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Note

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Synthesis of 5*H*-Dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones from Benzamides via Palladium-Catalyzed Double C–H Bond Activation

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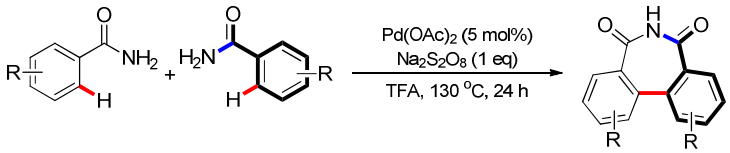
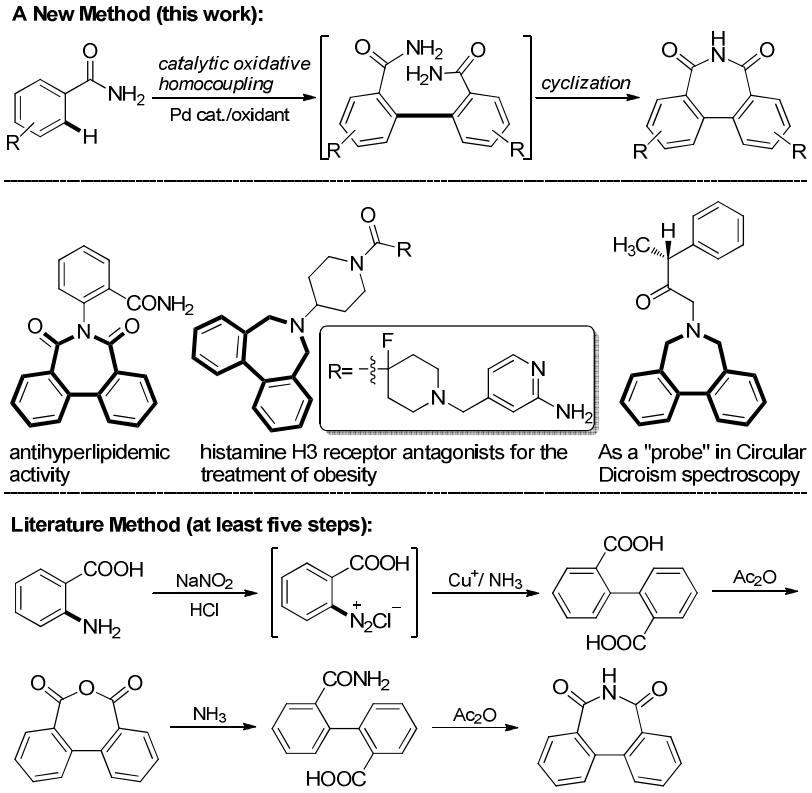


ABSTRACT: A convenient and efficient method for the synthesis of 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones from simple and readily available benzamides is described in this work. The palladium-catalyzed homo-coupling of benzamides occurred via *ortho*-selective double C–H bond activation using the simplest amide $CONH_2$ as a directing group. The subsequent intramolecular condensation reaction proceeded smoothly to produce 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones in satisfactory to excellent yields in one pot.

The transition-metal-catalyzed direct coupling between aromatic rings via double C–H bond activation has recently emerged as an extremely powerful tool for the synthesis of biaryl compounds.[1,2] An appropriate directing group is usually required to control regioselectivity in this type of C_{aryl}–C_{aryl} bond coupling reaction, which includes cross-coupling and homo-coupling. Over the past decades, various directing groups, such as heterocycles,[3] acyl groups,[4] carboxyl groups,[5] *N*-substituted-amide groups,[6] and *N*-substituted acetamide groups,[7] have been successfully employed for this purpose. Among the myriad directing groups utilized so far, *N*-substituted-amide groups, including secondary and tertiary amide groups, have been frequently used not only for the C_{aryl}–C_{aryl} bond coupling reaction, but also for other kinds of coupling reactions because of their unique reactivities in transition-metal-catalyzed C–H functionalizations.[8] In comparison with *N*-substituted-amide groups, the free form, namely, primary amide group ($CONH_2$), has been rarely utilized as a directing group in the C–H functionalizations. Only two examples have been previously reported in the literature; such studies used primary amide as the directing group in the *ortho*-arylation of benzamides with aryl iodides[9] as well as in the benzylation of benzamides with benzyl bromides.[10] The primary amide-directing group is more easily functionalized after the desired operation. Therefore, the development of a new C–H functionalization method for C_{aryl}–C_{aryl} bond coupling reaction, using primary amide as the directing group, is an

important requirement. The direct homo-coupling of benzamides can provide a new protocol with which to access 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones (Scheme 1).

Scheme 1. Methods for the synthesis of 5*H*-dibenzo[*c*,*e*] azepine-5,7(6*H*)-diones.



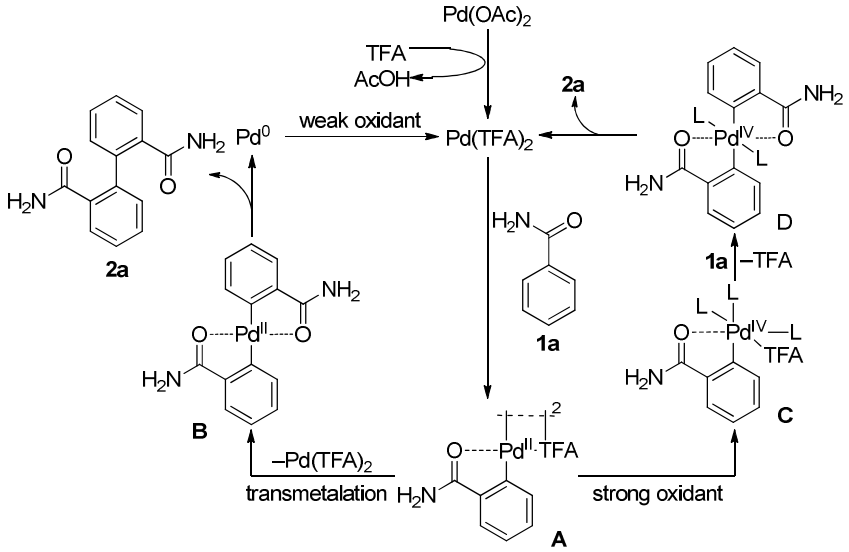
5*H*-Dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones represent an interesting structural motif found frequently in biologically active compounds. As pharmaceuticals, 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-dione derivatives and their analogues exhibit remarkable properties, such as antihyperlipidemic active,[11] P-glycoprotein(P-gp)-mediated multidrug resistance (MDR) reversal agents,[12]

hypolipidemic agents in rats,[13] histamine H3 receptor antagonists for the treatment of obesity,[14] potent inhibitors of the activity of human Tmolt4 T cell leukemia type IIIMP dehydrogenase (IMPDH),[15] and anti-epinephrine activity.[16] Therefore, the development of a convenient and efficient method for the synthesis of 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones has attracted considerable attention. The 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-dione skeleton is conventionally synthesized through a sequence of steps, including aryl–aryl linkage through the homo-coupling of 2-amino benzoic acids through azo intermediate, diphenicanhydride formation through intramolecular dehydrative condensation of diphenic acid, nucleophilic substitution of diphenicanhydride with ammonia, and intramolecular dehydrative cyclization (Scheme 1).[11]

Homo-coupling products of benzamides have been observed as byproducts in small amounts in the palladium-catalyzed direct *ortho*-arylation of benzamides with aryl iodides.[9] This finding indicates that the diarylated benzamides might be obtained as major products after optimization of reaction conditions. Based on the literatures, the palladium-catalyzed direct homo-coupling of benzamides is speculated to proceed through different two catalysis cycles (Scheme 2): one catalysis cycle involves Pd^{0} and Pd^{II} species in the presence of weak oxidant,[17] and another involves two sequential C–H activation at Pd^{II} and Pd^{IV}, respectively, in the presence of strong oxidant.[18] Satisfactory yields of diarylated benzamides could not be obtained by using a weak oxidant.[9] This observation encourages further examination of the palladium-catalyzed direct

homo-coupling of benzamides by using a strong oxidant. The homo-coupling of benzamides occurred, as expected, in the presence of a strong oxidant to produce 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones in one pot. The results are reported in the current work.

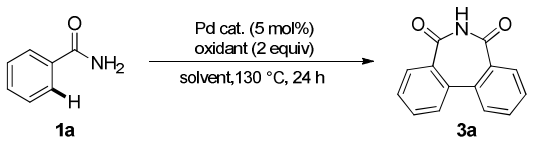
Scheme 2. Proposed reaction mechanism for palladium-catalyzed direct homo-coupling of benzamides.



The palladium-catalyzed homo-coupling reaction of benzamide (**1a**) was selected as a model reaction to optimize the reaction conditions in the initial studies. The optimization included the selection of the most suitable precatalysts, oxidants, solvents, and reaction temperature as shown in Table 1. Several palladium precatalysts, including $Pd(OAc)_2$, $Pd(acac)_2$, $PdCl_2$, $Pd_2(dba)_3$, and $Pd(PPh_3)_2Cl_2$, were initially tested in the presence of a

strong oxidant, potassium persulfate ($K_2S_2O_8$), in trifluoroacetic acid (TFA) at 130 °C (entries 1–5). The desired product, 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-dione (**3a**), was obtained in 43% yield by using $Pd(OAc)_2$ as the precatalyst (entry 1), thus indicating that the homo-coupling reaction of **1a** occurred as expected when a strong oxidant was utilized. The oxidants were subsequently screened using $Pd(OAc)_2$ as a precatalyst and TFA as a solvent. $Na_2S_2O_8$ proved to be the best among the tested oxidants, namely, $K_2S_2O_8$, ammonium persulfate [$(NH_4)_2S_2O_8$], 1,4-benzoquinone (BQ), 2-hydroperoxy-2-methylpropane (^{t}BuOOH), di-*tert*-butyl peroxide (DTBP), and sodium persulfate ($Na_2S_2O_8$) (entry 1 vs. entries 6–10). The reaction time and temperature were subsequently screened using $Pd(OAc)_2$, $Na_2S_2O_8$, and TFA as the precatalyst, oxidant, and solvent, respectively. The **3a** yield decreased or did not changed when the reaction time was shortened to 12 h or prolonged to 36 h (entry 10 vs. entries 11 and 12); the **3a** yield was decreased to 52% or 60% when the model reaction was performed at 120 °C or 140 °C (entry 10 vs. entries 13 and 14). TFA proved to be the best solvent after screening. Therefore, the subsequent double C–H activation reactions of various benzamides were performed for 24 h in the presence of $Pd(OAc)_2$ as a precatalyst and $Na_2S_2O_8$ as an oxidant in TFA at 130 °C.

Table 1. Reaction Condition Screening[a]



1a **3a**

entry	catalyst	oxidant	solvent	yield (%)
1	$Pd(OAc)_2$	$K_2S_2O_8$	TFA	43[b]
2	$Pd(acac)_2$	$K_2S_2O_8$	TFA	0[c]
3	$PdCl_2$	$K_2S_2O_8$	TFA	0[c]
4	$Pd_2(dba)_3$	$K_2S_2O_8$	TFA	0[c]
5	$Pd(PPh_3)_2Cl_2$	$K_2S_2O_8$	TFA	0[c]
6	$Pd(OAc)_2$	$(NH_4)_2S_2O_8$	TFA	trace[c]
7	$Pd(OAc)_2$	BQ	TFA	0[c]
8	$Pd(OAc)_2$	^{t}BuOOH	TFA	0[c]
9	$Pd(OAc)_2$	DTBP	TFA	0[c]
10	$Pd(OAc)_2$	$Na_2S_2O_8$	TFA	83
11	$Pd(OAc)_2$	$Na_2S_2O_8$	TFA	56[d]
12	$Pd(OAc)_2$	$Na_2S_2O_8$	TFA	83[e]
13	$Pd(OAc)_2$	$Na_2S_2O_8$	TFA	52[f]
14	$Pd(OAc)_2$	$Na_2S_2O_8$	TFA	60[g]
15	$Pd(OAc)_2$	$Na_2S_2O_8$	AcOH	trace[c]
16	$Pd(OAc)_2$	$Na_2S_2O_8$	dioxane	trace[c]

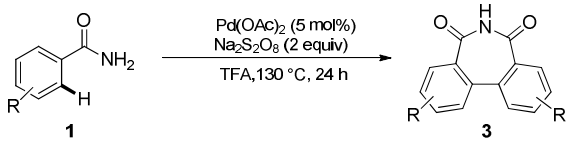
[a]Reaction conditions: **1a** (1.0 mmol, 121.1 mg), catalyst (5 mol%), oxidant (1.0 mmol) in solvent (2.0 mL) at 130 °C for 24 h under air atmosphere. [b]^{1}H NMR yield; dibromomethane was used as an internal standard. [c]Starting material **1a** was recovered. [d]The reaction was performed for 12 h. [e]The reaction was performed for 36 h. [f]The reaction was performed at 120 °C. [g]The reaction was performed at 140 °C.

The scope and limitation of this type of double C–H activation reaction were determined under the optimal reaction conditions. The results are summarized in Table 2. The reaction of substrate **1b** bearing a methyl group on the *para*-position of benzene ring proceeded smoothly under the optimized conditions, like the simplest substrate **1a**, to offer an excellent yield (90%) of the corresponding cyclic compound **3b** (entries 1 and 2). However, a methyl group linked on the *meta*-position of benzamide substrate **1c** led to

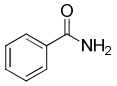
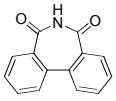
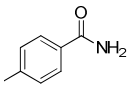
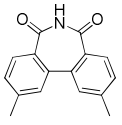
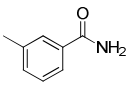
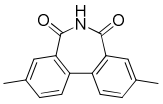
the formation of cyclic compound **3c** in a relatively low yield (entry 3, 73%). Furthermore, no reaction was observed when the benzamide substrate **1d** bearing a methyl group on the *ortho*-position of benzene ring was examined (entry 4). The relatively low yield and non-reaction observed can be attributed to the steric hindrance caused by the *meta*- or *ortho*-methyl group linked on benzene ring. Meanwhile, a moderate yield (64%) was observed when the benzamide substrate **1e** bearing two methyl groups on the *meta*- and *para*-positions of benzene ring was treated under the optimized conditions (entry 5). The reaction of benzamide substrate **1f** proceeded smoothly to produce the desired cyclic compound **3f** in a good yield (87%), even though a bulky substituent (^{t}Bu) was linked on the *para*-position of benzene ring (entry 6). The steric effect of methoxy group (MeO) on the reactivity of benzamide substrate was more evident than that of the methyl group (entry 7 vs. entry 3). A low yield (46%) was observed in the reaction of *meta*-methoxy benzamide (**1g**). Low yields (40% and 37%, respectively) were observed in the reactions of benzamide substrates **1h** and **1i** containing an electron-withdrawing group (F) on the benzene ring (entries 8 and 9). The results indicated that the reactivity of benzamide substrate was lowered by a strong electron-withdrawing group, and the substituent position did not exert significant influence on reactivity. The reaction of *para*-brominated benzamide **1j** or *para*-chlorinated benzamide **1l** resulted in excellent yields (91% and 93%, respectively) of the corresponding cyclic compounds **3j** or **3l** (entries 10 and 12). In addition, the desired product, **3k**, was obtained in a relatively low yield (43%) owing to the steric

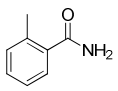
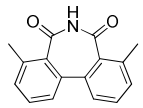
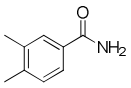
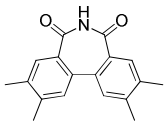
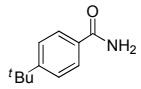
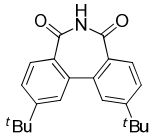
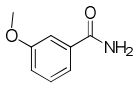
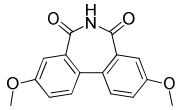
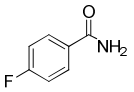
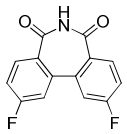
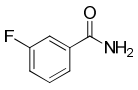
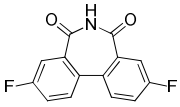
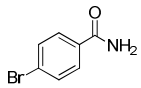
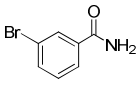
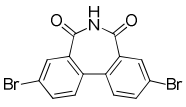
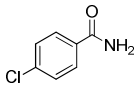
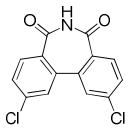
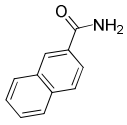
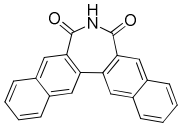
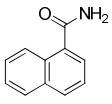
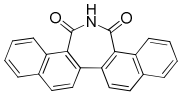
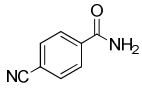
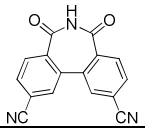
hindrance of *meta*-bromine atom (entry 11). Br and Cl atoms linked to the benzene ring were notably maintained in the structures of products **3j**−**3l**, suggesting that further manipulation may produce more useful compounds. To further explore the reaction scope, the fused aromatic ring-containing substrates, 2-naphthamide (**1m**) and 1-naphthamide (**1n**), were examined under the optimized reaction conditions. The desired product, **3m**, was obtained in 57% yield (entry 13). However, no reaction was observed when the 1-naphthamide (**1n**) was examined (entry 14). This behavior was attributed to the steric hindrance caused in the substrate molecule. No reaction was observed again when 4-cyanobenzamide (**1o**) bearing a more stronger electron-withdrawing group was treated under the optimal reaction conditions; the starting material **1o** was recovered in 26% yield (entry 15).

Table 2. Synthesis of 5*H*-Dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones from various Benzamides[a]



1 **3**

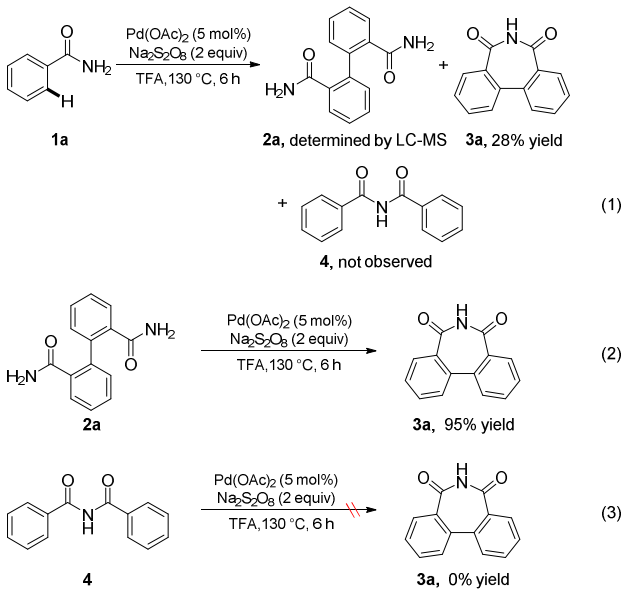
entry	ketone **1**		product **3**		yield (%)
1		**1a**		**3a**	83
2		**1b**		**3b**	90
3		**1c**		**3c**	73

4		**1d**		**3d**	0
5		**1e**		**3e**	64
6		**1f**		**3f**	87
7		**1g**		**3g**	46
8		**1h**		**3h**	40
9		**1i**		**3i**	37
10		**1j**		**3j**	91
11		**1k**		**3k**	43
12		**1l**		**3l**	93
13		**1m**		**3m**	57
14		**1n**		**3n**	0
15		**1o**		**3o**	0

[a]Reaction conditions: benzamide (**1**, 1.0 mmol), $Pd(OAc)_2$ (11.2 mg, 5 mol%), and $Na_2S_2O_8$ (238.11 mg, 1.0 mmol) in TFA (2.0 mL) at 130 °C for 24 h under air atmosphere.

Control experiments were conducted to gain insights into the mechanism of this type of double C–H bond activation reaction. The palladium-catalyzed double C–H activation reaction of benzylamide (**1a**) was conducted using $Na_2S_2O_8$ as the oxidant in TFA at 130 °C for 6 h. The formation of small amount of intermediate **2a**, namely, the homo-coupling product, was observed by HPLC-MS determination. The cyclic product, **3a**, was separated and produced a 28% yield, whereas no formation of *N*-benzoylbenzamide (**4**) was observed; the sarting material **1a** was recovered in 46% yield (Scheme3, Eq. 1). Intermediates **2a** and **4** were prepared and treated under optimized reaction conditions to further confirm the reaction mechanism (Scheme3, Eqs. 2 and 3). The target product, **3a**, was obtained in 95% yield through the intramolecular condensation of **2a**. No reaction was observed when **4** was treated at the same conditions. These results demonstrated that the desired cyclic products, 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones, were formed via homo-coupling products of benzamides.

Scheme 3. Control experiments.



In summary, a convenient and efficient method is developed for the synthesis of 5*H*-dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones through palladium-catalyzed direct homo-coupling reaction of benzamides and subsequent intramolecular condensation reaction in one pot. The simplest amide $CONH_2$ is succesfully used as a directing group for C_{aryl}–C_{aryl} bond coupling reaction in the presence of a strong oxidant for the first time. The wide availability of the starting materials and experimental simplicity could make the present method more useful in future organic synthesis applications.

EXPERIMENTAL SECTION

General Information.

Solvents were purified by standard techniques without special instructions. ^{1}H and ^{13}C

NMR spectra were recorded on a 400 spectrometer (400 MHz for ^{1}H, 100 MHz for ^{13}C); DMSO-d_6 was used as a solvent. The chemical shifts are reported in ppm (δ), and the coupling constants J are given in Hz. The peak patterns are indicated as follows: s, singlet; d, doublet; m, multiplet. IR spectra were recorded on a FT-IR spectrometer. High resolution mass spectra were recorded on either a Q-TOF mass spectrometer or a GC-TOF mass spectrometer. TLC was carried out on SiO_2, and the spots were located with UV light. The starting materials **1a**–**1o** are commercially available.

Procedure for Preparation of 2,2'-Diphenyldicarboxamide

To diphenic acid (1.21g, 5 mmol) $SOCl_2$ (8.0 ml) was slowly added at 0 °C. After the mixture was refluxed for 4 h, the excess of $SOCl_2$ was removed under reduced pressure. Then, the crude product was treated with concentrated ammonia solution at 0 °C and stirred at room temperature for 2 h. The crude product was extracted with ethyl acetate (10 mL × 3), and the combined organic layers were washed with brine (10 mL × 2), dried over Na_2SO_4. The solvent was removed under reduced pressure, and the residue was purified via silica gel chromatography (eluent: petroleum ether/ethyl acetate = 5:1) to afford the desired product **2a** as a white solid (516 mg, 43% yield).**Representative Procedure for the Synthesis of 5*H*-Dibenzo[*c*,*e*]azepine-5,7(6*H*)-diones**

A reaction flask was charged with a mixture of $Pd(OAc)_2$ (11.2 mg, 0.05 mmol), $Na_2S_2O_8$ (238.1 mg, 1 mmol), benzamide (**1a**, 121.1 mg, 1 mmol), and trifluoroacetic acid (2 mL). The reaction mixture was stirred at 130 °C for 24 h, and then was cooled to room temperature. The solvent was removed under reduced pressure, and the residue

obtained was neutralized with Et_3N (1.0 mL). The crude product was dissolved in saturated $NaHCO_3$ solution followed by extraction with ether (10 mL × 3), and the combined organic layers were dried over anhydrous Na_2SO_4. The solvent was removed under vacuum. The crude product was purified by column chromatography (eluent, ethyl acetate : petroleum ether = 1 : 5) to afford **3a** as a white solid (92.5 mg, 83% yield).

2,2'-Diphenyldicarboxamide (**2a**):[19] white solid (516 mg, 43% yield), mp 208–210 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.97 (s, 2H), 7.55–7.46 (m, 2H), 7.46–7.37 (m, 4H), 7.31 (s, 2H), 7.11–7.01 (m, 2H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 171.6, 139.2, 137.1, 129.7, 129.4, 127.8, 127.5.

5H-Dibenzo[c,e]azepine-5,7(6H)-dione (**3a**):[20] white solid (92.5 mg, 83% yield), mp 184–186 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.71 (s, 1H), 7.93 (dd, J = 7.8, 1.2 Hz, 2H), 7.83 (d, J = 7.8 Hz, 2H), 7.80–7.74 (m, 2H), 7.65–7.58 (m, 2H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 168.6, 135.4, 133.4, 133.3, 131.0, 130.5, 129.4; HRMS-APCI (m/z): [M-H]$^-$ Calculated for $C_{14}H_8NO_2$, 222.0561; found, 222.0570.

2,10-Dimethyl-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3b**): pale yellow solid (113.0 mg, 90% yield), mp 222–224 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.51 (s, 1H), 7.82 (d, J = 8.0 Hz, 2H), 7.65 (s, 2H), 7.40 (dd, J = 8.0, 0.8 Hz, 2H), 2.45 (s, 6H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 168.4, 143.6, 135.5, 131.2, 130.8, 130.6, 130.0, 21.5; IR (KBr): 3453.7, 1697.2, 1658.7, 1602.3, 1353.1, 1297.4, 1269.2, 1152.7, 657.0 cm^{-1}; HRMS-APCI (m/z): [M-H]$^-$ Calculated for $C_{16}H_{12}NO_2$, 250.0874; found, 250.0870.

3,9-Dimethyl-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3c**): white solid (91.6 mg, 73% yield), mp 216–218 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.62 (s, 1H), 7.73 (d, J = 1.1

Hz, 2H), 7.70 (s, 1H), 7.68 (s, 1H), 7.56 (dd, J = 8.1, 1.4 Hz, 2H), 2.41 (s, 6H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6) δ: 168.6, 138.8, 134.1, 132.8, 132.8, 131.6, 130.2, 20.9; IR (KBr): 3445.8, 1683.9, 1660.8, 1447.2, 1313.6, 823.0 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{16}H_{12}NO_2$, 250.0874; found, 250.0869.

2,3,9,10-Tetramethyl-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3e**): white solid (89.28 mg, 64% yield), mp 233–235 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.44 (s, 1H), 7.70 (s, 2H), 7.62 (s, 2H), 2.37 (s, 6H), 2.32 (s, 6H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6) δ: 167.9, 142.0, 137.1, 132.6, 131.3, 130.5, 129.9, 19.4, 18.8; IR (KBr): 3182.2, 3070.6, 1655.4, 1606.5, 1287.5 427.4 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{18}H_{16}NO_2$, 278.1187; found, 278.1192.

2,10-Di-tert-butyl-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3f**): yellow denser liquid (145.7 mg, 87%). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.53 (s, 1H), 7.89 (s, 1H), 7.87 (s, 1H), 7.71 (d, J = 1.7 Hz, 2H), 7.66 (dd, J = 8.3, 1.7 Hz, 2H), 1.37 (s, 18H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6) δ: 168.3, 156.3, 135.7, 131.1, 130.7, 127.0, 126.5, 35.4, 31.1; IR (neat): 3336.4, 2961.9, 1678.9, 1158.6, 789.0, 700.0 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{22}H_{24}NO_2$, 334.1813; found, 334.1814.

3,9-Dimethoxy-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3g**): white solid (65.1 mg, 46% yield), mp 217–219 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.67 (s, 1H), 7.73 (d, J = 8.7 Hz, 2H), 7.40 (d, J = 2.9 Hz, 2H), 7.33 (dd, J = 8.7, 2.9 Hz, 2H), 3.87 (s, 6H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6) δ: 168.2, 159.2, 133.7, 131.9, 128.0, 120.1, 114.7, 56.0; IR (KBr): 3446.1, 3179.3, 2924.4, 1601.6. 1486.7, 1337.1, 1239.0, 1042.0, 818.8, 760.6,

624.3 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{16}H_{12}NO_4$, 282.0772; found, 282.0780.

2,10-Difluoro-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3h**): white solid (51.8 mg, 40% yield), mp 246–248 ºC. ^1H NMR (400 MHz, DMSO-d_6) δ: 11.76 (s, 1H), 7.99 (dd, J = 8.8, 6.1 Hz, 2H), 7.77 (dd, J = 10.5, 2.5 Hz, 2H), 7.52–7.44 (m, 2H); $^{13}C\{^1H\}$ NMR (100 MHz, DMSO-d_6) δ: 166.8, 164.3 (d, J_{C-F} = 199.6 Hz), 136.5 (d, J_{C-F} = 7.2 Hz), 134.1 (d, J_{C-F} = 7.6 Hz), 129.4 (d, J_{C-F} = 2.2 Hz), 116.8 (d, J_{C-F} = 15.1 Hz), 116.7 (d, J_{C-F} = 13.3 Hz); IR (KBr): 3449.0, 2920.4, 1702.2, 1670.1, 1364.9, 1300.6, 1210.7, 860.2 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{14}H_6F_2NO_2$, 258.0372; found, 258.0372.

3,9-Difluoro-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3i**): white solid (48.0 mg, 37% yield), mp 236–238 ºC. ^1H NMR (400 MHz, DMSO-d_6) δ: 11.95 (s, 1H), 7.89 (dd, J = 8.6, 5.3 Hz, 2H), 7.74–7.58 (m, 4H); $^{13}C\{^1H\}$ NMR (100 MHz, DMSO-d_6) δ: 166.5, 161.6 (d, J_{C-F} = 246.6 Hz), 134.5 (d, J_{C-F} = 7.5 Hz), 132.9 (d, J_{C-F} = 8.1 Hz), 130.7 (d, J_{C-F} = 3.4 Hz), 120.2 (d, J_{C-F} = 21.4 Hz), 116.8 (d, J_{C-F} = 24.0 Hz); IR (KBr): 3179.9, 3074.9, 1679.2, 1587.0, 1420.1, 1313.8, 830.7, 769.6 cm^{-1}; HRMS-APCI (m/z): $[M-H]^-$ Calculated for $C_{14}H_6F_2NO_2$, 258.0372; found, 258.0365.

2,10-Dibromo-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3j**): white solid (173.3 mg, 91% yield), mp 288–290 ºC. ^1H NMR (400 MHz, DMSO-d_6) δ: 11.83 (s, 1H), 8.11 (s, 2H), 7.84 (s, 4H); $^{13}C\{^1H\}$ NMR (100 MHz, DMSO-d_6) δ: 167.6, 135.8, 133.2, 133.0, 132.8, 132.5, 127.3; IR (KBr): 3434.4, 3335.5, 3252.6, 1692.7, 1584.7, 1382.0, 1347.8, 1302.0, 1147.2, 840.6 cm^{-1}; HRMS-ESI (m/z): $[M-H]^-$ Calculated for $C_{14}H_6Br_2NO_2$, 379.8751;

found, 379.8750.

3,9-Dibromo-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3k**): white solid (82.0 mg, 43% yield), mp 306–308 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.96 (s, 1H), 8.02 (d, J = 2.2 Hz, 2H), 7.96 (dd, J = 8.5, 2.2 Hz, 2H), 7.79 (s, 1H), 7.77 (s, 1H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 166.9, 136.2, 134.8, 133.7, 133.3, 132.6, 122.9; IR (KBr): 3449.1, 3065.3, 2890.6, 1667.4, 1398.5, 1306.2, 822.1, 685.3 cm^{-1}; HRMS-APCI (m/z): [M-H]$^{-}$ Calculated for $C_{14}H_6Br_2NO_2$, 379.8751; found, 379.8764.

2,10-Dichloro-5H-dibenzo[c,e]azepine-5,7(6H)-dione (**3l**): white solid (135.7 mg, 93% yield), mp 270–272 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.83 (s, 1H), 8.00 (d, J = 2.1 Hz, 2H), 7.94 (s, 1H), 7.92 (s, 1H), 7.71 (dd, J = 8.5, 2.1 Hz, 2H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 167.4, 138.3, 135.9, 133.3, 132.1, 130.2, 129.7; IR (KBr): 3443.3, 3072.4, 1669.6, 1387.8, 1309.1, 871.5, 840.2 cm^{-1}; HRMS-APCI (m/z): [M-H]$^{-}$ Calculated for $C_{14}H_7Cl_2NO_2$, 289.9781; found, 289.9786.

6H-Dinaphtho[2,3-c:2',3'-e]azepine-6,8(7H)-dione (**3m**):[21] white solid (92.0 mg, 57% yield), mp. >300 ºC. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.75 (s, 1H), 8.60 (s, 2H), 8.49 (s, 2H), 8.20–8.15 (m, 4H), 7.75–7.66 (m, 4H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6) δ: 168.7, 135.1, 132.4, 132.1, 132.1, 131.5, 130.7, 129.4, 129.2, 128.6, 128.2.

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SUPPORTING INFORMATION

Copies of ^{1}H and ^{13}C NMR spectra. This material is available free of charge via the Internet at http://pubs.acs.org.

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