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[3 + 2]-Cycloaddition of *in Situ* Generated Nitrile Imines and Acetylene for Assembling of 1,3-Disubstituted Pyrazoles with Quantitative Deuterium Labeling

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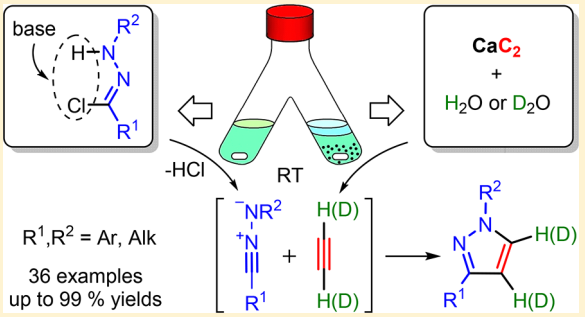
Supporting Information

ABSTRACT: A novel synthetic methodology for the preparation of 1,3-disubstituted pyrazoles from *in situ* generated nitrile imines and acetylene is reported. The reactions are performed in a simple two-chamber reactor. One part of the reactor is loaded with hydrazonoyl chloride precursors of active nitrile imine species and a base. The other part is used to generate acetylene from CaC_2 and water. Partitioning of the reactants improves the yields of desired pyrazoles up to 99% and simplifies their isolation to a simple procedure of solvent evaporation. The approach requires no complex equipment and utilizes inexpensive, safe, and easy to handle calcium carbide as a starting material. A model deuterium incorporation is carried out according to the developed methodology, producing a series of novel 4,5-dideuteropyrazoles with excellent deuterium enrichment. Theoretical calculations on reaction mechanism and characterization of possible intermediate structures were performed.



INTRODUCTION

Pyrazoles are important *N*-heterocyclic compounds that find extensive use in the pharmaceutical industry.[1] Several pyrazole derivatives have been found to possess analgesic,[2] antimicrobial,[3] anti-inflammatory,[4] antidiabetic,[5] antidepressant, anticonvulsant,[6] anticancer, and antituberculosis activity.[7] Celecoxib, sulfaphenazole, lonazolac, mepiprazole, and rimonabant are pyrazole-based commercially available drugs. Substituted pyrazole derivatives have also been employed as ligands for the transition-metal-catalyzed cross-coupling reactions.[8] Due to the multiple important applications of pyrazoles, advanced methodologies for their synthesis are currently in demand.

The 1,3-dipolar cycloaddition is a conventional synthetic route to five-membered heterocycles, widely used because of its high efficiency and versatility.[9] In particular, 1,3-dipolar cycloaddition reaction between the triple carbon−carbon bond and nitrile imines, generated *in situ* from hydrazonoyl halides and a base, leads to pyrazole products.[10] Various acetylene derivatives are commonly applied to set up these reactions, but these do not include the acetylene itself. To put it more generally, synthetic applications of the simplest alkyne, acetylene, are poorly developed as compared with the chemistry of substituted alkynes. High risks of explosion, handling difficulties, flammability, and specific high-pressure equipment requirements[11] complicate experiments that involve acetylene gas supplied in high-pressure cylinders.[12,13] These obstacles may introduce several difficulties in the laboratory applications of acetylene (Scheme 1A). Recently, a methodology based on calcium carbide as an acetylene source was proposed for synthetic applications.[13] Generated *in situ* from CaC_2 and water, acetylene can be successfully utilized as a starting material in various nucleophilic addition and cross-coupling reactions giving rise to vinyl ethers,[14] vinyl sulfides,[15] vinyl indoles,[16] enaminones,[17] acetylenic alcohols,[18] and aryl- and diarylacetylenes.[19] Besides, 1,3-dipolar cycloaddition of the calcium carbide-derived acetylene to azides,[20] diazo compounds,[21] and nitrile oxides[22] is possible. Calcium carbide has a number of advantages over the gaseous acetylene, and it is more safe and convenient to handle. However, introducing calcium carbide and water straight into the reaction mixture is incompatible with functioning of base- or water-sensitive systems (Scheme 1A).

This study reports 1,3-dipolar cycloaddition of nitrile imines to the unsubstituted acetylene, where both components of the studied [3 + 2]-cycloaddition reaction (nitrile imines and acetylene) are generated *in situ*. A two-chamber reactor is employed in order to separate the water-sensitive nitrile imines from the acetylene-generating mixture (Scheme 1B). Using the developed approach, 1,3-disubstituted pyrazoles are obtained, and 4,5-dideuteropyrazoles are synthesized for the first time. Overall, cycloaddition of nitrile imines to the unsubstituted

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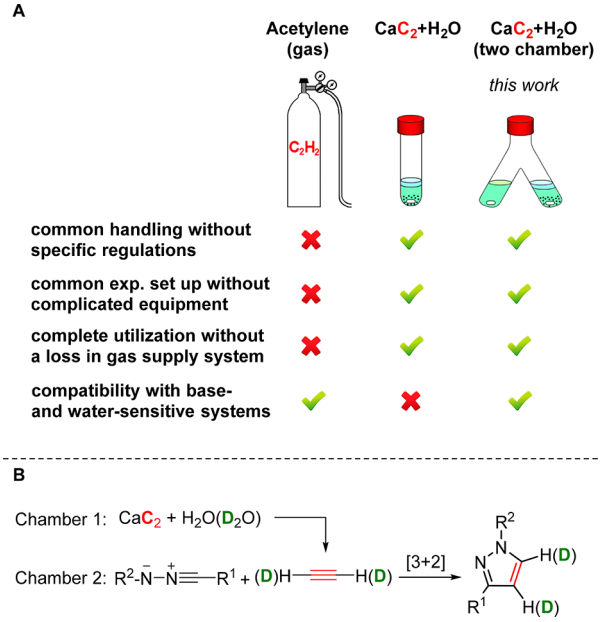
Scheme 1. Comparison of Different Acetylene Sources and Protocols (A) and the Developed Synthetic Procedure (B)

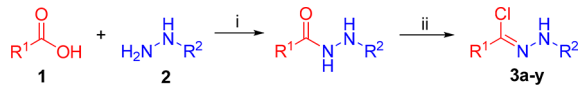


acetylene, especially allowing quantitative deuteration of the products, is a novel point of this study. Certain problems that complicate this type of synthesis are solved by utilization of the two-chamber reactor, which was not employed in reactions with calcium carbide before.

RESULTS AND DISCUSSION

Initial materials, hydrazonoyl chlorides **3a–y**, were obtained from commercially available carboxylic acids and hydrazines according to the standard procedures described elsewhere (Scheme 2).[23] 4-*tert*-Butyl-*N*′-phenylbenzohydrazonoyl chlor-

Scheme 2. Synthesis of Hydrazonoyl Chlorides 3a–y

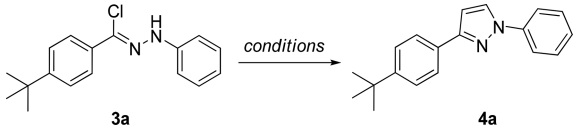


i) **1**, $SOCl_2$, toluene, reflux, then **2**, Py, 0 °C to RT; ii) CH_3CN, CCl_4, PPh_3

ide (**3a**) was chosen as a model substrate since it could be readily obtained from 4-*tert*-butylbenzoyl chloride and phenylhydrazine. Moreover, a characteristic signal of the *tert*-butyl group facilitated NMR monitoring of the reactions.

Several types of settings and various conditions were examined for the reaction of the hydrazonoyl chlorides with acetylene generated from CaC_2. At first, we attempted to perform pyrazole synthesis by mixing all the components in the same vessel. We assumed that calcium carbide reacting with the water would simultaneously provide the source of both acetylene and $Ca(OH)_2$ which could act as a base for the dipole generation. Various reaction conditions were examined to obtain the corresponding product, 3-(4-*tert*-butylphenyl)-1-phenyl-1*H*-pyrazole (**4a**), in good yield. We screened different solvents, substrate concentrations, and amounts of calcium carbide. In highly polar solvents, like MeOH and DMF, the pyrazole yield was low (entries 1 and 2; Table 1), and a better yield was obtained in ether (entry 3, Table 1). Good yields of the desired product were obtained using toluene (entry 4,

Table 1. Optimization of Reaction Conditions for Pyrazole Synthesis[a]



entry	solvent	CaC_2, mmol	H_2O, mmol	amount of **3a**,[b] mg/mL of solvent	yield (conversion), %[c]
1	MeOH	0.875	1.75	100	14 (100)
2	DMF	0.875	1.75	100	25 (100)
3	Et_2O	0.875	1.75	100	56 (100)
4	toluene	0.875	1.75	100	74 (100)
5	CH_2Cl_2	0.875	1.75	100	69 (100)
6	CCl_4	0.875	1.75	100	76 (100)
7	$CHCl_3$	0.875	1.75	100	79 (100)
8[d]	$CHCl_3$	0.875	1.75	100	79 (100)
9	$CHCl_3$	0.525	1.05	100	56 (68)
10	$CHCl_3$	0.7	1.4	100	74 (88)
11	$CHCl_3$	1.05	2.1	100	70 (100)
12	$CHCl_3$	0.875	1.75	35	62 (100)
13	$CHCl_3$	0.875	1.75	70	74 (100)
14	$CHCl_3$	0.875	1.75	150	78 (100)
15	$CHCl_3$	0.875	1.75	200	71 (100)
16[e,f]	$CHCl_3$	1.5	5.5	50	99 (100)
17[e,g]	$CHCl_3$	1.5	5.5	50	93 (100)
18[e,g,h]	$CHCl_3$	1.5	5.5	50	70 (100)

[a]Reaction conditions: **3a** (0.35 mmol, except entries 12–18, solvent (1 mL), CaC_2, water, 20 °C, 48 h). [b]0.12, 0.25, 0.53, 0.70, and 0.175 mmol quantities of **3a** were used for entries 12, 13, 14, 15, and 16–18, respectively. [c]NMR conversions and yields, except entry 16 where yield of pure product is shown. [d]0.7 mmol of Et_3N was added. [e]Reactions were conducted in the two-chamber reactors. [f]0.35 mmol of Et_3N was used as a base. [g]0.438 mmol of $Ca(OH)_2$ was used as a base. [h]0.875 mmol of H_2O was added to the reactant part of the two-chamber reactor.

Table 1) and chlorinated solvents (entries 5–7, Table 1). The best result was achieved in $CHCl_3$ as a solvent at the **3a** concentration of 100 mg/mL with 2.5 equiv of CaC_2 (entry 7, Table 1). Using Et_3N as an additional base did not improve the pyrazole yield under the studied conditions (entry 8, Table 1). Variations of the amount of CaC_2 (entries 9–11, Table 1) and concentration of **3a** (entries 12–15, Table 1) did not improve the product yield.

We supposed that $Ca(OH)_2$ formed *in situ* upon reaction of CaC_2 with water was a suboptimal base for this reaction, and its excess, as well as the presence of water in the reaction mixture, promoted collateral processes and decreased the yields of the desired pyrazole. To check this hypothesis, we separated CaC_2 and water from the substrate and used Et_3N as a milder base. The reaction was carried out in a two-chamber reactor. One part of the reactor was loaded with a solution of hydrazonoyl chloride **3a** and Et_3N in chloroform, while the other part was loaded with CaC_2, a layer of chloroform, and water. The chloroform layer prevented the reaction of calcium carbide with water from proceeding too fast and ensured slow release of acetylene under stirring. Acetylene evolving from the calcium carbide chamber readily dissolved in the reaction mixture in the other chamber, provided that the reactor was hermetically sealed. The NMR shift of acetylene (δ = 1.91 ppm) was detected in the ^{1}H NMR spectra of the reaction mixture after 1 h. In this way, gaseous acetylene was introduced into the

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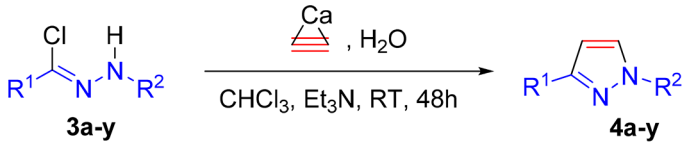
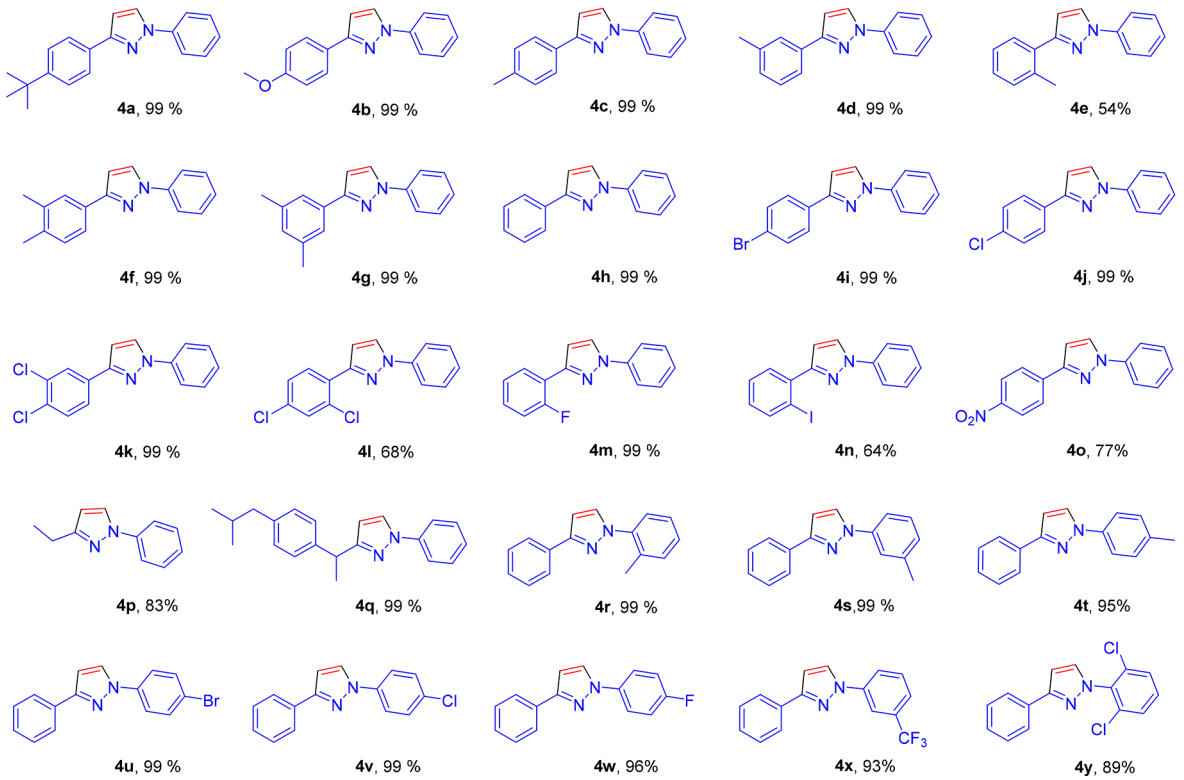
Table 2. Preparation of 1,3-Disubstituted Pyrazoles in the Two-Chamber Reactors[a]





[a]Reaction conditions: **3** (0.2 mmol), Et_3N (0.4 mmol), CaC_2 (100 mg), water (0.1 mL), $CHCl_3$ (1 mL in each vessel), 20 °C, 48 h.

reaction mixture without using separate equipment. At the same time, a contact of the reactants with the CaC_2/water system was avoided due to usage of the two-chamber reactor. Triethylamine turned out to be a good base for the dipole generation. After its addition to a solution of **3a** in chloroform, the resulting mixture was analyzed by electrospray ionization mass spectrometry (ESI-MS), and the corresponding nitrile imine was detected (m/z = 251.1547 $[M + H]^+$).

The reaction in the two-chamber reactor was studied, and pyrazole **4a** was obtained in high yield after 48 h (Table 1, entry 16). The product did not require special purification: washing with water and evaporation of the solvent resulted in a pure compound. Two control experiments were carried out using $Ca(OH)_2$ and $Ca(OH)_2/H_2O$ systems as a base in the two-chamber reactor. When $Ca(OH)_2$ was added to the reactant chamber, a high yield of **4a** was observed (Table 1, entry 17). However, the product yield significantly decreased in the case of addition of the $Ca(OH)_2/H_2O$ system (Table 1, entry 18). Therefore, the absence of water is an important factor to achieve better product yields (the experiment confirmed that the direct addition of calcium carbide and water to the reactant solution should be avoided). Spatial partitioning of nitrile imine and generation of acetylene by means of the two-chamber reactor solved this problem and prevented the contact of the active dipole with water.

Additionally, reaction of **3a** with gaseous acetylene from a standard external gas supply system was carried out. Similar yields can be achieved, but the acetylene consumption was several times higher compared with the reaction in the two-chamber reactor because of gas losses in the supply system. Taking into account a low price of calcium carbide and the technical simplicity of the proposed method, the suggested usage of a two-chamber reactor would be a procedure of choice for carrying out this reaction.

With this simple and efficient procedure in hand, a considerable scope of various hydrazonoyl chloride substrates was examined. In particular, a number of *N*′-arylbenzohydrazonoyl chlorides with various substituents at aryl fragments were tested, and most of them afforded good or quantitative yields of the desired pyrazoles (Table 2). The method worked well for alkyl-, halogeno-, methoxy-, and nitro-derivatives. Quantitative yields were obtained for 3-(4-(*tert*-butyl)phenyl)- and 3-(4-methoxyphenyl)-1-phenylpyrazoles **4a**, **4b**, methyl- and dimethyl-derivatives **4c**, **4d**, **4f**, **4g**, **4r**, **4s**, and diphenylpyrazole **4h**. Bromo-, chloro-, fluoro-, and dichloro-derivatives **4i**−**k**, **4m**, **4u**−**w**, and **4y** were prepared in good or quantitative yields. 3-(4-Nitrophenyl)-1-phenyl-, 3-phenyl-1-(4-tolyl)-, and 1-(3-(trifluoromethyl)phenyl)-3-phenylpyrazoles were also obtained in high yields (Table 2). Moderate yields were obtained for 2-methyl-, 2,4-dichloro-, and 2-iodo-*N*′-phenylbenzohydrazonoyl chlorides **3e**, **3l**, and **3n** only. *N*′-Phenylpropionohydrazonoyl chloride (**3p**) and hydrazonoyl chloride **3q** derived from ibuprofen also showed excellent results and were converted to the corresponding pyrazoles **4p**

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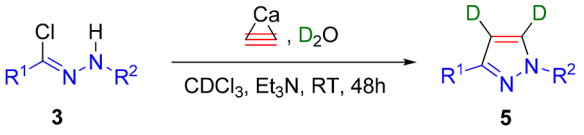
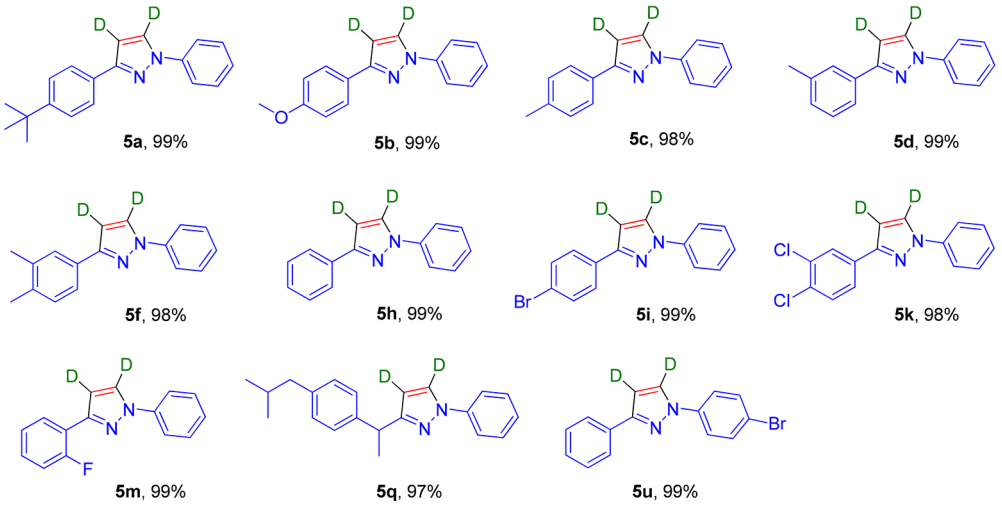
Table 3. Preparation of 4,5-Dideuteropyrazoles[a]





[a]Reaction conditions: **3** (0.2 mmol), Et_3N (0.4 mmol), CaC_2 (100 mg), D_2O (0.1 mL), $CDCl_3$ (1 mL in each vessel), 20 °C, 48 h.

Scheme 3. Pyrazole Synthesis by 1,3-Dipolar Cycloaddition Reaction

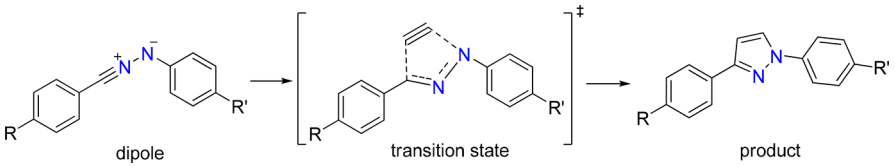


Table 4. Activation Energies ($\Delta E^{\ddagger}$, $\Delta H^{\ddagger}$, $\Delta G^{\ddagger}$, kcal/mol) and Reaction Energies (ΔE, ΔH, ΔG, kcal/mol) for 1,3-Dipolar Cycloaddition Reaction (see Scheme 3) in Chloroform Media

	$\Delta E^{\ddagger}$	$\Delta H^{\ddagger}$	$\Delta G^{\ddagger}$	ΔE	ΔH	ΔG
I (R = H, R′ = H)	5.5	5.7	16.8	−113.1	−108.4	−94.3
II (R = Me, R′ = H)	5.3	5.4	16.2	−112.7	−107.9	−94.3
III (R = *t*-Bu, R′ = H)	5.3	5.4	16.3	−112.7	−108.1	−94.4
IV (R = OMe, R′ = H)	4.9	5.0	16.4	−112.3	−107.7	−93.7
V (R = Cl, R′ = H)	5.3	5.5	16.2	−114.0	−109.3	−95.4
VI (R = NO_2, R′ = H)	7.0	7.1	17.6	−114.8	−110.0	−96.3
VII (R = H, R′ = Me)	5.3	4.8	16.6	−113.6	−109.0	−95.6
VIII (R = H, R′ = Br)	5.6	5.8	16.2	−112.4	−107.8	−94.3
IX (R = H, R′ = Cl)	5.6	5.7	16.4	−112.5	−107.9	−94.5
X (R = H, R′ = F)	5.3	5.4	16.1	−113.2	−108.5	−94.7

and **4q** in a good and quantitative yield, respectively. Therefore, the scope of application of our method can be extended to other substrates derived from aliphatic carboxylic acids, including pharmacologically active compounds. In total, 25 disubstituted pyrazoles have been successfully prepared from the corresponding hydrazonoyl chloride precursors, and 16 of them have been isolated in excellent yields and purity without any additional purification.

In order to further evaluate a potential practical application of the developed procedure the reaction was carried out in a larger scale using 800 mg of hydrazonoyl chloride **3a** and 1.6 g of CaC_2 to produce pure **4a** in 95% yield (731 mg).

Deuterated acetylene C_2D_2, easily generated in the reaction of CaC_2 with D_2O, was subsequently engaged in the studied reaction with active dipoles to give the corresponding dideuterated cycloadducts. This approach allowed us to obtain novel 4,5-dideuteropyrazoles. Chloroform and water within the reactor were replaced with $CDCl_3$ and deuterium oxide, respectively, in order to prevent D−H exchange between D_2O or C_2D_2 and the solvent. Several substrates were studied using the developed procedure. In all cases, the expected 4,5-dideuteropyrazoles were isolated in excellent yields with high deuterium enrichment (Table 3). Content of the 4,5-dideuterated pyrazoles in obtained isotopic mixtures exceeded 95% for all products. Synthesized 4,5-dideuteropyrazoles **5** were stable and easy to purify without a noticeable change in the isotope purity.

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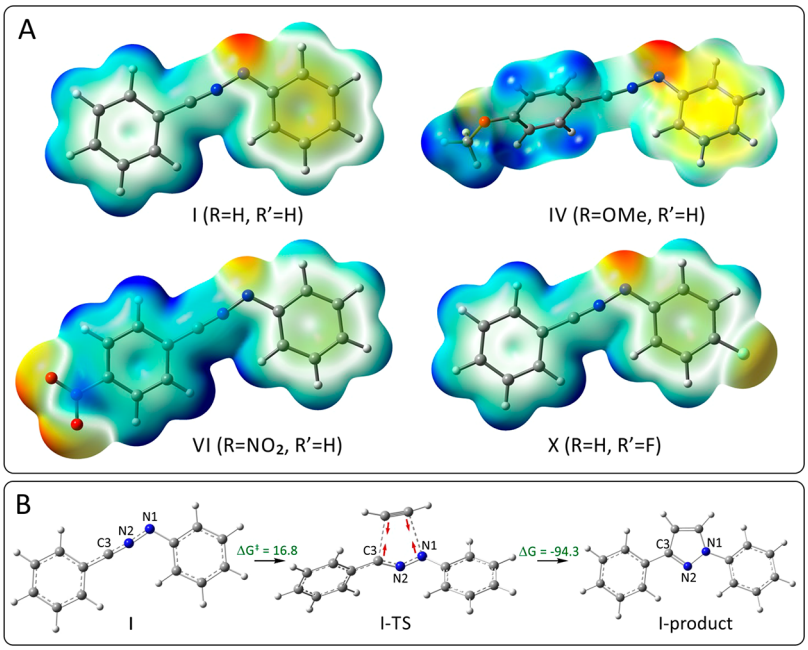

Figure 1. (A) Mapped surface of the molecular electrostatic potential for nitrile imines **I**, **IV**, **VI**, and **X**. (B) Molecular structures of nitrile imine, transition state, and product of the 1,3-dipolar cycloaddition reaction for **I** with Gibbs energies (ΔG, kcal/mol) in chloroform media. Calculations were carried out at the PBE1PBE/6-311+G(d,p)&D3BJ&SMD level.

It should be noted that the developed methodology is handy and practically relevant. The reaction may be performed in standard glassware (either a two-chamber reactor or a widely available H-tube reactor;[24] see photos in Supporting Information). The reaction with calcium carbide is easy to implement in any conventional chemical laboratory: it requires no dedicated equipment as in the case of acetylene gas.

For an insight into the reaction mechanism, theoretical calculations of the intermediate structures and the reaction pathway were carried out to estimate the role of substituents in aryl fragments (Figures S1–S3, Table S1). To address this question and to analyze electronic structures, theoretical calculations were performed at the PBE1PBE/6-311+G(d,p) level with D3BJ corrections for the dispersion interactions and SMD continuum model for the effect of solvent.

The key stage of the whole process is 1,3-dipolar cycloaddition of nitrile imine to acetylene. Several substrate molecules with different substituents were considered (Scheme 3, Table 4, and Figure 1). We took the electronic structure of the unsubstituted nitrilimine molecule (R = H, R′ = H) as a reference point (Figure 1).

Quantum-chemical calculations of atomic charges, bond orders, natural bond orbitals, and molecular electrostatic potentials confirmed that the −N1N2C3− nitrilimine group is a dipole with the positive charge localized within the C3 carbon atom region and the negative charge localized within the N1 nitrogen atom region (Figures 1A and S1), wherein the natural bond orbital charge of the nitrogen atom N2 is rather small. It should be noted that the total Wiberg bond index for the N2 nitrogen atom is 3.59 for molecule **I** (R = H, R′ = H); that is, the N2 atom forms a double bond with the C3 carbon atom and "one and a half" bond with the N1 nitrogen atom. Therefore the N1−N2−C3 fragment may be considered to involve a contribution from the cumulene structure. The Wiberg bond indices are in good agreement with the Bader delocalization indices (δ). Delocalization indices may be considered as bond orders for C−C and C−N bonds.[25] Total delocalization index for the N2 atom (calculated as a sum of δ values) is 3.44 for molecule **I**, wherein the δ value for the N1−N2 bond is 1.57; that is, multiplicity of this bond is expressed to a greater extent as compared with multiplicity calculated by the Wiberg bond indices (1.36) (Figure S1). It should be noted that variation of the R substituent results in more considerable changes of the electronic parameters of the −N1N2C3− nitrilimine group as compared with variation of the R′ substituent. For example, NBO charges of the N1 atom are −0.360, −0.387, −0.323, and −0.361 for molecules **I** (R = H, R′ = H), **IV** (R = OMe, R′ = H), **VI** (R = NO_2, R′ = H), and **X** (R = H, R′ = F), respectively (Figure S1).

The 1,3-dipolar cycloaddition reaction proceeds over the concerted transition states with C−C and C−N bonds formed simultaneously. Small activation barriers (∼16−17 kcal/mol) and large driving force values (>90 kcal/mol) were found computationally (Table 4). Indeed, the studied reactions should easily proceed at room temperature. Very similar activation barriers and reaction energies for the studied substituted substrates confirm a general scope for substituents with different electronic effect.

In conclusion, a novel highly efficient protocol for the synthesis of 1,3-disubstituted pyrazoles in excellent yields is reported. The procedure is based on 1,3-dipolar cycloaddition between nitrile imines and acetylene, generated *in situ* from calcium carbide. Using a simple two-chamber reactor, a procedure with a controlled and spatially isolated acetylene generation was developed. The process appears to be a 1,3-dipolar cycloaddition reaction proceeding over the concerted transition state, and theoretical calculations confirmed good functional group tolerance at the key cycloaddition step. Replacing water with D_2O allowed formation of 4,5-dideuteropyrazoles with high levels of deuterium incorporation.

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EXPERIMENTAL SECTION

General. Chemicals were purchased from Sigma-Aldrich, Alfa Aesar, and Acros Organics in reagent grade or better quality and checked by NMR before use. Calcium carbide (granulated, technical, ≥75% purity) was obtained from Sigma-Aldrich. NMR spectra were recorded on a Bruker Avance III spectrometer (^{1}H 400 MHz; ^{13}C 101 MHz, ^{19}F 376 MHz). Chemical shifts δ are reported in ppm relative to residual $CHCl_3$ (^{1}H, δ = 7.26) and $CDCl_3$ (^{13}C, δ = 77.16) as internal standards. High-resolution mass spectra (HRMS) were recorded on a Bruker micrOTOF 10223 spectrometer using electrospray ionization (ESI). A mass spectrum of **3x** was measured on a high-resolution time-of-flight Bruker maXis instrument using atmospheric pressure chemical ionization (APCI-MS). Reactions were monitored by TLC analysis using Merck UV-254 plates. Preparative column chromatography was performed on Merck silica gel 60 (230−400 Mesh) pretreated with triethylamine.

Calculation Details. All structures were optimized by the PBE1PBE[26] method with 6-311+G(d,p)[27] basis set. Dispersion interaction was accounted for by Grimme D3BJ[28] empirical corrections. Vibrational analysis was performed for all structures, and vibrational spectra of all transition states had one imaginary frequency corresponding to 1,3-dipolar cycloaddition. The intrinsic reaction coordinate calculations (IRCs) were carried out for the verification of the founded transition state structures. Influence of the solvent medium (chloroform) was modeled by the SMD continuum model.[29] All structures were optimized considering the solvent effects. The calculations were performed by the Gaussian 16 program package.[30] Visualization of the molecular structures and MESP surfaces was performed by GaussView 6.0 software.

Experimental Details and Spectral Data for Hydrazonoyl Chlorides. Hydrazonoyl chlorides were prepared in 62−89% yields by a procedure reported previously.[23c]

*4-(tert-Butyl)-N-phenylbenzohydrazonoyl Chloride (**3a**).* Obtained from 2.684 g (10 mmol) of 4-*tert*-butyl-*N*′-phenylbenzohydrazide, yield 2.237 g (78%). Beige solid; mp 55−57 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.88−7.85 (m, 2H), 7.46−7.43 (m, 2H), 7.35−7.30 (m, 2H), 7.20−7.17 (m, 2H), 6.95 (tt, *J* = 7.6, 1.1 Hz, 1H), 1.36 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.7, 143.6, 131.9, 129.5 (2C), 126.4 (2C), 125.5 (2C), 125.0, 121.2, 113.5 (2C), 34.9, 31.4 (3C). HRMS (ESI) Calcd for $C_{17}H_{19}ClN_2Na^+$ [M + Na]$^+$ 309.1129, found 309.1148.

*2-Methyl-N-phenylbenzohydrazonoyl Chloride (**3e**).* Obtained from 453 mg (2 mmol) of 2-methyl-*N*′-phenylbenzohydrazide, yield 304 mg (62%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (s, 1H), 7.66−7.63 (m, 1H), 7.32−7.26 (m, 5H), 7.14−7.11 (m, 2H), 6.95−6.91 (m, 1H), 2.59 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.6, 136.9, 134.5, 131.3, 129.7, 129.5 (2C), 129.1, 126.0, 123.8, 121.2, 113.4 (2C), 22.0. HRMS (ESI) Calcd for $C_{14}H_{14}ClN_2^+$ [M + H]$^+$ 245.0840, found 245.0847.

*3,4-Dimethyl-N-phenylbenzohydrazonoyl Chloride (**3f**).* Obtained from 601 mg (2.5 mmol) of 3,4-dimethyl-*N*′-phenylbenzohydrazide, yield 440 mg (68%). Beige solid; mp 97−99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95−7.93 (m, 3H), 7.44−7.35 (m, 3H), 7.08 (d, *J* = 8.1 Hz, 1H), 7.00 (s, 1H), 6.94 (d, *J* = 8.1 Hz, 1H), 2.29 (s, 3H), 2.24 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 141.6, 137.8, 134.8, 130.5, 129.4, 129.1, 128.5 (2C), 126.5 (2C), 124.0, 115.0, 111.0, 20.2, 19.1.

HRMS (ESI) Calcd for $C_{15}H_{16}ClN_2^+$ [M + H]$^+$ 259.0997, found 259.0999.

*3,5-Dimethyl-N-phenylbenzohydrazonoyl Chloride (**3g**).* Obtained from 601 mg (2.5 mmol) of 3,5-dimethyl-*N*′-phenylbenzohydrazide, yield 455 mg (70%). Beige solid; mp 44−47 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (s, 1H), 7.56 (s, 2H), 7.36−7.31 (m, 2H), 7.21−7.19 (m, 2H), 7.03 (s, 1H), 6.98−6.94 (m, 1H), 2.40 (s, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.6, 138.1 (2C), 134.5, 131.2, 129.5 (2C), 125.2, 124.5 (2C), 121.2, 113.6 (2C), 21.5. HRMS (ESI) Calcd for $C_{15}H_{16}ClN_2^+$ [M + H]$^+$ 259.0997, found 259.1004.

*3,4-Dichloro-N-phenylbenzohydrazonoyl Chloride (**3k**).* Obtained from 700 mg (2.5 mmol) of 3,4-dichloro-*N*′-phenylbenzohydrazide, yield 629 mg (84%). Pale yellow solid; mp 119−121 °C (lit. 121−122 °C).[31] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.98 (d, *J* = 2.2 Hz, 1H), 7.74 (dd, *J* = 8.5, 2.2 Hz, 1H), 7.46 (d, *J* = 8.5 Hz, 1H), 7.35−7.31 (m, 2H), 7.18−7.16 (m, 2H), 6.98 (t, *J* = 7.3 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 142.9, 134.5, 133.2, 133.0, 130.4, 129.6 (2C), 128.0, 125.4, 122.2, 121.9, 113.7 (2C). HRMS (ESI) Calcd for $C_{13}H_{10}Cl_3N_2^+$ [M + H]$^+$ 298.9904, found 298.9898.

*2-Fluoro-N-phenylbenzohydrazonoyl Chloride (**3m**).* Obtained from 576 mg (2.5 mmol) of 2-fluoro-*N*′-phenylbenzohydrazide, yield 447 mg (72%). White solid; mp 77−80 °C (lit. 82−83.5 °C).[32] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (s, 1H, NH), 7.73 (td, *J* = 7.7, 1.7 Hz, 1H), 7.39−7.29 (m, 3H), 7.22−7.12 (m, 4H), 6.98−6.94 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.9 (d, *J* = 256.3 Hz), 143.3, 130.8 (d, *J* = 8.6 Hz), 130.3 (d, *J* = 1.1 Hz), 129.5 (2C), 124.1 (d, *J* = 3.8 Hz), 123.3 (d, *J* = 10.0 Hz), 121.5, 118.9 (d, *J* = 5.7 Hz), 116.7 (d, *J* = 22.0 Hz), 113.7 (2C). ^{19}F NMR (376 MHz, $CDCl_3$) δ −112.12 ppm. HRMS (ESI) Calcd for $C_{13}H_{10}ClFN_2Na^+$ [M + Na]$^+$ 271.0409, found 271.0410.

*4-Nitro-N-phenylbenzohydrazonoyl Chloride (**3o**).* Obtained from 643 mg (2.5 mmol) of 4-nitro-*N*′-phenylbenzohydrazide, yield 535 mg (78%). Red solid; mp 158−159 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27−8.23 (m, 3H), 8.08−8.04 (m, 2H), 7.37−7.33 (m, 2H), 7.22−7.20 (m, 2H), 7.04−7.00 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.8, 142.6, 140.3, 129.7 (2C), 126.8 (2C), 123.9 (2C), 122.4, 122.3, 114.0 (2C). HRMS (ESI) Calcd for $C_{13}H_{10}N_3O_2ClNa^+$ [M + Na]$^+$ 298.0354, found 298.0344.

*N-Phenylpropionohydrazonoyl Chloride (**3p**).* Obtained from 493 mg (3 mmol) of *N*′-phenylpropionohydrazide, yield 350 mg (64%). Red solid; mp 38−42 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (s, 1H), 7.29−7.25 (m, 2H), 7.06 (d, *J* = 7.6 Hz, 2H), 6.89 (t, *J* = 7.3 Hz, 1H), 2.67 (q, *J* = 7.4 Hz, 2H), 1.28 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 144.1, 129.4 (2C), 129.0, 120.7, 113.2 (2C), 32.7, 11.6. HRMS (ESI) Calcd For $C_9H_{11}N_2^+$ [M − Cl]$^+$ 147.0917, found 147.0920.

*2-(4-Isobutylphenyl)-N-phenylpropanehydrazonoyl Chloride (**3q**).* Obtained from 741 mg (2.5 mmol) of 2-(4-isobutylphenyl)-*N*′-phenylpropanehydrazide, yield 574 mg (73%). Brown oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (s, 1H), 7.29−7.26 (m, 2H), 7.21 (d, *J* = 8.1 Hz, 2H), 7.12−7.06 (m, 4H), 6.92−6.88 (m, 1H), 3.97 (q, *J* = 7.0 Hz, 1H), 2.46 (d, *J* = 7.2 Hz, 2H), 1.95−1.78 (m, 1H), 1.63 (d, *J* = 7.1 Hz, 3H), 0.91 (d, *J* = 6.6 Hz, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 144.1, 140.7, 138.9, 130.8, 129.4 (4C), 127.4 (2C), 120.8, 113.3 (2C), 48.7, 45.2, 30.3, 22.5, 19.8. HRMS (ESI) Calcd for $C_{19}H_{24}ClN_2^+$ [M + H]$^+$ 315.1623, found 315.1616.

*N-(2-Tolyl)benzohydrazonoyl Chloride (**3r**).* Obtained from 566 mg (2.5 mmol) of *N*′-2-tolylbenzohydrazide, yield 410 mg (67%). White solid, mp 64−66 °C (lit. 64.5−66 °C).[32] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99−7.97 (m, 3H), 7.57 (d, *J* = 8.1 Hz, 1H), 7.46−7.38 (m, 3H), 7.26 (t, *J* = 7.7 Hz, 1H), 7.16 (d, *J* = 7.4 Hz, 1H), 6.91 (t, *J* = 7.4 Hz, 1H), 2.33 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 141.4, 134.6, 130.7, 129.4, 128.6 (2C), 127.5, 126.6 (2C), 125.7, 121.3, 120.9, 113.4, 17.0. HRMS (ESI) Calcd for $C_{14}H_{14}ClN_2^+$ [M + H]$^+$ 245.0840, found 245.0839.

*N-(3-Tolyl)benzohydrazonoyl Chloride (**3s**).* Obtained from 566 mg (2.5 mmol) of *N*′-2-tolylbenzohydrazide, yield 415 mg (68%). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (s, 1H), 7.96−7.93 (m, 2H), 7.45−7.36 (m, 3H), 7.22 (t, *J* = 7.7 Hz, 1H), 7.03 (s, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 6.78 (d, *J* = 7.5 Hz, 1H), 2.38 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.5, 139.5, 134.6, 129.4, 129.3, 128.5 (2C), 126.5 (2C), 124.6, 122.2, 114.2, 110.8, 21.7. HRMS (ESI) Calcd for $C_{14}H_{14}ClN_2^+$ [M + H]$^+$ 245.0840, found 245.0849.

*N-(3-(Trifluoromethyl)phenyl)benzohydrazonoyl Chloride (**3x**).* Obtained from 700 mg (2.5 mmol) of *N*′-(3-(trifluoromethyl)-phenyl)benzohydrazide, yield 560 mg (75%). White solid, mp 85−87 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.95−7.92 (m, 2H), 7.46−7.40 (m, 5H), 7.32 (d, *J* = 8.2 Hz, 1H), 7.19 (d, *J* = 7.6 Hz, 1H).^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.9, 134.2, 132.0 (q, *J* = 32.2 Hz), 130.0, 129.8, 128.6 (2C), 126.7 (2C), 126.5, 124.3 (q, *J* = 272.4 Hz), 117.7 (q, *J* = 3.8 Hz), 116.6, 110.2 (q, *J* = 3.9 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.82 ppm. HRMS (APCI) Calcd for $C_{14}H_{11}ClF_3N_2^+$ [M + H]$^+$ 299.0557, found 299.0555.

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*N-(2,6-Dichlorophenyl)benzohydrazonoyl Chloride (**3y**).* Obtained from 700 mg (2.5 mmol) of *N′*-(2,6-dichlorophenyl)-benzohydrazide, yield 590 mg (79%). White solid, mp 66−69 °C (lit. 69.5−70.5 °C).[33] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (s, 1H), 7.96−7.93 (m, 2H), 7.43−7.39 (m, 3H), 7.34 (d, J = 8.1 Hz, 2H), 6.94 (t, J = 8.1 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 137.2, 134.2, 129.9, 129.4 (2C), 128.6 (2C), 127.7, 126.8 (2C), 125.6 (2C), 123.9. HRMS (ESI) Calcd for $C_{13}H_{10}Cl_3N_2^+$ [M + H]$^+$ 298.9904, found 298.9915.

General Procedure for the Synthesis of Pyrazoles. The first vessel of the two-chamber reactor was loaded with the calcium carbide (100 mg). Then, the corresponding hydrazonoyl chloride (0.2 mmol) was loaded to the second vessel, and 1.0 mL of $CHCl_3$ was added to each part. Next, triethylamine (0.4 mmol) was added to the hydrazonoyl chloride solution, and distilled water (0.1 mL) was poured into the carbide vessel. The reactor was immediately sealed, and the mixture was stirred at room temperature for 48 h. After completing the reaction, the contents of the second vessel were collected by a syringe, washed thrice with water, dried with Na_2SO_4, and filtered, and then the solvent was removed on a rotary evaporator. Pyrazoles **4a−d**, **4f−k**, **4m**, **4q−s**, and **4u,v** did not require special purification and were obtained in individual form after drying of reaction mixture. The products **4e,l**, **4n−p**, **4t**, and **4w−y** were purified by column chromatography using hexane−ethyl acetate as an eluent (eluent compositions for each compound are given below). For deuterated pyrazoles **5**, D_2O and $CDCl_3$ were used instead of water and chloroform. All compounds **5** were isolated without chromatographic purification. Isotopic purity of the synthesized products was in the range of 95−99%.

*3-(4-(tert-Butyl)phenyl)-1-phenyl-1H-pyrazole (**4a**).* Yield 55 mg (99%). Beige solid; mp 103−105 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 2.5 Hz, 1H), 7.86 (d, J = 8.4 Hz, 2H), 7.78 (d, J = 7.9 Hz, 2H), 7.49−7.45 (m, 4H), 7.29 (t, J = 7.4 Hz, 1H), 6.76 (d, J = 2.5 Hz, 1H), 1.37 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.1, 151.2, 140.4, 130.5, 129.5 (2C), 128.0, 126.3, 125.74 (2C), 125.69 (2C), 119.1 (2C), 105.1, 34.8, 31.5. HRMS (ESI) Calcd for $C_{19}H_{21}N_2^+$ [M + H]$^+$ 277.1699, found 277.1709.

*3-(4-Methoxyphenyl)-1-phenyl-1H-pyrazole (**4b**).* Yield 49.5 mg (99%). Beige solid; mp 101−103 °C (lit. 102−104 °C).[33] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, J = 2.4 Hz, 1H), 7.86 (d, J = 8.6 Hz, 2H), 7.78−7.76 (m, 2H), 7.46 (t, J = 7.8 Hz, 2H), 7.28 (t, J = 7.8 Hz, 1H), 6.97 (d, J = 8.6 Hz, 2H), 6.71 (d, J = 2.4 Hz, 1H), 3.86 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.8, 152.9, 140.4, 129.5 (2C), 128.0, 127.2 (2C), 126.3, 126.1, 119.0 (2C), 114.2 (2C), 104.7, 55.4. HRMS (ESI) Calcd for $C_{16}H_{15}N_2O^+$ [M + H]$^+$ 251.1179, found 251.1183.

*1-Phenyl-3-(4-tolyl)-1H-pyrazole (**4c**).* Yield 46.5 mg (99%). Beige solid; mp 92−94 °C (lit. 91−92 °C).[34] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 2.5 Hz, 1H), 7.83−7.77 (m, 4H), 7.49−7.45 (m, 2H), 7.31−7.24 (m, 3H), 6.75 (d, J = 2.5 Hz, 1H), 2.40 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.1, 140.4, 137.9, 130.5, 129.53 (2C), 129.48 (2C), 128.0, 126.3, 125.9 (2C), 119.1 (2C), 105.0, 21.4. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1245.

*1-Phenyl-3-(3-tolyl)-1H-pyrazole (**4d**).* Yield 46.5 mg (99%). Beige solid; mp 68−70 °C (lit. oil).[34] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, J = 2.5 Hz, 1H), 7.80−7.77 (m, 3H), 7.72 (d, J = 7.7 Hz, 1H), 7.50−7.45 (m, 2H), 7.36−7.28 (m, 2H), 7.17 (d, J = 7.6 Hz, 1H), 6.77 (d, J = 2.5 Hz, 1H), 2.44 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.2, 140.4, 138.4, 133.1, 129.5 (2C), 129.0, 128.7, 128.1, 126.6, 126.4, 123.2, 119.2 (2C), 105.2, 21.6. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1237.

*1-Phenyl-3-(2-tolyl)-1H-pyrazole (**4e**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 100:1) to give the product as yellow oil. Yield 25 mg (54%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, J = 2.5 Hz, 1H), 7.79−7.76 (m, 2H), 7.68−7.64 (m, 1H), 7.49−7.44 (m, 2H), 7.31−7.27 (m, 4H), 6.65 (d, J = 2.5 Hz, 1H), 2.59 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.6, 140.4, 136.4, 133.0, 131.1, 129.5 (2C), 129.4, 128.0, 127.0, 126.3, 126.0, 119.0 (2C), 108.1, 21.6. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1233.

*3-(3,4-Dimethylphenyl)-1-phenyl-1H-pyrazole (**4f**).* Yield 49 mg (99%). Beige solid; mp 76−77 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 2.5 Hz, 1H), 7.79−7.74 (m, 3H), 7.65 (d, J = 7.8 Hz, 1H), 7.49−7.45 (m, 2H), 7.29 (t, J = 7.4 Hz, 1H), 7.21 (d, J = 7.8 Hz, 1H), 6.75 (d, J = 2.5 Hz, 1H), 2.35 (s, 3H), 2.32 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.3, 140.4, 136.9, 136.6, 130.8, 130.0, 129.5 (2C), 128.0, 127.1, 126.3, 123.5, 119.2 (2C), 105.0, 20.0, 19.7. HRMS (ESI) Calcd for $C_{17}H_{17}N_2^+$ [M + H]$^+$ 249.1386, found 249.1394.

*3-(3,5-Dimethylphenyl)-1-phenyl-1H-pyrazole (**4g**).* Yield 49 mg (99%). Beige solid; mp 65−67 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 2.5 Hz, 1H), 7.79−7.77 (m, 2H), 7.56 (s, 2H), 7.49−7.45 (m, 2H), 7.29 (t, J = 7.4 Hz, 1H), 7.00 (s, 1H), 6.76 (d, J = 2.5 Hz, 1H), 2.40 (s, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.3, 140.4, 138.3 (2C), 133.0, 129.9, 129.5 (2C), 128.0, 126.4, 123.8 (2C), 119.2 (2C), 105.2, 21.5 (2C). HRMS (ESI) Calcd for $C_{17}H_{17}N_2^+$ [M + H]$^+$ 249.1386, found 249.1396.

*1,3-Diphenyl-1H-pyrazole (**4h**).* Yield 44 mg (99%). Beige solid; mp 82−85 °C (lit. 80−82 °C).[33] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97−7.93 (m, 3H), 7.81−7.77 (m, 2H), 7.50−7.43 (m, 4H), 7.38−7.35 (m, 1H), 7.30 (t, J = 7.4 Hz, 1H), 6.78 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.1, 140.4, 133.3, 129.5 (2C), 128.8 (2C), 128.15, 128.09, 126.4, 126.0 (2C), 119.2 (2C), 105.1. HRMS (ESI) Calcd for $C_{15}H_{13}N_2^+$ [M + H]$^+$ 221.1073, found 221.1081.

*3-(4-Bromophenyl)-1-phenyl-1H-pyrazole (**4i**).* Yield 59 mg (99%). Beige solid; mp 122−124 °C (lit. 124−126 °C).[35] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, J = 2.5 Hz, 1H), 7.81−7.75 (m, 4H), 7.57−7.54 (m, 2H), 7.49−7.45 (m, 2H), 7.31 (t, J = 7.4 Hz, 1H), 6.75 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.0, 140.3, 132.3, 131.9 (2C), 129.6 (2C), 128.3, 127.5 (2C), 126.7, 122.1, 119.2 (2C), 105.1. HRMS (ESI) Calcd for $C_{15}H_{12}N_2Br^+$ [M + H]$^+$ 299.0178, found 299.0183.

*3-(4-Chlorophenyl)-1-phenyl-1H-pyrazole (**4j**).* Yield 50.5 mg (99%). Beige solid; mp 119−120 °C (lit. 118 °C).[33] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, J = 2.5 Hz, 1H), 7.87−7.85 (m, 2H), 7.78−7.75 (m, 2H), 7.50−7.46 (m, 2H), 7.42−7.39 (m, 2H), 7.33−7.29 (m, 1H), 6.75 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 151.9, 140.2, 133.9, 131.8, 129.6 (2C), 128.9 (2C), 128.3, 127.2 (2C), 126.7, 119.2 (2C), 105.1. HRMS (ESI) Calcd for $C_{15}H_{12}N_2Cl^+$ [M + H]$^+$ 255.0684, found 255.0673.

*3-(3,4-Dichlorophenyl)-1-phenyl-1H-pyrazole (**4k**).* Yield 58 mg (99%). Beige solid; mp 95−97 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, J = 1.9 Hz, 1H), 7.95 (d, J = 2.5 Hz, 1H), 7.76−7.71 (m, 3H), 7.50−7.46 (m, 3H), 7.32 (t, J = 7.4 Hz, 1H), 6.73 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.7, 140.1, 133.4, 133.0, 131.8, 130.7, 129.6 (2C), 128.5, 127.7, 126.8, 125.1, 119.3 (2C), 105.2. HRMS (ESI) Calcd for $C_{15}H_{11}N_2Cl_2^+$ [M + H]$^+$ 289.0294, found 289.0293.

*3-(2,4-Dichlorophenyl)-1-phenyl-1H-pyrazole (**4l**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 20:1) to give the product as colorless solid; mp 88−90 °C. Yield 39.5 mg (68%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, J = 2.5 Hz, 1H), 7.92 (d, J = 8.4 Hz, 1H), 7.77−7.75 (m, 2H), 7.50−7.45 (m, 3H), 7.33−7.30 (m, 2H), 7.01 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 149.8, 140.1, 134.2, 133.1, 131.6, 130.8, 130.2, 129.6 (2C), 127.5, 127.4, 126.8, 119.3 (2C), 109.0. HRMS (ESI) Calcd for $C_{15}H_{11}N_2Cl_2^+$ [M + H]$^+$ 289.0294, found 289.0308.

*3-(2-Fluorophenyl)-1-phenyl-1H-pyrazole (**4m**).* Yield 47 mg (99%). Beige solid; mp 59−61 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (td, J = 7.7, 1.8 Hz, 1H), 7.98 (d, J = 2.5 Hz, 1H), 7.80−7.78 (m, 2H), 7.50−7.46 (m, 2H), 7.34−7.29 (m, 2H), 7.23 (td, J = 7.6, 1.2 Hz, 1H), 7.16 (ddd, J = 11.3, 8.2, 1.1 Hz, 1H), 6.94 (dd, J = 3.9, 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 160.5 (d, J = 249.8 Hz), 147.8 (d, J = 1.1 Hz), 140.3, 129.6 (2C), 129.5 (d, J = 8.6 Hz), 128.7 (d, J = 3.6 Hz), 127.8 (d, J = 2.2 Hz), 126.6, 124.4 (d, J = 3.5 Hz), 121.1 (d, J = 11.8 Hz), 119.3 (2C), 116.2 (d, J = 22.1 Hz), 108.6 (d, J = 10.5 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ −115.95 ppm. HRMS (ESI) Calcd for $C_{15}H_{12}N_2F^+$ [M + H]$^+$ 239.0979, found 239.0987.

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*3-(2-Iodophenyl)-1-phenyl-1H-pyrazole (**4n**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 100:1) to give the product as white solid; mp 93−95 °C. Yield 44.5 mg (64%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00−7.98 (m, 2H), 7.79−7.76 (m, 2H), 7.66 (dd, J = 7.7, 1.7 Hz, 1H), 7.49−7.38 (m, 3H), 7.32−7.28 (m, 1H), 7.06 (td, J = 7.7, 1.7 Hz, 1H), 6.85 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 154.7, 140.29, 140.25, 138.45, 131.0, 129.7, 129.6 (2C), 128.3, 127.0, 126.6, 119.3 (2C), 108.7, 97.2. HRMS (ESI) Calcd for $C_{15}H_{12}N_2I^+$ [M + H]$^+$ 347.0040, found 347.0050.

*3-(4-Nitrophenyl)-1-phenyl-1H-pyrazole (**4o**).* The crude material was purified by PTLC (*n*-hexane/EtOAc 10:1) to give the product as orange solid; mp = 134−136 °C (lit. 138−140 °C).[33] Yield 41 mg (77%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31−8.28 (m, 2H), 8.10−8.06 (m, 2H), 8.01 (d, J = 2.5 Hz, 1H), 7.80−7.77 (m, 2H), 7.53−7.48 (m, 2H), 7.37−7.33 (m, 1H), 6.88 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.6, 147.4, 140.0, 139.5, 129.7 (2C), 128.8, 127.2, 126.3 (2C), 124.2 (2C), 119.4 (2C), 106.01. HRMS (ESI) Calcd for $C_{15}H_{12}N_3O_2^+$ [M + H]$^+$ 266.0924, found 266.0918.

*3-Ethyl-1-phenyl-1H-pyrazole (**4p**).*[36] The crude material was purified by column chromatography (gradient elution *n*-hexane/EtOAc 100:1 to 20:1) to give the product as orange oil. Yield 28.5 mg (83%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, J = 2.4 Hz, 1H), 7.68−7.65 (m, 2H), 7.45−7.39 (m, 2H), 7.26−7.22 (m, 1H), 6.28 (d, J = 2.4 Hz, 1H), 2.77 (q, J = 7.6 Hz, 2H), 1.32 (t, J = 7.6 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 156.7, 140.4, 129.4 (2C), 127.3, 126.0, 119.0 (2C), 106.1, 21.8, 14.0. HRMS (ESI) Calcd for $C_{11}H_{13}N_2^+$ [M + H]$^+$ 173.1073, found 173.1069.

*3-(1-(4-Isobutylphenyl)ethyl)-1-phenyl-1H-pyrazole (**4q**).* Yield 60.5 mg (99%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, J = 2.4 Hz, 1H), 7.70−7.68 (m, 2H), 7.45−7.41 (m, 2H), 7.27−7.23 (m, 3H), 7.10 (d, J = 8.0 Hz, 2H), 6.20 (d, J = 2.4 Hz, 1H), 4.29 (q, J = 7.2 Hz, 1H), 2.46 (d, J = 7.2 Hz, 2H), 1.92−1.81 (m, 1H), 1.72 (d, J = 7.2 Hz, 3H), 0.92 (d, J = 6.6 Hz, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.1, 142.9, 140.5, 139.6, 129.4 (2C), 129.2 (2C), 127.3 (2C), 126.0, 119.1 (2C), 106.1, 45.2, 39.1, 30.3, 22.6 (2C), 21.7. HRMS (ESI) Calcd for $C_{21}H_{25}N_2^+$ [M + H]$^+$ 305.2012, found 305.2017.

*3-Phenyl-1-(2-tolyl)-1H-pyrazole (**4r**).*[37] Yield 46.5 mg (99%). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93−7.90 (m, 2H), 7.63 (d, J = 2.4 Hz, 1H), 7.45−7.40 (m, 3H), 7.35−7.28 (m, 4H), 6.76 (d, J = 2.4 Hz, 1H), 2.34 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.4, 140.2, 133.9, 133.5, 132.0, 131.5, 128.7 (2C), 128.5, 127.9, 126.8, 126.2, 125.9 (2C), 103.7, 18.4. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1232.

*3-Phenyl-1-(3-tolyl)-1H-pyrazole (**4s**).* Yield 46.5 mg (99%). Beige solid; mp 71−73 °C (lit. oil).[34] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95−7.93 (m, 3H), 7.64 (s, 1H), 7.54 (d, J = 8.0 Hz, 1H), 7.44 (t, J = 7.6 Hz, 2H), 7.35 (t, J = 7.6 Hz, 2H), 7.11 (d, J = 7.5 Hz, 1H), 6.77 (d, J = 2.5 Hz, 1H), 2.45 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.0, 140.3, 139.6, 133.3, 129.3, 128.8 (2C), 128.2, 128.1, 127.3, 126.0 (2C), 120.0, 116.2, 105.0, 21.6. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1238.

*3-Phenyl-1-(4-tolyl)-1H-pyrazole (**4t**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 100:1) to give the product as colorless solid; mp 111−112 °C (lit. 110−111 °C).[33] Yield 44.5 mg (95%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97−7.93 (m, 3H), 7.68 (d, J = 8.4 Hz, 2H), 7.48−7.44 (m, 2H), 7.39−7.35 (m, 1H), 7.30−7.28 (m, 2H), 6.79 (d, J = 2.4 Hz, 1H), 2.43 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.7, 138.1, 136.1, 133.3, 129.9, 128.6, 127.9, 125.8, 119.1, 104.7, 21.0. Two signals are overlaid by the other signals. HRMS (ESI) Calcd for $C_{16}H_{15}N_2^+$ [M + H]$^+$ 235.1230, found 235.1220.

*1-(4-Bromophenyl)-3-phenyl-1H-pyrazole (**4u**).* Yield 60 mg (99%). Beige solid; mp 133−134 °C (lit. 135−146 °C).[34] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93−7.90 (m, 3H), 7.68−7.64 (m, 2H), 7.60−7.56 (m, 2H), 7.46−7.43 (m, 2H), 7.38−7.34 (m, 1H), 6.78 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.4, 139.3, 133.0, 132.6 (2C), 128.8 (2C), 128.3, 128.0, 126.0 (2C), 120.5 (2C), 119.6, 105.6. HRMS (ESI) Calcd for $C_{15}H_{12}N_2Br^+$ [M + H]$^+$ 299.0178, found 299.0187.

*1-(4-Chlorophenyl)-3-phenyl-1H-pyrazole (**4v**).* Yield 50.5 mg (99%). Beige solid; mp 129−130 °C (lit. 132−133 °C).[33] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92−7.90 (m, 3H), 7.74−7.70 (m, 2H), 7.46−7.41 (m, 4H), 7.37−7.34 (m, 1H), 6.78 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.4, 138.9, 133.0, 131.9, 129.6 (2C), 128.8 (2C), 128.3, 128.0, 126.0 (2C), 120.2 (2C), 105.5. HRMS (ESI) Calcd for $C_{15}H_{12}N_2Cl^+$ [M + H]$^+$ 255.0684, found 255.0688.

*1-(4-Fluorophenyl)-3-phenyl-1H-pyrazole (**4w**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 40:1) to give the product as white solid; mp 90−92 °C (lit. 87−88 °C).[34] Yield 45.5 mg (96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93−7.90 (m, 2H), 7.88 (d, J = 2.5 Hz, 1H), 7.76−7.70 (m, 2H), 7.46−7.42 (m, 2H), 7.37−7.34 (m, 1H), 7.19−7.13 (m, 2H), 6.77 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 161.2 (d, J = 245.7 Hz), 151.2, 136.8 (d, J = 2.8 Hz), 133.1, 128.8 (2C), 128.23, 128.22, 125.9 (2C), 121.0 (d, J = 8.2 Hz, 2C), 116.3 (d, J = 23.2 Hz, 2C), 105.2 (C). ^{19}F NMR (376 MHz, $CDCl_3$) δ −116.13 ppm. HRMS (ESI) Calcd for $C_{15}H_{12}N_2F^+$ [M + H]$^+$ 239.0979, found 239.0989.

*1-(3-(Trifluoromethyl)phenyl)-3-phenyl-1H-pyrazole (**4x**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 100:1) to give the product as beige solid; mp 70−71 °C. Yield 53.5 mg (93%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (s, 1H), 7.99 (d, J = 2.6 Hz, 1H, H_{pyr}), 7.96−7.94 (m, 3H), 7.60−7.53 (m, 2H), 7.48−7.45 (m, 2H), 7.40−7.36 (m, 1H), 6.82 (d, J = 2.6 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.7, 140.6, 132.8, 132.1 (q, J = 32.8 Hz), 130.1, 128.8 (2C), 128.5, 128.0, 126.0 (2C), 123.9 (q, J = 272.6 Hz), 122.8 (q, J = 3.7 Hz), 121.7, 115.8 (q, J = 4.0 Hz), 105.9. ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.71 ppm. HRMS (ESI) Calcd for $C_{16}H_{12}N_2F_3^+$ [M + H]$^+$ 289.0947, found 289.0945.

*1-(2,6-Dichlorophenyl)-3-phenyl-1H-pyrazole (**4y**).* The crude material was purified by column chromatography (*n*-hexane/EtOAc 40:1) to give the product as beige solid; mp 110−111 °C (lit. 109−110 °C).[37] Yield 51.5 mg (89%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91−7.89 (m, 2H), 7.58 (d, J = 2.5 Hz, 1H), 7.47 (d, J = 8.3 Hz, 2H), 7.44−7.40 (m, 2H), 7.37−7.31 (m, 2H), 6.82 (d, J = 2.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.3, 136.7, 134.9 (2C), 133.1, 130.7, 128.9 (2C), 128.8 (2C), 128.2, 126.2 (2C), 104.2. One of the carbon signals is overlapped by the other signals. HRMS (ESI) Calcd for $C_{15}H_{11}N_2Cl_2^+$ [M + H]$^+$ 289.0294, found 289.0295.

*4,5-Dideutero-3-(4-(tert-butyl)phenyl)-1-phenyl-1H-pyrazole (**5a**).* Yield 55 mg (99%). Beige solid; mp 100−102 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, J = 8.5 Hz, 2H), 7.79 (d, J = 7.8 Hz, 2H), 7.49−7.45 (m, 4H), 7.29 (t, J = 7.4 Hz, 1H), 1.38 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.0, 151.2, 140.4, 130.5, 129.5 (2C), 127.7 (t, J = 27.4 Hz), 126.3, 125.73 (2C), 125.69 (2C), 119.1 (2C), 104.7 (t, J = 26.2 Hz), 34.8, 31.5. HRMS (ESI) Calcd for $C_{19}H_{19}D_2N_2^+$ [M + H]$^+$ 279.1825, found 279.1831.

*4,5-Dideutero-3-(4-methoxyphenyl)-1-phenyl-1H-pyrazole (**5b**).* Yield 50 mg (99%). Beige solid; mp 100−101 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, J = 8.8 Hz, 2H), 7.77 (d, J = 7.7 Hz, 2H), 7.46 (t, J = 7.9 Hz, 2H), 7.28 (t, J = 7.8 Hz), 6.98 (d, J = 8.8 Hz, 2H), 3.86 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.8, 152.8, 140.4, 129.5 (2C), 127.2 (2C), 126.3, 126.1, 119.0 (2C), 114.2 (2C), 104.4 (t, J = 26.8 Hz), 55.4. HRMS (ESI) Calcd for $C_{16}H_{13}D_2N_2O^+$ [M + H]$^+$ 253.1304, found 253.1298.

*4,5-Dideutero-1-phenyl-3-(4-tolyl)-1H-pyrazole (**5c**).* Yield 46.5 mg (98%). Beige solid; mp 93−94 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 8.1 Hz, 2H), 7.78 (dd, J = 8.5, 0.8 Hz, 2H), 7.49−7.45 (m, 2H), 7.31−7.25 (m, 3H), 2.41 (s, 3H, CH_3). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.1, 140.4, 137.9, 130.5, 129.51 (2C), 129.47 (2C), 127.7 (t, J = 28.5 Hz), 126.3, 125.9 (2C), 119.1 (2C), 104.7 (t, J = 26.4 Hz), 21.4. HRMS (ESI) Calcd for $C_{16}H_{13}D_2N_2^+$ [M + H]$^+$ 237.1355, found 237.1348.

*4,5-Dideutero-1-phenyl-3-(3-tolyl)-1H-pyrazole (**5d**).* Yield 47 mg (99%). Beige solid; mp 69−71 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81−7.78 (m, 3H), 7.74 (d, J = 7.7 Hz, 1H), 7.51−7.45 (m, 2H), 7.37−7.29 (m, 2H), 7.19 (d, J = 7.5 Hz, 1H), 2.45 (s, 3H, CH_3). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.1, 140.4, 138.4, 133.1, 129.5

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(2C), 128.9, 128.7, 127.7 (t, J = 28.8 Hz), 126.6, 126.4, 123.1, 119.1 (2C), 104.9 (t, J = 26.8 Hz), 21.6. HRMS (ESI) Calcd for $C_{16}H_{13}D_2N_2^+$ $[M + H]^+$ 237.1355, found 237.1355.

*4,5-Dideutero-3-(3,4-dimethylphenyl)-1-phenyl-1H-pyrazole (**5f**).* Yield 49 mg (98%). Beige solid; mp 75–77 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (dd, J = 8.5, 0.9 Hz, 2H), 7.74 (s, 1H), 7.65 (dd, J = 7.8, 1.3 Hz, 1H), 7.49–7.45 (m, 2H), 7.29 (t, J = 7.4 Hz, 1H), 7.21 (d, J = 7.8 Hz, 1H), 2.35 (s, 3H), 2.32 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.2, 140.4, 136.9, 136.6, 130.8, 130.0, 129.5 (2C), 127.7 (t, J = 28.8 Hz), 127.1, 126.3, 123.5, 119.1 (2C), 104.7 (t, J = 26.8 Hz), 19.9, 19.7. HRMS (ESI) Calcd for $C_{17}H_{15}D_2N_2^+$ $[M + H]^+$ 251.1512, found 251.1500.

*4,5-Dideutero-1,3-diphenyl-1H-pyrazole (**5h**).* Yield 44 mg (99%). Beige solid; mp 83–85 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97–7.95 (m, 2H), 7.81–7.78 (m, 2H), 7.50–7.44 (m, 4H), 7.37 (t, J = 7.4 Hz, 1H), 7.30 (t, J = 7.4 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.0, 140.3, 133.3, 129.5 (2C), 128.8 (2C), 128.1, 127.8 (t, J = 28.4 Hz), 126.4, 126.0 (2C), 119.1 (2C), 104.8 (t, J = 26.7 Hz). HRMS (ESI) Calcd for $C_{15}H_{11}D_2N_2^+$ $[M + H]^+$ 223.1199, found 223.1205.

*3-(4-Bromophenyl)-4,5-dideutero-1-phenyl-1H-pyrazole (**5i**).* Yield 59.5 mg (99%). Beige solid; mp 123–125 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81–7.75 (m, 4H), 7.57–7.54 (m, 2H), 7.49–7.45 (m, 2H), 7.31 (t, J = 7.4 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 151.9, 140.2, 132.3, 131.9 (2C), 129.6 (2C), 127.5 (2C), 126.6, 122.1, 119.2 (2C), 104.8 (t, J = 27.3 Hz). HRMS (ESI) Calcd for $C_{15}H_{10}BrD_2N_2^+$ $[M + H]^+$ 303.0283, found 303.0293.

*3-(3,4-Dichlorophenyl)-4,5-dideutero-1-phenyl-1H-pyrazole (**5k**).* Yield 57 mg (98%). Beige solid; mp 102–104 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, J = 2.0 Hz, 1H), 7.76–7.71 (m, 3H), 7.50–7.46 (m, 3H), 7.32 (t, J = 7.4 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.7, 140.1, 133.4, 133.0, 131.8, 130.7, 129.6 (2C), 127.7, 126.8, 125.1, 119.2 (2C), 104.9 (t, J = 26.4). HRMS (ESI) Calcd for $C_{15}H_9Cl_2D_2N_2^+$ $[M + H]^+$ 291.0419, found 291.0421.

*4,5-Dideutero-3-(2-fluorophenyl)-1-phenyl-1H-pyrazole (**5m**).* Yield 47.5 mg (99%). Beige solid; mp 63–65 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (td, J = 7.7, 1.8 Hz, 1H), 7.80–7.78 (m, 2H), 7.48 (t, J = 8.0, Hz, 2H), 7.35–7.29 (m, 2H), 7.23 (td, J = 7.6, 1.2 Hz, 1H), 7.16 (ddd, J = 11.2, 8.2, 1.0 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 160.5 (d, J = 249.5 Hz), 147.7, 140.3, 129.6 (2C), 129.4 (d, J = 8.4 Hz), 128.7 (d, J = 3.6 Hz), 127.6 (t, J = 29.4 Hz), 126.6, 124.4 (d, J = 3.5 Hz), 121.1 (d, J = 11.9 Hz), 119.3 (2C), 116.2 (d, J = 22.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ −115.96 ppm. HRMS (ESI) Calcd for $C_{15}H_{10}D_2FN_2^+$ $[M + H]^+$ 241.1105, found 241.1100.

*4,5-Dideutero-3-(1-(4-isobutylphenyl)ethyl)-1-phenyl-1H-pyrazole (**5q**).* Yield 59 mg (99%). Isotopic purity 99%. Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70–7.68 (m, 2H), 7.45–7.41 (m, 2H), 7.27–7.23 (m, 3H), 7.10 (d, J = 8.0 Hz, 2H), 4.29 (q, J = 7.2 Hz, 1H), 2.46 (d, J = 7.2 Hz, 2H), 1.92–1.82 (m, 1H), 1.72 (d, J = 7.2 Hz, 3H), 0.92 (d, J = 6.6 Hz, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.0, 142.9, 140.5, 139.6, 129.4 (2C), 129.2 (2C), 127.3 (2C), 127.0 (t, J = 28.3 Hz), 126.0, 119.1 (2C), 105.7 (t, J = 26.6 Hz), 45.2, 39.1, 30.3, 22.6 (2C), 21.7. HRMS (ESI) Calcd for $C_{21}H_{23}D_2N_2^+$ $[M + H]^+$ 307.2138, found 307.2131.

*1-(4-Bromophenyl)-4,5-dideutero-3-phenyl-1H-pyrazole (**5u**).* Yield 59.5 mg (99%). Beige solid; mp 137–138 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93–7.91 (m, 2H), 7.68–7.64 (m, 2H), 7.59–7.56 (m, 2H), 7.46–7.43 (m, 2H), 7.38–7.34 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.3, 139.3, 133.0, 132.6 (2C), 128.8 (2C), 128.3, 127.7 (t, J = 28.7 Hz), 126.0 (2C), 120.5 (2C), 119.5, 105.3 (t, J = 26.7 Hz). HRMS (ESI) Calcd for $C_{15}H_{10}BrD_2N_2^+$ $[M + H]^+$ 303.0283, found 303.0277.

Synthesis of 4a in a Larger Scale. For this reaction, a 45 mL capacity two-chamber reactor was utilized. The first vessel of the reactor was loaded with 1.6 g of calcium carbide and 3.0 mL of $CHCl_3$. Then, 800 mg (2.79 mmol) of 4-(*tert*-butyl)-*N*-phenylbenzohydrazonoyl chloride **3a** with 16.0 mL of $CHCl_3$ was loaded to the second vessel. Next, triethylamine (0.777 mL, 5.58 mmol) was added to the hydrazonoyl chloride solution, and 1.6 mL of distilled water was poured into the carbide vessel. The reactor was immediately sealed, and the stirring was gradually turned on (from 300 to 1100 rpm for 2 h) to avoid vigorous reaction of CaC_2 with water. Then, the reaction was stirred at room temperature for 72 h. After completion of the reaction, the contents of the second vessel were collected by a syringe, washed thrice with water, and dried over sodium sulfate. The resulting solution was additionally passed through a layer of silica gel. The evaporation of the solvent gave pure **4a** (731 mg, 95%).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.8b00155.

Photographs of the two-chamber reactor and experiments, copies of ^{1}H, ^{13}C NMR, and ^{19}F NMR spectra for new compounds, and details on DFT calculations (PDF)

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Notes

The authors declare no competing financial interest.

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