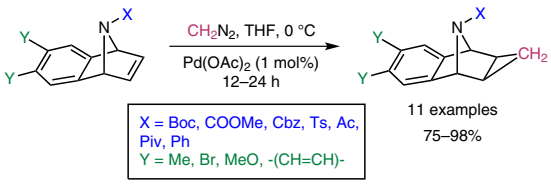
Synthesis E. Carlson, W. Tam Paper

Synthesis of Cyclopropanated 7-Azabenzonorbornadienes

Emily Carlson
William Tam*

Guelph-Waterloo Centre for Graduate Work in Chemistry and Biochemistry, Department of Chemistry, University of Guelph, Guelph, Ontario, N1G 2W1, Canada
wtam@uoguelph.ca



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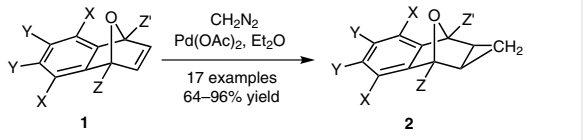
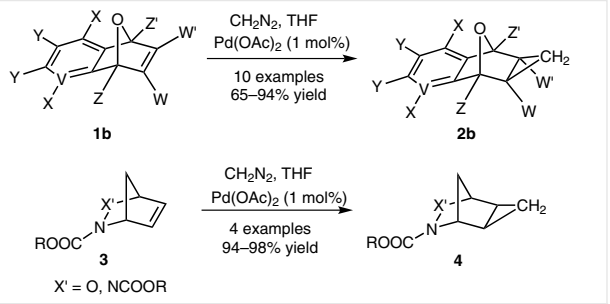
Abstract 7-Azabenzonorbornadienes bearing various aryl or N-substituents were treated with diazomethane in the presence of palladium to afford desirable yields of cyclopropanated products (75–98%). The current approach suggests an efficient synthesis for CH_2-cyclopropanated 7-azabenzonorbornadienes which lends promise to the development of new ring-opening preparations of biologically useful organic frameworks.

Key words 7-azabenzonorbornadiene, cyclopropanation, diazo compounds, diastereoselectivity, palladium catalysis

Synthetic organic chemistry involving cyclopropane intermediates has received significant attention in recent years.[1–3] Most notably, advances in the development of stereoselective cyclopropanation reactions have led to the facile syntheses of bioactive compounds.[4,5] Despite these advancements, cyclopropanation of heterobicycloalkenes is still a largely unexplored area of research, with only a small number of literature reports to date.[6–14] The limitations in cyclopropanation of heterobicycloalkenes may arise from undesirable interactions between heteroatoms and transition-metal catalysts, although the mechanism for this restriction is not yet understood. Using methods documented by Miller and Ji,[7] we have recently succeeded in accomplishing the palladium-catalyzed stereoselective cyclopropanation of 7-oxabenzonorbornadienes **1** to construct a large number of cyclopropanated products **2** (Scheme 1).[9] Furthermore, upon procedural modifications, we have improved the reaction yields and expanded the reaction scope to include more diversely substituted versions of oxabicycloalkenes **1b**, as well as other [2.2.1] heterobicycloalkenes such as 2,3-diaza- and 2-oxa-3-azabicycloalkenes **3**, providing further examples of novel cyclopropanes **2b** and **4** (Scheme 2).[10] All of the observed products were *exo*-cyclopropanated, as confirmed through ^{1}H-coupling analysis, NOE experiments, or X-ray crystal structure data.[9,10]



Scheme 1 Cyclopropanation of 7-oxabenzonorbornadienes[9]

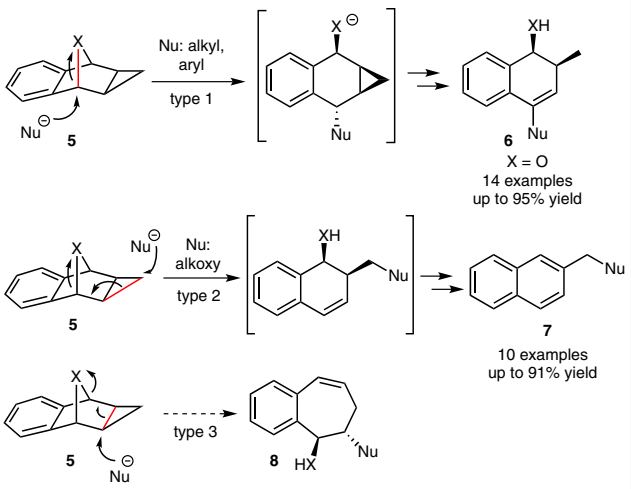


Scheme 2 Recent cyclopropanations of [2.2.1] heterobicycloalkenes[10]

Our particular interest in cyclopropanated heterobicycloalkenes stems from the fact that cyclopropanes are known to exhibit similar reactivities to alkenes.[15] It is thus possible that many of the diverse transformations which heterobicycloalkenes can undergo, such as ring-opening[16–19] or aromatization,[20,21] might be observed with their cyclopropanated analogues. We anticipate that such chemical transformations could lead to the discovery of synthetically useful organic intermediates.

For example, the structure of cyclopropanated heterobicycloalkene **5** suggests three distinct sites of nucleophilic attack (Scheme 3). Shortly after our report on the cyclopropanation of 7-oxabenzonorbornadienes,[9] we learned that

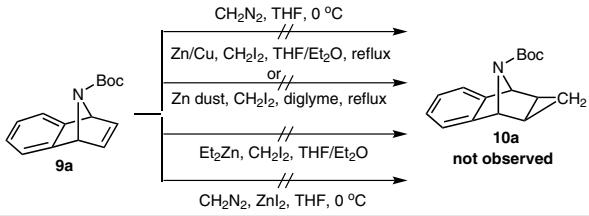
ring-opening reactions of these compounds (X = O in **5**) are capable of producing dihydronaphthalenols **6** or naphthalenes **7**, depending on the reaction conditions.[22,23] Furthermore, the formation of a seven-membered cyclic product **8** could be predicted as an alternative outcome. It thus seemed that extending this chemistry to other heterobicyclic compounds and examining their reactivities could provide valuable insight into these transformations.



Scheme 3 Three distinct modes of nucleophilic ring-opening of cyclopropanated 7-heterobenzonorbornadienes

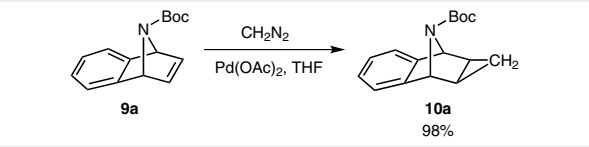
The cyclopropanation of 7-azabenzonorbornadienes has been previously achieved under palladium- or ruthenium-catalyzed conditions, where an internal or terminal alkyne furnishes the cyclopropane carbon.[11–13] The products obtained from these methods, however, bear substituted cyclopropanes which could bias or complicate studies of our proposed modes of nucleophilic attack (Scheme 3). Prinzbach and co-workers have affected the CH_2-cyclopropanation of an electron-deficient 7-azabenzonorbornadiene by uncatalyzed 1,3-dipolar cycloaddition followed by dinitrogen extrusion.[14] While the Prinzbach paper utilizes cyclopropanation as a means to characterize azabicyclic systems, it does not suggest synthetic value of the cyclopropanation chemistry itself. In the present investigation, we demonstrate a method of cyclopropanation which is applicable to a large class of substituted azabenzonorbornadienes for synthetic purposes.

When *tert*-butoxycarbonyl-protected azabenzonorbornadiene **9a** was treated with diazomethane in the absence of any transition-metal catalyst, as described in the Prinzbach publication, no reaction was observed (Scheme 4). It is possible that the uncatalyzed conditions are only fruitful with highly electron-deficient alkenes since, to the best of our knowledge, the dipolar cycloaddition approach for [2.2.1] heterobicycloalkenes has only been shown to proceed with alkenes bearing COOR groups.[8,14] Attempts to cyclopropanate **9a** using other traditional methods according to Simmons and Smith[24] or a modification thereof,[25] Furukawa,[26] and Wittig[27] were each unsuccessful, resulting in complicated mixtures of products or minimal reaction after several days.



Scheme 4 Unsuccessful attempts to cyclopropanate **9a**

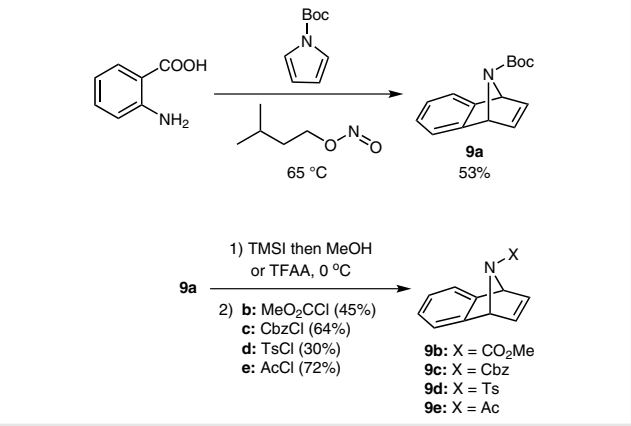
Upon subjecting alkene **9a** to our previously successful reaction conditions in the presence of palladium,[10] we were pleased to find that **9a** was cyclopropanated stereoselectively to provide **10a** in 98% yield (Scheme 5). Encouraged by this observation, additional examples of functionalized azabenzonorbornadienes for cyclopropanation were sought and prepared.



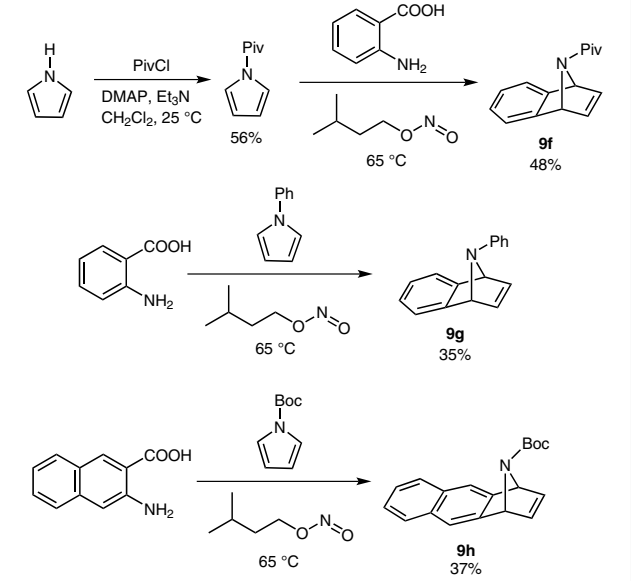
Scheme 5 Cyclopropanation of Boc-protected 7-azabenzonorbornadiene **9a**

Initially, a large quantity of **9a** was prepared by Diels–Alder reaction between commercial *N*-Boc-pyrrole and benzyne, which was generated in situ using *ortho*-aminobenzoic acid and isopentyl nitrite (Scheme 6).[28] Several N-substituted derivatives, **9b**,[29] **9c**[29] and **9d**,[30] could then be obtained from **9a** by utilizing literature methods for deprotection of the *tert*-butoxy group, followed by trapping with the appropriate electrophile. Alkene **9e** was similarly prepared by trapping with acetyl chloride, which was a novel route to its synthesis. Alkenes **9f**,[31] **9g**,[32] and **9h**[31] were also obtained through literature methods involving Diels–Alder cycloaddition between the appropriate N-functionalized pyrrole and an aryne generated between *ortho*-aminobenzoic (or naphthoic) acid and isopentyl nitrite (Scheme 7).

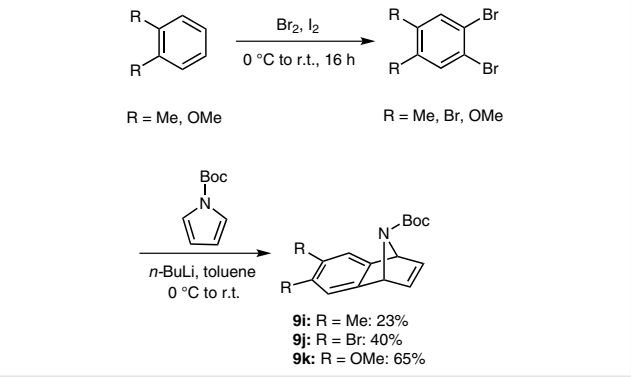
Arene-substituted azabenzonorbornadienes **9i–k** were prepared via derivatization[33] and lithium halide exchange on the benzene ring (Scheme 8).[34] The preparation of **9k** by this method was a new approach to that previously reported.[29] Each of the 7-azabenzonorbornadienes **9a–k** thus prepared were then subjected to cyclopropanation.



Scheme 6 Preparation of N-substituted azabenzonorbornadienes **9a–e**

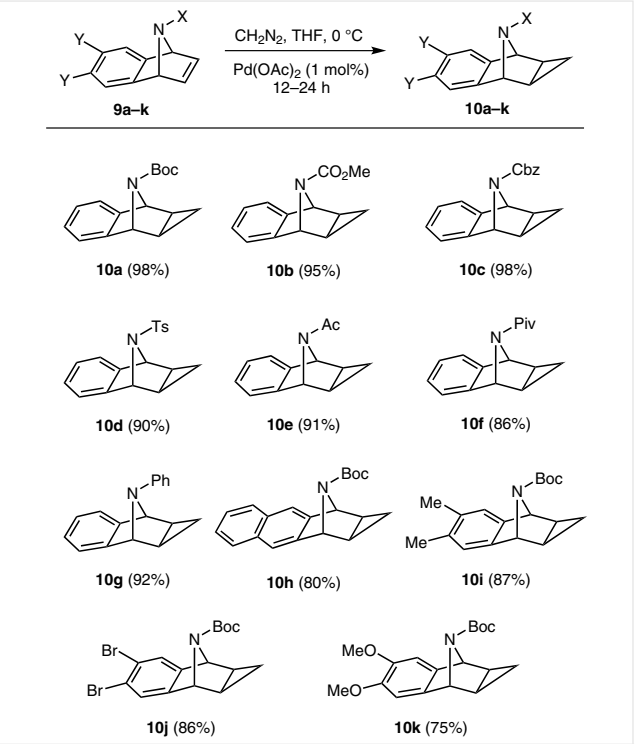


Scheme 7 Preparation of 7-azabenzonorbornadienes **9f–h**



Scheme 8 Preparation of arene-substituted azabenzonorbornadienes **9i–k**

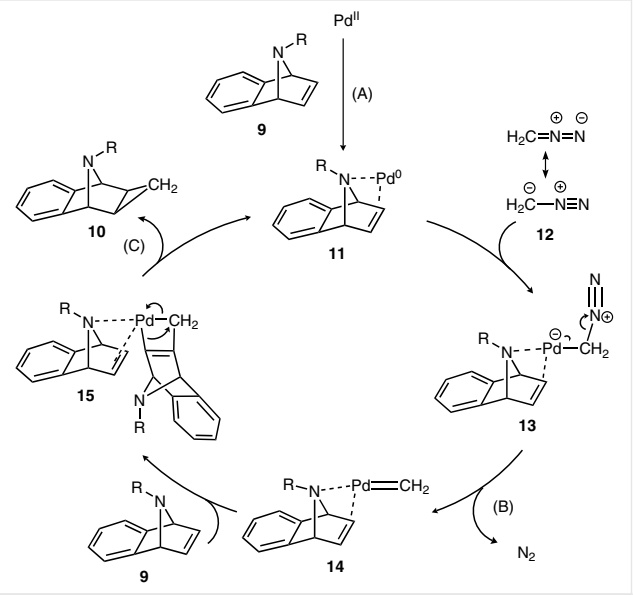
The results of the palladium-catalyzed cyclopropanations of alkenes **9a–k** are summarized in Scheme 9. All the substrates underwent conversion efficiently, with yields being especially high for the *N*-alkoxycarbonyl-substituted substrates **9a–c** (≥95% in all three experiments). Alkenes **9d–g** bearing various other functional groups on nitrogen were also cyclopropanated in excellent yields (≥86%). Arene-substituted azabenzonorbornadienes **9h–k** produced comparable, but slightly lower yields of cyclopropanes **10h–k** in general (75–87%), and no apparent substituent effects could be inferred from this similarity in product yields. Overall, the present cyclopropanation of 7-azabenzonorbornadienes proved to be effective for a wide variety of substitution patterns on the substrate.



Scheme 9 Synthesis of N- and arene-substituted cyclopropanated azabenzonorbornadienes **10a–k**; yields refer to those of isolated products after column chromatography

Mechanistically, we suggest that palladium is central to the reaction, since experiments in the absence of any transition-metal catalyst showed no consumption of the precursor alkene, and attempts to intercept any pyrazoline intermediates in the absence of heat or light were unsuccessful. Thus, it is likely that the mechanism for the cyclopropanation of 7-azabenzonorbornadienes in this work closely follows that of the generally accepted stepwise cyclopropanation of alkenes (Scheme 10).[35,36] In this mechanism, $Pd(OAc)_2$ is first reduced to its active Pd(0) species (A), which proceeds to coordinate with the azabicycloalkene **9**, likely in a bridged fashion which also involves

nitrogen to give **11**. With the introduction of diazomethane (**12**), this complex **11** equilibrates to give intermediate **13** with the expulsion of dinitrogen gas in a rate-limiting step (B). The resulting carbene complex **14** can interact with a second equivalent of the reactant alkene **9**, rearranges into palladacyclobutane **15** and then undergoes reductive elimination (C) to give the cyclopropane product **10**. Since the coordination modes of palladium in general are believed to involve reversible ligand exchange, an accurate picture of the coordination to alkene **9** could be more complex than that shown in Scheme 10.



Scheme 10 Proposed mechanism for the palladium-catalyzed cyclopropanation of 7-azabenzonorbornadienes **9**

In conclusion, we have successfully cyclopropanated 11 examples of 7-azabenzonorbornadienes using CH_2N_2 in the presence of $Pd(OAc)_2$. All the reactions proceeded smoothly, providing high isolated yields of the desired products (75–98%). The cyclopropanes obtained in this work will be implemented in studies of transition-metal-catalyzed ring-opening reactions. As we continue to explore the reactivities of cyclopropanated heterobicycloalkenes, the compounds obtained in this work should provide valuable insight toward the mechanism of the transformations of these unique organic frameworks.

All reactions were performed using a continuous flow apparatus under inert atmosphere, as described previously.[10] Commercial reagents were used without further purification. Flash column chromatography was performed on Silicycle brand 230–400 mesh silica gel, following standard flash column chromatography techniques.[37] Analytical TLC was performed on Silicycle brand precoated silica gel 250 µm 60 F254 aluminum plates. TLC plates were made visual under UV light and by staining with *p*-anisaldehyde or $KMnO_4$. Melting points were obtained using an Electrothermal MEL-TEMP® model 1001D instrument. FTIR spectra were obtained as thin films on NaCl discs using a Nicolet 380-FTIR spectrophotometer, or as solids on an ALPHA platinum single reflection diamond ATR spectrophotometer, and are reported in wavenumbers (cm^{-1}). ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance 400 MHz spectrometer equipped with a cryoprobe and are reported in parts per million (ppm) from the solvent as internal standard ($CDCl_3$: 7.24 ppm for ^1H; 77.0 ppm for ^{13}C); *JMOD* = J-modulated spin-echo. Where ^{13}C NMR peaks appear split due to relative orientation about nitrogen in different invertomers, duplicate peaks are expressed in brackets. HRMS analyses were performed using a Micromass GCT spectrometer at the Queen's Mass Spectrometry and Proteomics Unit, Kingston, Ontario. The samples were ionized by electron impact (EI) and detection of the ions was performed by time of flight (TOF).

7-Azabenzonorbornadienes 9a–k

The azabenzonorbornadienes **9a–k** were synthesized following literature procedures,[28–34] or modifications thereof, as described in the text.

Cyclopropanated 7-Azabenzonorbornadienes 10a–k; General Procedure

HAZARD ALERT! Diazomethane can be fatal if inhaled and can undergo detonation if appreciably concentrated. Refer to Figure 1 for the reaction setup (see the supporting information). Reactor [C], equipped with a small stir bar, was charged with alkene (2.5–6.4 mmol), $Pd(OAc)_2$ (1 mol% with respect to the alkene) and THF (40 mL), and then capped with a septum [E]. To the outlet of reactor [C] was connected in series with Tygon tubing [I]: an empty bubbler [J] to serve as a suck-back trap and a glass inlet tube [K] inserted into filter flask [L]. Bubbler [L] was filled prior to setup with a mixture of glacial AcOH–H_2O (1:1). The outlet of bubbler [L] was connected to a piece of Tygon tubing [I_c] directed to the back of the fume hood. Reactor [C] was then securely fitted to the end of tube [H_b] while cooling its contents in an ice bath. Funnel [A] was filled with 25% (12.5 M) aq NaOH (100–150 equivalents with respect to the alkene) ensuring that stopper [D] was tightly shut, and the funnel was capped with septum [E]. Flask [B], equipped with an extra-large stir bar, was charged with Diazald® (2.6–3.0 equivalents with respect to the alkene) and 95% EtOH (50–100 mL), and the solution was stirred. Flask [B] was then fitted with a stopper [G] containing the inert gas inlet [F], tubing [H_a], and addition funnel [A]. The apparatus was securely clamped at both funnel [A] and flask [B] and a slow stream of argon was passed through the system such that ~3 bubbles per second (bps) were observed from tube [H_a]. Once a constant flow rate of 3–5 bps was established, the 25% NaOH solution was added from funnel [A] into flask [B] at a rate of 1–2 mL/min, maintaining efficient stirring and bubbling. Formation of light yellow CH_2N_2 gas was observed with the dissolution of Diazald®. Upon complete dissipation of the yellow color (4–8 hours), the reaction was assessed by TLC for completion. Once the reaction was seen to be complete by TLC, both septa [E] were removed and the apparatus was left to vent any trace CH_2N_2 (8–16 hours). Reactor [C] was removed and its contents were poured over Celite. The filter cake was washed with several portions of Et_2O (4 × 10–20 mL). The filtrate was then concentrated and the residue purified by column chromatography (hexanes–EtOAc).

Cyclopropanated *N*-Butoxycarbonyl-7-azabenzonorbornadiene (10a)

Yield: 1.61 g (98%); white solid; mp 48–50 °C; R_f = 0.30 (EtOAc–hexanes, 1:9).

IR (NaCl): 3053, 3011, 2978, 2931, 1698 (C=O), 1367, 1172, 1093, 1050, 739 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.28–7.26 (br s, 2 H), 7.11–7.07 (m, 2 H), 5.05 (br s, 1 H), 4.94 (br s, 1 H), 1.37 (s, 9 H), 1.34–1.31 (m, 1 H), 1.21–1.19 (m, 2 H), 1.01–0.96 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 154.9, (148.0, 147.6), 125.7, (120.1, 119.6), 79.9, (61.0, 60.2), 28.3, (21.5, 20.8), 15.9.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{16}H_{19}NO_2$: 257.1416; found: 257.1412.

Cyclopropanated *N*-Methoxycarbonyl-7-azabenzonorbornadiene (10b)

Yield: 511 mg (95%); white solid; mp 162–163 °C; R_f = 0.28 (EtOAc–hexanes, 1:4).

IR (NaCl): 3077, 3028, 2957, 1697 (C=O), 1450, 1368, 1257, 1106 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.31 (br s, 2 H), 7.12 (m, 2 H), 5.14 (br s, 1 H), 5.03 (br s, 1 H), 3.61 (s, 3 H), 1.43 (m, 1 H), 1.25 (m, 2 H), 1.01 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 156.0, (147.9, 147.4), 125.9, (120.2, 119.7), (60.7, 60.5), 52.5, (21.3, 20.7), 16.0.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{13}H_{13}NO_2$: 215.0946; found: 215.0941.

Cyclopropanated *N*-Carboxybenzyl-7-azabenzonorbornadiene (10c)

Yield: 178 mg (98%); white solid; mp 79–82 °C; R_f = 0.20 (EtOAc–hexanes, 1:9).

IR (NaCl): 3031, 3012, 2944, 1702 (C=O), 1453, 1392, 1338, 1246, 1080, 819 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.39–7.24 (m, 7 H), 7.18–7.11 (m, 2 H), 5.20 (s, 1 H), 5.11 (s, 1 H), 5.09 (s, 1 H), 5.03 (s, 1 H), 1.41–1.39 (m, 1 H), 1.27–1.24 (m, 2 H), 1.08–1.03 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 155.3, (147.8, 147.4), 136.5, 128.5, 127.9, 127.7, 125.9, 120.2, 119.7, 66.8, (60.8, 60.7), (21.3, 20.7), 16.0.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{19}H_{17}NO_2$: 291.1259; found: 291.1260.

Cyclopropanated *N*-*p*-Toluenesulfonyl-7-azabenzonorbornadiene (10d)

Yield: 660 mg (90%); beige solid; mp 193–195 °C; R_f = 0.62 (EtOAc–hexanes, 1:1).

IR (NaCl): 3066, 2994, 1337, 1161, 1093, 1042, 1024, 908, 776, 732, 693 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.27–7.25 (m, 2 H), 6.91–6.89 (m, 4 H), 6.81–6.79 (m, 2 H), 4.89 (s, 2 H), 2.25 (s, 3 H), 2.03–2.02 (m, 1 H), 1.27–1.24 (m, 2 H), 1.06 (q, *J* = 6.4 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 145.7, 142.7, 135.3, 128.9, 127.7, 125.7, 120.3, 63.2, 21.7, 21.4, 16.5.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{18}H_{17}NSO_2$: 311.0980; found: 311.0985.

Cyclopropanated *N*-Acetyl-7-azabenzonorbornadiene (10e)

Yield: 517 mg (91%); beige solid; mp 103–105 °C; R_f = 0.08 (EtOAc–hexanes, 1:1).

IR (neat): 3270, 3004, 1627, 1446, 1230, 1204, 1082, 1033, 811 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.34–7.29 (m, 2 H), 7.15–7.13 (m, 2 H), 5.47 (s, 1 H), 4.94 (s, 1 H), 1.98 (s, 3 H), 1.30–1.28 (m, 2 H), 1.17–1.14 (m, 1 H), 1.08–1.04 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 166.8, 147.4, 146.8, 126.1, 125.8, 120.2, 119.4, 61.6, 58.2, 21.5, 21.1, 20.0, 15.9.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{13}H_{13}NO$: 199.0997; found: 199.0999.

Cyclopropanated *N*-Pivaloyl-7-azabenzonorbornadiene (10f)

Yield: 348 mg (86%); white solid; mp 160–162 °C; R_f = 0.38 (EtOAc–hexanes, 3:7).

IR (NaCl): 3046, 3030, 2978, 2965, 1613 (C=O), 1454, 1199, 1044, 746 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.28–7.26 (m, 2 H), 7.11–7.08 (m, 2 H), 5.44 (br s, 1 H), 5.40 (br s, 1 H), 1.25–1.20 (m, 3 H), 1.17 (s, 9 H), 1.01–0.96 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.3, (147.7, 147.0), 125.9, (120.2, 119.1), (61.6, 59.1), 38.7, 27.7, (21.3, 19.5), 15.7.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{16}H_{19}NO$: 241.1467; found: 241.1471.

Cyclopropanated *N*-Phenyl-7-azabenzonorbornadiene (10g)

Yield: 968 mg (92%); white solid; mp 116–118 °C; R_f = 0.47 (EtOAc–hexanes, 1:9).

IR (neat): 3056, 2998, 1595, 1497, 1451, 1317, 1247, 1077, 945, 822 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.39–7.37 (m, 2 H), 7.22–7.14 (m, 4 H), 6.85–6.81 (m, 3 H), 4.99 (s, 2 H), 2.15–2.12 (m, 1 H), 1.44–1.41 (m, 2 H), 1.11–1.06 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 147.9, 147.4, 128.9, 125.8, 121.2, 119.8, 117.2, 63.5, 21.7, 16.0.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{17}H_{15}N$: 233.1204; found: 233.1201.

Cyclopropanated *N*-Butoxycarbonyl-7-azanaphthonorbornadiene (10h)

Yield: 243 mg (80%); white solid; mp 168–169 °C; R_f = 0.35 (EtOAc–hexanes, 1:9).

IR (neat): 3005, 2970, 2932, 1682 (C=O), 1423, 1365, 1253, 1161, 1092, 872 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.82–7.80 (m, 2 H), 7.68 (br s, 1 H), 7.65 (br s, 1 H), 7.48–7.46 (m, 2 H), 5.19 (br s, 1 H), 5.08 (br s, 1 H), 1.38 (s, 9 H), 1.33–1.30 (m, 1 H), 1.27–1.25 (m, 2 H), 0.97–0.93 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 155.2, 145.1, 132.3, (128.2, 128.0), 125.7, (118.4, 117.8), 80.1, (60.8, 60.0), 28.3, (20.6, 20.0), 13.4.

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{20}H_{21}NO_2$: 307.1572; found: 307.1569.

Cyclopropanated *N*-Butoxycarbonyl-*o*-dimethyl-7-azabenzonorbornadiene (10i)

Yield: 560 mg (87%); white solid; mp 121–122 °C; R_f = 0.50 (EtOAc–hexanes, 1:4).

IR (NaCl): 3007, 2975, 2929, 1701, 1392, 1366, 1253, 1173, 1092 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.09 (br d, *J* = 3.4 Hz, 2 H), 5.01 (br s, 1 H), 4.91 (br s, 1 H), 2.25 (s, 6 H), 1.39 (s, 9 H), 1.31–1.27 (m, 1 H), 1.21–1.19 (m, 2 H), 0.97 (q, *J* = 6.4 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 154.7, (145.7, 145.4), 133.4, (121.7, 121.1), 79.8, (60.8, 59.9), 28.3, (21.6, 21.0), 19.9, 15.7.

HRMS (EI): m/z [M]$^+$ calcd for $C_{18}H_{23}NO_2$: 285.1729; found: 285.1722.

Cyclopropanated *o*-Dibromo-*N*-butoxycarbonyl-7-azabenzonorbornadiene (10j)

Yield: 1.33 g (86%); white solid; mp 131–133 °C; R_f = 0.50 (EtOAc–hexanes, 1:4).

IR (NaCl): 3013, 2977, 2935, 1699, 1477, 1392, 1367, 1253, 1169, 1095, 1050, 872, 825 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52 (br s, 2 H), 5.00 (br s, 1 H), 4.91 (br s, 1 H), 1.41–1.38 (m, 1 H), 1.37 (s, 9 H), 1.21–1.19 (m, 2 H), 1.01 (q, J = 6.5 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 154.7, (149.0, 148.6), (125.6, 125.0), 121.4, 80.6, (60.6, 59.8), 28.2, (21.1, 20.4), 15.7.

HRMS (EI): m/z [M]$^+$ calcd for $C_{16}H_{17}NO_2Br_2$: 412.9626; found: 412.9620.

Cyclopropanated *N*-Butoxycarbonyl-*o*-dimethoxy-7-azabenzonorbornadiene (10k)

Yield: 227 mg (75%); beige solid; mp 120–122 °C; R_f = 0.16 (EtOAc–hexanes, 1:4).

IR (neat): 3004, 1692, 1484, 1352, 1288, 1166, 1074, 1067, 858 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.93 (s, 1 H), 6.89 (s, 1 H), 4.96 (s, 1 H), 4.86 (s, 1 H), 3.82 (s, 6 H), 1.33 (s, 9 H), 1.31–1.28 (m, 1 H), 1.15–1.12 (m, 2 H), 0.96–0.91 (m, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$, JMOD): δ = 154.9, 146.5, (140.6, 140.1), (105.6, 105.2), 79.9, (61.3, 60.4), (56.3, 56.2), 28.3, (21.9, 21.2), 16.2.

HRMS (EI): m/z [M]$^+$ calcd for $C_{18}H_{23}NO_4$: 317.1627; found: 317.1622.

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Supporting Information

Supporting information for this article is available online at http://dx.doi.org/10.1055/s-0035-1561600.

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