45 (s, 1H), 5.46 (t, *J* = 5.3, 5.3 Hz, 1H),

4.73 (s, 2H), 3.11-2.88 (m, 2H), 2.52 (ddd, *J* = 10.0, 7.8, 2.6 Hz, 1H), 2.48-2.38 (m, 2H), 2.01 (d, *J* = 1.2 Hz, 3H), 1.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 149.6, 144.3, 132.5, 126.2, 122.9, 119.4, 109.3, 41.2, 36.1, 33.4, 23.1, 20.5; MS (EI, 70 eV) *m*/*z*: 188.30, 173.28, 147.24, 131.21; HRMS ESI (m/z): calcd for $C_{12}H_{17}N_2$ $[M + H]^+$: 189.1386, found: 189.1383. $[\alpha]_D^{20}$ = 37.7 (*c* 0.945, CH_2Cl_2).

(5*S*,5a*R*,7*S*)-5,5a-Dimethyl-7-(prop-1-en-2-yl)-2,4,5,5a,6,7,8,9-octahydrobenzo[5,6]cyclohepta[1,2-*c*]pyrazole (8)

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 10:1), the product was isolated as a brown oil (57.6 mg, 45%); IR (KBr): 3164, 2933, 1733, 1447, 884 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.81 (dr, 1H), 7.32 (s, 1H), 6.07 (s, 1H), 4.71 (s, 2H), 2.92-2.72 (m, 2H), 2.60-2.19 (m, 4H), 1.93-1.72 (m, 5H), 1.32-1.24 (m, 2H), 1.14-0.98 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 150.2, 146.8, 143.6, 132.5, 116.9, 112.8, 108.7, 45.7, 43.3, 41.0, 40.9, 37.0, 33.6, 30.8, 20.8, 19.5, 17.6; MS (EI, 70 eV) *m*/*z*: 256.18, 213.15, 187.12, 145.10; HRMS ESI (m/z): calcd for $C_{17}H_{25}N_2$ $[M + H]^+$: 257.2012, found: 257.2011. Anal. Calcd for $C_{17}H_{24}N_2$: C, 79.64; H, 9.44; N, 10.92; Found: C, 79.98; H, 9.34; N, 10.68. $[\alpha]_D^{20}$ = 85.3 (*c* 0.842, CH_2Cl_2).

D_2-4m

The title compound was prepared via the general procedure. After purification by silica gel column chromatography (petroleum ether/EtOAc = 5:1), the product was

isolated as a brown oil (86.5 mg, 80%); IR (KBr): 2932, 1600, 1494, 1248, 1032 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.62 (s, 0.03H), 7.13 (s, 0.03H), 6.75 (d, *J* = 2.7 Hz, 1H), 6.54 (dd, *J* = 8.6, 2.8 Hz, 1H), 6.14 (d, *J* = 8.6 Hz, 1H), 3.75 (s, 3H), 3.11-2.89 (m, 2H), 2.54-2.36 (m, 1H), 2.10-1.88 (m, 2H), 1.86-1.70 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* ppm 159.3, 147.2 (*J* = 27.1 Hz), 142.6 (*J* = 28.5 Hz), 139.1, 126.6, 118.5, 114.6, 112.5, 98.1, 55.1, 29.9, 29.5, 21.9; MS (EI, 70 eV) *m/z*: 216.31, 215.29, 200.24, 116.19; HRMS ESI (m/z): calcd for $C_{13}H_{12}D_2N_2O$ $[M + H]^+$: 216.1226, found: 216.1230.

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Supporting Information

X-ray Crystal Structure of Compound **3b**, crystal Structure Determination, copies of ^1H and ^{13}C NMR spectra for all new products. This material is available free of charge via the Internet at http://pubs.acs.org.

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