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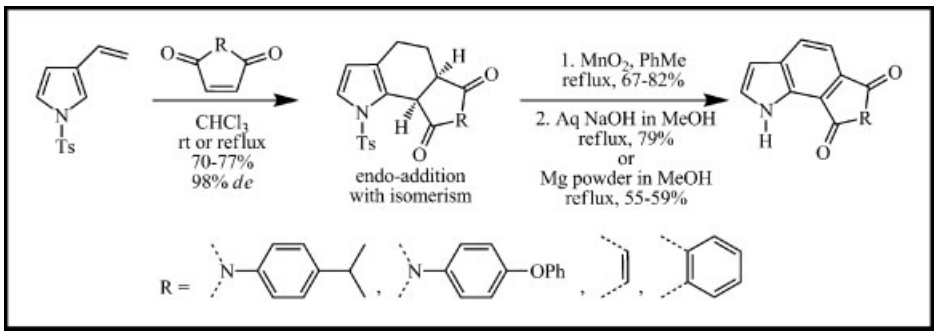

N-*p*-Toluenesulfonyl-3-vinylpyrrole underwent *endo*-addition [4 + 2] cycloaddition reactions with maleimides and benzoquinones, followed by isomerization to give tetrahydroindoles in good yields. Dehydrogenation with activated MnO_2 in refluxing toluene gave the corresponding indoles in fair to good yields. Detosylation *via* saponification or with magnesium in refluxing methanol gave the *N*-H indoles in moderate to good yields. This method for formation of indoles is both convergent and versatile and uses starting materials that are conveniently prepared.

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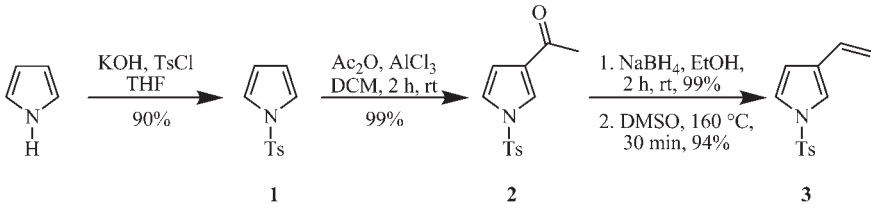
INTRODUCTION

Synthesis of the indole nucleus continues to receive much attention [1] due to its common occurrence in the molecules of living systems and also the biological activity exhibited in both natural [2] and synthetic [3] indole-containing products. We have reported that tetrahydroindoles are available *via* 2-vinylpyrroles derived from an acid-catalyzed condensation of pyrrole with cyclic ketones, followed by *in situ* trapping by various maleimides in a Diels-Alder reaction [4,5]. We recently reported that indoles are available from oxidation of tetrahydroindoles synthesized by Diels-Alder reactions of both *N*-H and *N*-alkyl-2-vinylpyrroles with a wide range of *N*-substituted maleimides [6]. To expand upon this general methodology, in a desire to find improved synthetic methods towards indole and to generate novel indoles for biological testing, we chose to study the use of 3-vinylpyrroles as the diene in Diels-Alder reactions.

Pyrrole preferentially undergoes electrophilic attack at its 2-position as the most stable resonance structure of the reactive species has its greatest electron density α to the iminium nitrogen. Therefore, 2-vinylpyrroles are the most obviously accessible vinylated pyrroles, and there are numerous examples of 2-vinylpyrroles being used as dienes in Diels-Alder reactions [4,7–10]. Several of these studies report biological activity from the resulting class of compounds and the corresponding aromatized indoles, particularly anti-cancer activity [4,10].

To the best of our knowledge, only four reports of 3-vinylpyrroles being used in Diels-Alder reactions exist [8,9,11,12]. Jones *et al*. reported the Diels-Alder reaction of *N*-*t*-butyl-3-vinylpyrrole with DMAD and oxidation with DDQ to give the corresponding indoles [8]. Murase *et al*. reported Diels-Alder reactions of sulfur-substituted *N*-methyl-3-vinylpyrrole generated *in situ* from the corresponding 3-thioacetylpyrrole, using as the dienophile DMAD, maleic anhydride, *N*-methylmaleimide, 1,4-naphthoquinone, and several unsymmetrical alkenes, followed by DDQ aromatization of the indoles [11]. The Diels-Alder adducts were not isolated, but were oxidized directly to the indoles in a maximum of 31% yield over three steps. Xiao and Ketcha reported Diels-Alder reactions of *N*-benzenesulfonyl-3-vinylpyrrole and ethyl 3-(1-(benzenesulfonyl)-1*H*-2-pyrrolyl)acrylate with *N*-phenylmaleimide and maleic anhydride, without taking the adducts through to the indoles [9]. Most recently, Hodges *et al*. reported Diels-Alder reactions of osmium-complexed *N*-methyl-3-vinylpyrroles with *N*-phenylmaleimide to give tetrahydroindoles, which were then oxidized with DDQ to give the corresponding indoles, but difficulties with oxidation and pyrrole polymerization were experienced [12]. In most of the prior examples of Diels-Alder reactions of 3-vinylpyrroles, the isolated tetrahydroindole had isomerized from the originally formed adducts, with a double bond having moved into the five-membered ring to form the aromatic pyrrole. In the one exception, the work by Hodges *et al*. [12], the

Scheme 1. Synthesis of *N*-*p*-toluenesulfonyl-3-vinylpyrrole **3**.



unrearranged adduct was complexed with osmium when isolated.

The synthesis of 3-vinylpyrrole was first reported, to the best of our knowledge, in 1979 by Jones *et al*., by the photoaddition of acetaldehyde and *N*-methylpyrrole followed by dehydration of the resulting alcohol to *N*-methyl-3-vinylpyrrole in 32% overall yield [13]. A more efficient method uses 3-(*N*-*t*-butylpyrrole)carboxaldehyde in a Wittig methylenation in 55% overall yield [14]. The *t*-butyl group, due to its steric bulk, directs selective Vilsmeier-Haack formylation to the 3-position. The most efficient method to 3-vinylate pyrrole is likely *via* *N*-benzenesulfonylation followed by 3-acetylation under Friedel-Crafts acylation conditions using $AlCl_3$ as the Lewis acid, which selectively acetylates the 3-position [15–17]. The resulting acetylpyrrole is then reduced and dehydrated to the 3-vinylpyrrole [9,17]. An extensive study by Huffman *et al*. indicates that subjecting *N*-*p*-toluenesulfonylpyrrole to Friedel-Crafts acylation conditions using $AlCl_3$ does not result in a Friedel-Crafts-type acylation, but instead causes reversible formation of 2- and 3-dichloroaluminum intermediates, the latter being sterically favored, and the former possibly experiencing a stabilizing electronic interaction between the electrophilic aluminum and an oxygen of the *N*-sulfonyl group [18]. The predominant and more reactive 3-substituted organoaluminum intermediate then reacts with the acylating agent to give mainly 3-acylpyrroles.

While altering the side to which the dienophile-component is fused in the resulting tetrahydroindole, using 3-vinylpyrroles in Diels-Alder reactions is significantly advantageous over the use of 2-vinylpyrroles. 2-Vinylpyrroles are generally volatile liquids which polymerize or decompose on exposure to air and light, but *N*-*p*-toluenesulfonyl-3-vinylpyrroles are robust crystalline solids which are easy to store and handle. 2-Vinylpyrroles are most efficiently made from pyrrole-2-carboxaldehyde or from the 2-acylpyrrole *via* a Wittig reaction in ~50% yield over two steps from *N*-H-pyrrole [6,19]. In comparison, *N*-*p*-toluenesulfonyl-3-vinylpyrrole is generated using the Lewis Acid-catalyzed process outlined above in 83% yield from *N*-H-pyrrole over four steps, a sizable increase in efficiency. In most of the prior examples, the 2-vinylpyrroles are *N*-alkylated due to the high reactivity and tendency towards polymerization and decomposition of *N*-H-2-vinylpyrroles, whereas an *N*-*p*-toluenesulfonyl group decreases reactivity, increases stability, and may be removed later to give the *N*-H-indole derivative, or the H can then be replaced with another group of choice.

RESULTS AND DISCUSSION

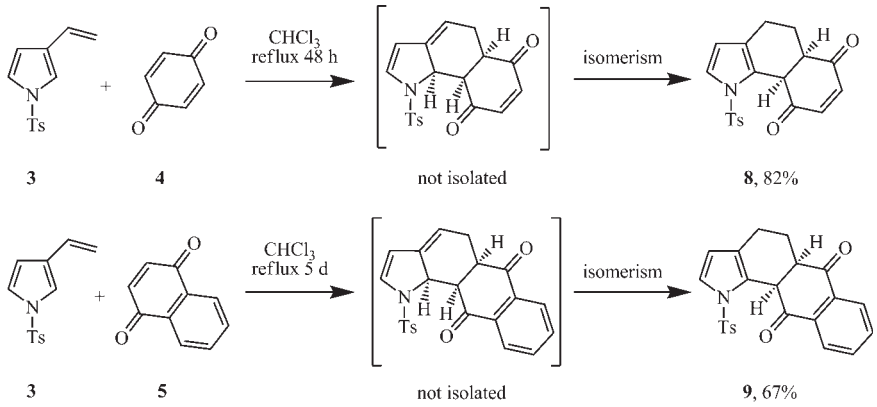
Synthesis of starting materials. Vinylpyrrole **3** was prepared in 83% overall yield in four steps from pyrrole by literature methods (Scheme 1) [9,15,17,20].

Commercial *p*-benzoquinone **4** and 1,4-naphthoquinone **5** were used. *N*-(4-Isopropylphenyl)maleimide **6** and *N*-(4-phenoxyphenyl)maleimide **7** were synthesized by reported procedures [6,21]. Flash chromatography on silica gel, followed by recrystallization, was used to purify the maleimides.

Diels-Alder reactions. Diels-Alder reactions of *N*-*p*-toluenesulfonyl-3-vinylpyrrole **3** with *p*-benzoquinone **4**, 1,4-naphthoquinone **5**, *N*-(4-isopropylphenyl)maleimide **6**, and *N*-(4-phenoxyphenyl)maleimide **7** in chloroform gave compounds **8**, **9**, **10**, and **11**, respectively (Schemes 2 and 3). The reactions were monitored by TLC. While the maleimide-containing reactions which gave adducts **10** and **11** went to completion at rt over 5 days, the Diels-Alder reactions giving **8** and **9** required, for completion, refluxing for 48 h and 5 days, respectively. In each reaction, the vinylpyrrole was used in slight excess (1.1 equiv.) to simplify the required chromatographic purification procedure, because the vinylpyrroles were always eluted first, unreacted maleimides or quinones were eluted very close to the adducts. Chromatography on silica gel, followed by recrystallization, was used to purify the adducts. Conditions for the Diels-Alder reactions were not optimized, except that chloroform was used as the solvent, which is based on the considerably higher yields obtained in our earlier work in Diels-Alder reactions with 2-vinylpyrroles in chloroform *versus* toluene [6].

In Diels-Alder reactions with *p*-benzoquinone and 1,4-naphthoquinone, unisomerized adducts were not isolated or detected; instead compounds **8** and **9** were isolated, in which a double-bond had moved into the five-membered ring, giving the more stable aromatic

Scheme 2. Diels-Alder reactions of *N-p*-toluenesulfonyl-2-vinylpyrrole **3** with quinones **4** and **5**.



3 **4** not isolated **8**, 82%

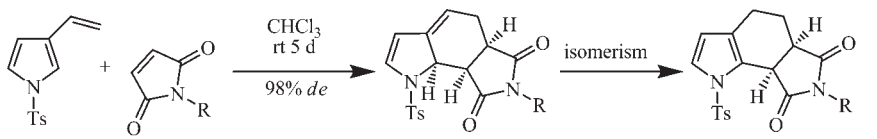
3 **5** not isolated **9**, 67%

pyrrole. In Diels-Alder reactions with maleimides, however, the unisomerized adducts **10** and **11** were isolated first, and quantitative isomerization of these compounds into the aromatic **12** and **13** occured in chloroform at rt over a month, or over several days at reflux (Scheme 3). Although unisomerized adducts were not isolated in our 2-vinylpyrrole work, evidence of them as intermediates was provided by the isolation of products likely resulting from a Michael addition of an unisomerized adduct with a maleimide [6]. NOE experiments were used to confirm the stereochemistry of **10** and **11**. This seems to be the first report of the isolation of unisomerized Diels-Alder adducts being formed from vinylpyrroles. The average yield of the Diels-Alder products **8**, **9**, **10**, and **11** was 74%, nearly identical with the 73% average for Diels-Alder products from 2-vinylpyrrole obtained in chloroform in our prior work [6], although a greater number of Diels-Alder reactions of 3-vinylpyrroles would be needed for an accurate comparison of the relative efficiency of the two procedures.

For descriptions of orientation, the diastereomer with the *cis*-protons at the points of diene fusion protruding from the α-face and the fused-dienophile protruding from the β-face will always be used; this convention is also used throughout the Experimental. In the ^{1}H NMR spectra of unisomerized adducts **10** and **11**, the 5α-H proton appears as a doublet of doublet of doublet of doublets; COSY experiments indicate that the 5α-H proton is coupled not only to the 5β-H, 4-H, and 5aα-H protons, but also to the 8bα-H proton, with a coupling constant of about 3.0 Hz [9,22]. For isomerized adduct **8**, the 7-H proton is coupled not only to the 8-H proton but also to the 5aα-H proton, with a coupling constant of about 1.2 Hz [23].

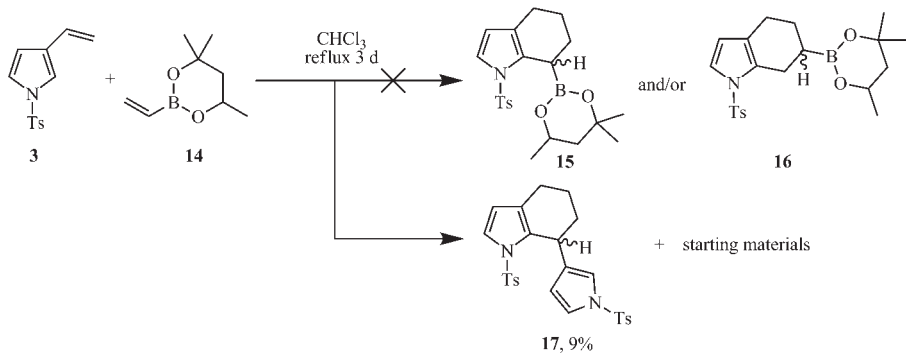
Diels-Alder dimerization. In an effort to extend our method to allow for a highly convergent synthetic step after indole formation *via* a potential Suzuki coupling [24], a Diels-Alder reaction between *N-p*-toluenesulfonyl-3-vinylpyrrole **3** and commercially available vinylboronic acid 2-methyl-2,4-pentanediol ester **14** was attempted (Scheme 4) [25]. Although Diels-Alder reactions of vinylboranes [26], vinylboronates [27], and of **14** [28] are known, to the best of our knowledge they are not reported to have occurred with vinylpyrroles. No reaction was observed to occur in chloroform at room temperature over 5 days, so the solution was refluxed. After 3 days, a new TLC spot had appeared, and no further consumption of the vinylpyrrole **3** seemed to be occurring. Isolation of the single new product from the remaining starting materials and purification revealed *via* ^{1}H NMR that the new product was in fact not the expected Diels-Alder adduct **15** and/or **16**, as it lacked any of the characteristic aliphatic methyl groups from vinyl boronate **14**. Characterization of this product using HRMS, COSY, and NOE studies showed it to be the result of a formal Diels-Alder reaction between two molecules of *N-p*-toluenesulfonyl-3-vinylpyrrole **3**, giving the dimer **17** (Fig. 1). In the ^{1}H NMR, the 4α-H and 4β-H protons were overlapped, which prevented distinguishing between them in the NOE study.

Scheme 3. Diels-Alder reactions of *N-p*-toluenesulfonyl-2-vinylpyrrole **3** with maleimides **6** and **7**.



3 **6**, R = 4-*i*PrPh; **7**, R = 4-PhOPh **10**, R = 4-*i*PrPh, 70%; **11**, R = 4-PhOPh, 77% **12**, R = 4-*i*PrPh, quant.; **13**, R = 4-PhOPh, quant.

Scheme 4. Attempted Diels-Alder reaction of *N-p*-toluenesulfonyl-3-vinylpyrrole **3** with vinylboronate **14**.



Formation of dimer **17** would occur when two vinylpyrroles approach each other with the terminal ends of their vinyl groups nearest to one another, but would seem to maximize proximity of repulsive like partial-charges and to violate the *ortho/para* rule [29] of adduct substitution in Diels-Alder reactions. Refluxing *N-p*-toluenesulfonyl-3-vinylpyrrole **3** in toluene or chloroform without vinylboronate **14** for 2 weeks produced no sign of dimer **17** by ^{1}H NMR and HRMS analysis; only starting materials were shown to be present by ^{1}H NMR. Refluxing 100 mg of *N-p*-toluenesulfonyl-3-vinylpyrrole **3** in 10 mL of chloroform with one drop of concentrated hydrochloric acid for several days produced no sign of dimer **17** by TLC analysis; only starting materials were present. It is likely that the vinylboronate acted as a Lewis acid and activated a vinylpyrrole to form the dimer **17**.

Considering the electron-rich nature of vinylpyrrole systems, the reaction reported above seems unexpected. Examples of compounds undergoing Diels-Alder-dimerization include butadiene [30], natural products [31], 2-styrylindolizine [32], 2-vinylindoles [33,34], 3-vinylindoles [35,36], and 2-vinylpyrroles [37]. Several of these dimeric products violate the '*ortho/para*' rule [34,36,37], and in each case the diene and the dienophile is connected to an electron-donating substituent, the nitrogen atom of the pyrrole ring, as in the present case, but no Lewis acid was present. This type of '*meta*' regioselectivity in Diels-Alder reactions having electron-donating substituents on the diene and dienophile was predicted by Houk in 1972 using frontier molecular orbital theory [38,39], and it has been experimentally observed in nondimerization Diels-Alder reactions not involving pyrrole as well (between the diene generated from benzocyclobutenes with the dienophiles propyne and ethoxyethene) [40]. As in some of the examples of *ortho/para* rule violation [34,36,37,40], a steric argument may also be made to help explain the formation of the dimer **17**, especially considering that in the present case dimer formation did not occur without the Lewis acid. This can be rationalized if one molecule of **3** complexes with the boronate **14** acting as a Lewis acid present at the more basic, terminal end of **3**. This may cause the terminal end of the vinylpyrrole to be so sterically bulky as to prohibit approach by either a free vinylpyrrole in the normal *ortho/para* regiochemistry or another Lewis acid-complexed vinylpyrrole (statistically unlikely), allowing only the approach of a free vinylpyrrole with the pyrrole ring farthest from the complexing-Lewis acid. The electrons of the nitrogen of the noncomplexed vinylpyrrole may then drive an attack from the α-carbon of that pyrrole to the α-carbon of the vinyl group of the complexed pyrrole, the positive charge of which is induced by complexation with the Lewis acid (Fig. 2). This is followed by dissociation of the catalyst and concomitant formation of a bond between the terminal carbons of each

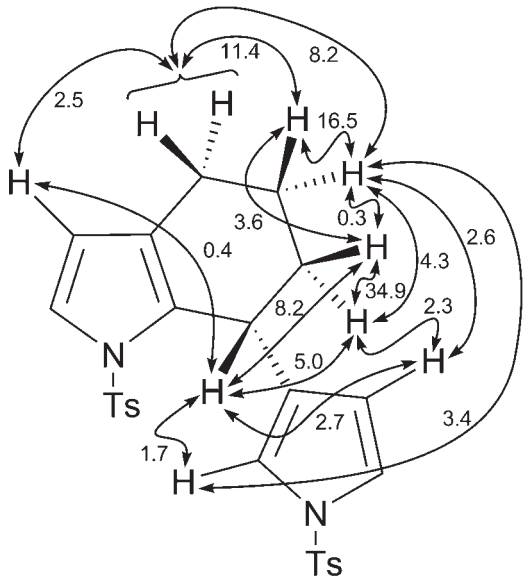


Figure 1. Relevant NOE interactions for Diels-Alder dimer **17***.

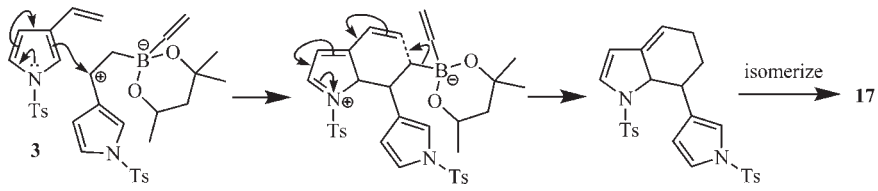


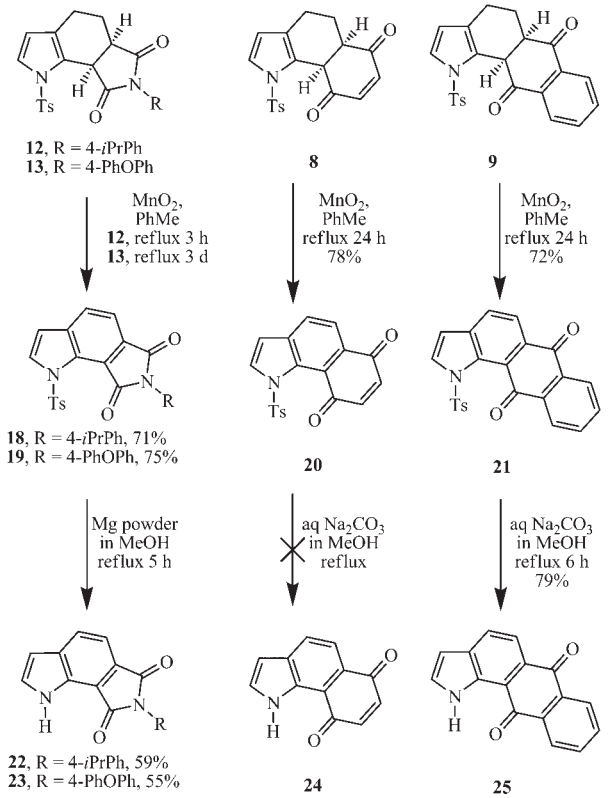
Figure 2. Formation of the 3-vinylpyrrole dimer **17**.

vinylpyrrole. Then, isomerization of the double bond in the adduct gives the observed 7-pyrrolyl-substituted tetrahydroindole **17**. In this proposed mechanism, nucleophilic attack by the free pyrrole in the first step effectively allows reversal of the normal polarity of the terminus of its vinyl group, allowing the second carbon-carbon bond formation, an example of umpolung [41]. Further studies are currently underway in our labs to determine the scope of such a dimerization approach towards indoles.

Aromatization of Diels-Alder adducts. Tetrahydroindoles **12**, **13**, **8**, and **9** were aromatized using MnO_2 in refluxing toluene for 3–72 h, giving **18**, **19**, **20**, and **21** in 71, 75, 78, and 72% yields, respectively (Scheme 5). The most consistent and high-yielding results were achieved using MnO_2 generated from manganese(II) sulfate and potassium permanganate [42], which was also used in our 2-vinylpyrrole work [6]. The average yield from dehydrogenations was 74%, higher than the 54% average achieved in aromatizing the adducts resulting from 2-vinylpyrrole, indicating that the tosyl group may help to facilitate the reaction or provide some degree of stability to the tetrahydroindoles during the aromatization process [6].

Detosylation of *N*-*p*-toluenesulfonylindoles. Detosylation of maleimide-derived indoles **18** and **19** was accomplished by magnesium in refluxing methanol for 5 h, giving **22** and **23** in 59 and 55% yield, respectively (Scheme 5) [43]. Detosylation of 1,4-naphthoquinone-derived indole **21** [44] was effected by saponification with aqueous sodium carbonate in methanol under reflux for 6 h. With saponification of **18** and **19**, competition between removal of the *p*-toluenesulfonyl group and hydrolysis of the imide was observed. When these two methods were applied to the *p*-benzoquinone-derived indole **20**, decomposition occurred with no recovery of starting materials. Various other methods were attempted, such as TBAF in refluxing THF/MeOH [45], 5% sodium-mercury amalgam in THF/MeOH [46], the dilithium salt of thioglycolate in DMF [47], and concentrated sulfuric acid [48], but none of these methods gave the desired *N*-H indole **24**. The failure to achieve compound **24** is likely due to the α,β-unsaturated dione portion of indole **20,** which is acting as a strong Michael acceptor. An example exists of saponification failing to detosylate an *N*-tosyl compound containing such a dione portion [49], an *N*-*p*-toluenesulfonyl-1*H*-indole-4,7-dione, but some precedent exists for detosylation of such compounds using TBAF in THF [50]. However, 1*H*-indole-4,7-diones may be distinguished from **20** because the carbonyls of these compounds are in more direct conjugation with the electron-releasing nitrogen, causing deactivation. If the conjugated dione of compound **20** indeed prevented its detosylation by the means attempted, then a masking technique could be used, such as reduction of **20** and formation of the *bis*-silyl ether [51], detosylation *via* conventional means, then desilylation followed by tautomerization to the quinone [52] to give *N*-H indole **24**. Such a route toward **24** is currently under investigation in our labs.

Scheme 5. Aromatization and detosylation of tetrahydroindoles **8**, **9**, **12**, and **13**.



Biological activity. While participating in the Developmental Therapeutics Program at the National Cancer Institute (NCI), we submitted eight compounds to the NCI for a one-dose 60-human tumor cell line prescreen: compounds **8**, **9**, **12**, **13**, **18**, **19**, **20**, and **21**. Of these, four compounds, **8**, **9**, **20**, and **21**, were judged by the NCI to have sufficient activity to justify screening with 60 human-tumor cell lines at five concentrations with 10-fold dilutions, from 1×10^{-4} M to 1×10^{-8} M. All four of these compounds were found to have high levels of activity against many of the 60 different cell lines tested. Compound **8** was most active against colon cancer HCT-116, melanoma M14, and nonsmall cell lung cancer, with IC_{50}'s of 67, 63, and 37 ng/mL, respectively. Compound **9** was most active against melanoma M14, and leukemia cell lines CCRF-CEM and HL-60(TB), with IC_{50}'s of 11, 13, and 11 ng/mL, respectively. Compound **20** was most active against melanoma UACC-257, and leukemia cell lines MOLT-4 and SR, with IC_{50}'s of 21, 56, and 50 ng/mL, respectively. Compound **21** was most active against CNS cancer SF-295, ovarian cancer OVCAR-3, and melanoma MDA-MB-435, with IC_{50}'s of 10, 9.6, and 9.1 ng/mL, respectively. Compounds **8** and **20** were selected by the NCI for toxicity testing and subsequent hollow fiber testing. Compound **8** had a maximum tolerated dose of 100 mg/Kg body wt in athymic nude mice, with death resulting in 3 days at 200 mg/Kg body wt and 2 days at 400 mg/Kg body wt. Hollow fiber testing of compound **8** against breast cancer MDA-MB-231, nonsmall cell lung cancer NCI-H23 and NCI-H522, colon cancer SW-620 and COLO 205, melanoma LOX IMVI, UACC-62, and MDA-MB-435, ovarian cancer OVCAR-3, CNS cancer U251 and SF-295 gave a score of 4/96 with no cell kill, below the 20/96 minimum score required for selection for xenograft testing. Toxicity and hollow fiber testing data for compound **20** were pending at the time of submission of this article.

CONCLUSION

N-*p*-Toluenesulfonyl-3-vinylpyrrole underwent *endo*-addition [4 + 2] cycloaddition reactions with *p*-benzoquinone, 1,4-naphthoquinone, and maleimides giving isomerized aromatic tetrahydroindoles with *p*-benzoquinone and 1,4-naphthoquinone, and unisomerized tetrahydroindoles with maleimides. In the presence of vinylboronic acid 2-methyl-2,4-pentanediol ester, *N*-tosyl-3-vinylpyrrole underwent a Diels-Alder dimerization. Dehydrogenation of the tetrahydroindoles with activated MnO_2 in refluxing toluene gave the corresponding indoles. The maleimide-fused indoles were detosylated *via* saponification, and the 1,4-naphthoquinone-fused indole was detosylated with magnesium in refluxing methanol, giving the *N*-H indoles in moderate to good yields. This efficient method for formation of indoles offers high convergency and easily accessible starting materials.

EXPERIMENTAL

General. Solvents and reagents were purchased and used as received. Flash chromatography was performed using 230–450 mesh silica gel. MPLC refers to medium pressure liquid chromatography was performed using 325–635 mesh silica gel. Ethyl acetate/hexanes were used as eluent unless otherwise specified. TLC analyses were performed on plastic-backed plates pre-coated with 0.2 mm silica with F_{254} indicator. Infrared spectra were recorded on a 4000 FT IR spectrometer; only the most intense and/or diagnostic peaks are reported. High-resolution mass spectra were recorded with a time-of-flight instrument using electrospray ionization with PEG as an internal calibrant. For NMR spectra, chemical shifts (δ) were compared to the solvent. ^{13}C NMR spectra were proton-decoupled. Melting points are uncalibrated. Elemental analyses were performed by M-H-W Laboratories, Phoenix, AZ. Petroleum ether refers to the 35–60°C boiling point fraction.

General method for Diels-Alder reactions. A mixture of *N*-*p*-toluenesulfonyl-3-vinylpyrrole **3** (1.237 g, 0.005 mol) and the dienophile (0.0045 mol, 1.1 equiv.) in chloroform (20 mL) was stirred at rt for 24 h and, if TLC analysis indicated insignificant consumption of the dienophile, was refluxed until the reaction was complete. The solvent was removed using a rotating evaporator. The crude adduct was purified by MPLC using ethyl acetate/hexanes as eluent, followed by recrystallization from dichloromethane/petroleum ether, giving the desired product in good yields.

General method for dehydrogenation of Diels-Alder adducts. A mixture of the adduct (0.003 mol) and activated MnO_2 [42] (0.015 mol, 5 equiv.) in toluene (30 mL) was stirred under reflux until the reaction was complete, as indicated by TLC analysis. The mixture was cooled to rt and vacuum-filtered through a fine glass fritted funnel. The insoluble manganese salts were washed using several portions of dichloromethane until the washings ran clear (5 × 20 mL). The combined organic filtrate and washings were evaporated to dryness using a rotating evaporator. MPLC with ethyl acetate/hexanes as eluant, followed by recrystallization from dichloromethane/petroleum ether, gave the desired product in fair to good yields.

1-p-Toluenesulfonyl-4,5,5aα,9aα-tetrahydro-1H-benzo[g]indole-6,9-dione (8). The general method with quinone **4** and reflux for 48 h gave **8** (1.325 g, 82%) as light-yellow crystals: mp 172–174°C; ^1H NMR (300 MHz, $CDCl_3$, δ) 7.74 (d, J = 8.4 Hz, 2H, Ts), 7.33 (d, J = 8.1 Hz, 2H, Ts), 7.20 (d, J = 3.5 Hz, 1H, 2-H), 6.88 (d, J = 10.2 Hz, 1H, 8-H), 6.70 (dd, J = 10.4, 1.4 Hz, 1H, 7-H), 6.17 (d, J = 3.6 Hz, 1H, 3-H), 4.84 (d, J = 5.7 Hz, 1H, 9aα-H), 3.06 (ddddd, J = 13.2, 5.5, 2.7, 1.4, 0.9 Hz, 1H, 5aα-H), 2.54–2.70 (m, 2H, 4α-H, 4β-H), 2.43 (s, 3H, Ts-CH_3), 2.07 (dddd, J = 13.6, 5.0, 2.5, 2.5 Hz, 1H, 5β-H), 1.68 (dddd, J = 13.2, 13.2, 10.4, 7.4 Hz, 1H, 5aα-H); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 200.6, 196.5, 145.0, 141.5, 138.9, 136.5, 129.9, 127.2, 124.2, 123.9, 123.3, 112.6, 49.8,

47.3, 26.3, 22.8, 21.8; IR (KBr, cm^{-1}) 3382(w), 3137(w), 3101(w), 3051(m), 2946(m), 2853(m), 1702(s), 1673(s), 1595(m), 1486(w), 1433(w), 1379(s), 1276(m), 1260(m), 1228(m), 1209(w), 1173(s), 1137(m), 1121(s), 1089(s), 1061(m), 1033(m), 986(m), 923(w), 902(w), 850(m), 813(m), 775(w), 734(w), 704(m), 673(s); HRMS m/z ($M + Na^+$) calcd 378.0771, found 378.0782. Anal. Calcd for $C_{19}H_{17}NO_4S$: C, 64.21; H, 4.82; N, 3.94. Found: C, 64.35; H, 4.73; N, 3.88.

1-p-Toluenesulfonyl-4,5,5aα,11aα-tetrahydro-1H-naphtho[2,3-g]indole-6,11-dione (9). The general method with naphthoquinone **5** and reflux for 5 d gave **9** (1.235 g, 67%) as a dark-orange powder: mp 114–116°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 8.11–8.17 (m, 1H, 10-H), 7.97–8.03 (m, 1H, 7-H), 7.74–7.83 (m, 4H, 8-H, 9-H, Ts), 7.34 (d, J = 8.4 Hz, 2H, Ts), 7.40 (d, J = 3.3 Hz, 1H, 2-H), 6.20 (d, J = 3.3 Hz, 1H, 3-H), 4.99 (d, J = 5.4 Hz, 1H, 11aα-H), 3.25 (ddd, J = 13.4, 5.3, 2.7 Hz, 1H, 5aα-H), 2.64–2.69 (m, 2H, 4α-H, 4β-H), 2.46 (s, 3H, Ts-CH_3), 2.13 (dddd, J = 12.7, 4.1, 2.6, 1.4 Hz, 1H, 5β-H), 1.71 (dddd, J = 12.7, 12.7, 8.8, 7.4 Hz, 1H, 5α-H); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 198.5, 195.5, 144.9, 136.6, 135.9, 134.8, 134.4, 133.3, 129.9, 127.3, 127.2, 127.0, 124.9, 123.8, 123.1, 112.6, 50.1, 47.4, 26.0, 23.0, 21.8; IR (KBr, cm^{-1}) 3140(w), 3067(w), 2920(m), 2853(w), 1702(s), 1687(s), 1594(m), 1485(w), 1434(w), 1400(w), 1364(s), 1291(m), 1272(m), 1243(m), 1208(m), 1175(s), 1142(m), 1127(s), 1106(m), 1089(m), 1058(w), 1043(w), 1027(w), 986(w), 903(w), 812(w), 759(w), 716(m), 703(m), 669(s), 611(w); HRMS m/z ($M + Na^+$) calcd 428.0928, found 428.0943. Anal. Calcd for $C_{23}H_{19}NO_4S$: C, 68.13; H, 4.72; N, 3.45. Found: C, 67.86; H, 4.71; N, 3.36.

7-(4-Isopropylphenyl)-1-p-toluenesulfonyl-5,5aα,8aα,8bα-tetrahydropyrrolo-1H,7H-benzo[g]indole-6,8-dione (10). The general method with maleimide **6** and rt for 5 d gave **10** (1.472 g, 70%) as light-orange crystals: mp 96–98°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 7.81 (d, J = 8.4 Hz, 2H, Ts), 7.35 (d, J = 8.4 Hz, 2H, Ts), 7.27 (d, J = 8.4 Hz, 2H, *i*PrPh), 7.08 (d, J = 8.4 Hz, 2H, *i*PrPh), 6.83 (d, J = 4.2 Hz, 1H, 2-H), 5.69 (d, J = 3.9 Hz, 1H, 3-H), 5.56 (ddd, J = 7.4, 3.8, 3.8 Hz, 1H, 4-H), 4.23 (ddd, J = 6.9, 3.3, 3.4 Hz, 1H, 8bα-H), 3.97 (dd, J = 9.0, 7.2 Hz, 1H, 8aα-H), 3.23 (ddd, J = 9.0, 7.2, 1.8 Hz, 1H, 5aα-H), 3.01 (ddd, J = 15.5, 7.4, 1.9 Hz, 1H, 5β-H), 2.91 (septet, J = 6.9 Hz, 1H, —C*H*$(CH_3)_2$), 2.45 (s, 3H, Ts-CH_3), 2.05 (dddd, J = 15.3, 7.2, 4.1, 3.0 Hz, 1H, 5α-H), 1.23 (d, J = 7.2 Hz, 6H, —CH(C*H*$_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 178.1, 173.1, 149.4, 144.5, 142.5, 137.7, 133.8, 130.1, 129.3, 127.7, 127.2, 126.2, 110.8, 110.6, 59.5, 42.3, 36.3, 34.0, 26.1, 24.0, 21.7; IR (KBr, cm^{-1}) 3472(w), 3138(w), 3104(w), 3049(w), 2960(m), 2929(m), 2870(m), 1781(w), 1714(s), 1596(m), 1565(w), 1514(m), 1491(w), 1449(m), 1371(s), 1306(m), 1294(m), 1170(s), 1123(s), 1091(m), 1056(m), 1018(m), 991(m), 900(w), 874(w), 832(m), 812(m), 767(w), 704(m), 669(s); HRMS m/z ($M + Na^+$) calcd 485.1506, found 485.1523. Anal. Calcd for $C_{26}H_{26}N_2O_4S$: C, 67.51; H, 5.67; N, 6.06. Found: C, 67.46; H, 5.61; N, 6.17.

7-(4-Phenoxyphenyl)-1-p-toluenesulfonyl-5,5aα,8aα,8bα-tetrahydropyrrolo-1H,7H-benzo[g]indole-6,8-dione (11). The general method with maleimide **7** and rt for 5 d gave **11** (1.794 g, 77%) as white crystals: mp 217–218°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 7.80 (d, J = 8.1 Hz, 2H, Ts), 7.32–7.40 (m, 4H, Ts, PhOPh), 7.14–7.17 (m, 3H, PhOPh), 6.99–7.05 (m, 4H, PhOPh), 6.85 (d, J = 3.9 Hz, 1H, 2-H), 5.69 (d, J = 3.9 Hz, 1H, 3-H), 5.56 (ddd, J = 7.3, 3.7, 3.6 Hz, 1H, 4-H), 4.23 (ddd, J = 6.8, 3.2, 3.2 Hz, 1H, 8bα-H), 3.99 (dd, J = 9.0, 7.2 Hz, 1H, 8aα-H), 3.24 (ddd, J = 8.9, 7.1, 1.7 Hz, 1H, 5aα-H), 3.02 (ddd, J = 15.5, 7.4, 1.4 Hz, 1H, 5β-H), 2.45 (s, 3H, Ts-CH_3), 2.06 (dddd, J = 15.9, 6.9, 4.0, 2.7 Hz, 1H, 5α-H); ^{1}H NMR (300 MHz, DMSO-d_6, δ) 7.80 (d, J = 8.1 Hz, 2H, Ts), 7.38–7.46 (m, 4H, PhOPh), 7.15–7.21 (m, 1H, PhOPh), 7.03–7.07 (m, 6H, PhOPh), 6.76 (d, J = 3.9 Hz, 1H, 2-H), 5.80 (d, J = 4.2 Hz, 1H, 3-H), 5.53 (ddd, J = 7.1, 3.7, 3.7 Hz, 1H, 4-H), 4.29 (ddd, J = 7.1, 3.3, 3.3 Hz, 1H, 8bα-H), 3.89 (dd, J = 8.7, 7.2 Hz, 1H, 8aα-H), 3.28 (ddd, J = 8.9, 7.1, 1.4 Hz, 1H, 5aα-H), 2.66 (ddd, J = 15.2, 7.1, 1.7 Hz, 1H, 5β-H), 2.40 (s, 3H, Ts-CH_3), 2.12 (dddd, J = 15.2, 7.1, 3.7, 3.3 Hz, 1H, 5α-H); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 178.9, 174.1, 157.0, 156.6, 144.8, 142.3, 138.0, 133.5, 130.7, 130.5, 129.0, 127.9, 127.8, 124.5, 119.6, 119.1, 111.9, 111.4, 59.8, 43.3, 36.9, 25.7, 21.6; IR (KBr, cm^{-1}) 3458(w), 3103(m), 3064(m), 2929(w), 2903(w), 2853(w), 1772(w), 1702(s), 1651(w), 1586(m), 1564(w), 1504(m), 1483(m), 1360(m), 1342(m), 1294(w), 1235(s), 1195(s), 1165(s), 1107(m), 1094(m), 1063(m), 1018(w), 991(w), 963(w), 912(w), 874(w), 845(m), 801(m), 730(m), 615(m); HRMS m/z ($M + Na^+$) calcd 535.1299, found 535.1311. Anal. Calcd for $C_{29}H_{24}N_2O_5S$: C, 67.95; H, 4.72; N, 5.47. Found: C, 68.13; H, 4.59; N, 5.16.

7-(4-Isopropylphenyl)-1-p-toluenesulfonyl-4,5,5aα,8aα-tetrahydropyrrolo-1H,7H-benzo[g]indole-6,8-dione (12). Diels-Alder adduct **10** (1.000 g, 2.162 mmol) was dissolved in chloroform (30 mL) and refluxed for 4 d. The solvent was removed with a rotating evaporator, giving **12** (1.000 g, quant.) as a white powder: mp 96–98°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 7.99 (d, J = 8.4 Hz, 2H, Ts), 7.28–7.34 (m, 4H, Ts, *i*PrPh), 7.18 (d, J = 8.7 Hz, 2H, *i*PrPh), 7.12 (d, J = 3.6 Hz, 1H, 2-H), 6.16 (d, J = 3.3 Hz, 1H, 3-H), 5.02 (d, J = 8.4 Hz, 1H, 8aα-H), 3.42 (ddd, J = 8.6, 5.9, 5.9 Hz, 1H, 5aα-H), 2.94 (septet, J = 7.1 Hz, 1H, —C*H*$(CH_3)_2$), 2.59 (ddd, J = 16.0, 5.5, 5.5 Hz, 1H, 4α-H), 2.43 (ddd, J = 16.3, 8.6, 4.6 Hz, 1H, 4β-H), 2.42 (s, 3H, Ts-CH_3), 2.29 (dddd, J = 13.3, 6.1, 6.1, 4.4 Hz, 1H, 5β-H), 1.99 (dddd, J = 14.0, 8.3, 5.2, 4.8 Hz, 1H, 5α-H), 1.26 (d, J = 6.9 Hz, 6H, —CH(C*H*$_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 178.1, 173.8, 149.4, 145.0, 136.5, 129.8, 129.5, 127.8, 127.3, 126.4, 125.6, 123.6, 123.0, 112.6, 41.2, 39.5, 34.0, 25.1, 24.0, 21.8, 21.2; IR (KBr, cm^{-1}) 3478(w), 3137(w), 3103(w), 3037(w), 2959(s), 2929(m), 2868(m), 1783(m), 1718(s), 1595(m), 1514(m), 1484(m), 1451(m), 1370(s), 1306(w), 1295(w), 1226(m), 1171(s), 1123(s), 1090(m), 1017(w), 990(m), 898(w), 873(w), 835(w), 812(m), 766(w), 702(m), 668(s); HRMS m/z ($M + Na^+$) calcd 485.1506, found 485.1527. Anal. Calcd for $C_{26}H_{26}N_2O_4S$: C, 67.51; H, 5.67; N, 6.06. Found: C, 67.24; H, 5.68; N, 6.16.

7-(4-Phenoxyphenyl)-1-p-toluenesulfonyl-4,5,5aα,8aα-tetrahydropyrrolo-1H,7H-benzo[g]indole-6,8-dione (13). Diels-Alder adduct **11** (1.000 g, 1.951 mmol) was dissolved in chloroform (30 mL) and refluxed for 4 d. The solvent was removed with a rotating evaporator, giving **13** (1.000 g, quant.) as an orange powder: mp 217–218°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 7.97 (d, J = 8.4 Hz, 2H, Ts), 7.30–7.41 (m, 4H, Ts, PhOPh), 7.13–7.25 (m, 4H, PhOPh), 7.02–7.08 (m, 4H, PhOPh, 2-H), 6.16 (d, J = 3.3 Hz, 1H, 3-H), 5.02 (d, J = 8.4 Hz, 1H, 8aα-H), 3.43 (ddd, J = 8.6, 5.9, 5.9 Hz, 1H, 5aα-H), 2.59 (ddd, J = 16.1, 5.4, 5.4 Hz, 1H, 4α-H), 2.43 (ddd, J =

16.2, 8.6, 4.7 Hz, 1H, 4β-H), 2.42 (s, 3H, Ts-CH_3), 2.29 (dddd, J = 13.4, 6.0, 6.0, 4.3 Hz, 1H, 5β-H), 1.99 (dddd, J = 13.6, 8.5, 5.4, 4.7 Hz, 1H, 5α-H); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 178.0, 173.8, 157.6, 156.5, 145.0, 136.5, 130.0, 129.9, 128.0, 127.7, 126.6, 125.7, 124.0, 123.7, 122.8, 119.6, 118.8, 112.6, 41.2, 39.5, 25.0, 21.8, 21.2; IR (KBr, cm^{-1}) 3464(w), 3146(w), 3111(m), 3065(m), 2943(m), 2850(w), 1773(w), 1707(s), 1586(m), 1505(m), 1484(m), 1445(w), 1397(m), 1372(m), 1335(m), 1293(w), 1232(s), 1203(m), 1187(s), 1167(s), 1120(m), 1091(m), 1017(w), 989(w), 916(w), 901(w), 885(m), 811(m), 782(m), 743(w), 703(m), 646(m); HRMS m/z ($M + Na^+$) calcd 535.1299, found 535.1318. Anal. Calcd for $C_{29}H_{24}N_2O_5S$: C, 67.95; H, 4.72; N, 5.47. Found: C, 67.93; H, 4.64; N, 5.26.

1-p-Toluenesulfonyl-7α-(1-p-toluenesulfonyl-1H-pyrrol-3-yl)-4,5,6,7β-tetrahydro-1H-indole (17). A mixture of *N-p*-toluenesulfonyl-3-vinylpyrrole **3** (1.237 g, 0.005 mol) and vinylboronic acid 2-methyl-2,4-pentanediol ester **14** (693 mg, 0.0045 mol, 1.1 equiv.) in chloroform (20 mL) was stirred under reflux for 3 d, at which point TLC analysis indicated that a new spot had formed and no starting materials were being consumed. The solvent was removed using a rotating evaporator. The crude mixture was purified by MPLC with ethyl acetate/hexanes as eluant, followed by recrystallization from dichloromethane/petroleum ether, giving **17** (210 mg, 9%) as a white powder: mp 157–158°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 7.61 (d, J = 8.4 Hz, 2H, 1′-Ts), 7.31 (d, J = 8.4 Hz, 2H, 1-Ts), 7.26 (d, J = 8.4 Hz, 2H, 1′-Ts), 7.26 (d, J = 3.3 Hz, 1H, 2-H), 7.12 (d, J = 8.1 Hz, 2H, 1-Ts), 6.87 (dd, J = 3.3, 2.4 Hz, 1H, 5′-H), 6.20 (dd, J = 2.4, 2.1 Hz, 1H, 2′-H), 6.12 (d, J = 3.3 Hz, 1H, 3-H), 6.02 (dd, J = 3.2, 1.7 Hz, 1H, 4′-H), 4.41 (dd, J = 5.1, 2.4 Hz, 1H, 7β-H), 2.31–2.54 (m, 2H, 4-H), 2.41 (s, 3H, Ts-CH_3), 2.39 (s, 3H, Ts-CH_3), 1.84 (dddd, J = 13.1, 13.1, 5.2, 3.1 Hz, 1H, 6β-H), 1.69 (dddd, J = 12.8, 3.8, 2.8, 2.8 Hz, 1H, 6α-H), 1.44–1.60 (m, 1H, 5β-H), 1.24–1.48 (m, 1H, 5α-H); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 144.8, 144.6, 136.4, 135.8, 132.8, 130.1, 130.0, 129.6, 126.6, 124.0, 121.9, 120.3, 118.9, 114.4, 111.9, 31.1, 31.0, 22.9, 21.72, 21.69, 17.0; IR (KBr, cm^{-1}) 3144(m), 3113(m), 3065(w), 3031(w), 2944(s), 2925(s), 2856(m), 1596(m), 1490(m), 1473(w), 1442(w), 1424(w), 1401(w), 1365(s), 1243(m), 1232(m), 1175(s), 1146(m), 1124(s), 1094(s), 1056(s), 1019(w), 996(m), 953(w), 905(w), 874(w), 855(w), 799(m), 780(m), 775(m), 748(m), 722(m), 673(s), 630(w); HRMS m/z ($M + Na^+$) calcd 517.1227, found 517.1241. Anal. Calcd for $C_{26}H_{26}N_2O_4S_2$: C, 63.13; H, 5.30; N, 5.66. Found: C, 62.91; H, 5.25; N, 5.71.

7-(4-Isopropylphenyl)-1-p-toluenesulfonyl-1H,7H-benzo[g]indole-6,8-dione (18). The general method with tetrahydroindole **12** and reflux for 3 h gave **18** (977 mg, 71%) as a white powder: mp 106–108°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 8.10 (d, J = 3.9 Hz, 1H, 2-H), 8.00 (d, J = 8.1 Hz, 1H, 4-H), 7.94 (d, J = 8.4 Hz, 2H, Ts), 7.88 (d, J = 7.8 Hz, 1H, 5-H), 7.35 (d, J = 8.4 Hz, 2H, *i*PrPh), 7.29 (d, J = 8.7 Hz, 4H, *i*PrPh, Ts), 6.91 (d, J = 3.9 Hz, 1H, 3-H), 2.97 (septet, J = 6.9 Hz, 1H, —C*H*$(CH_3)_2$), 2.43 (s, 3H, Ts-CH_3), 1.29 (d, J = 6.9 Hz, 6H, —CH$(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$, δ) 167.5, 164.6, 148.7, 144.8, 138.4, 136.5, 133.6, 129.73, 129.68, 129.5, 128.2, 127.7, 127.6, 127.1, 126.7, 118.4, 117.3, 108.0, 34.0, 24.0, 21.8; IR (KBr, cm^{-1}) 3648(w), 3475(w), 3154(w), 3123(w), 3070(w), 2959(s), 2901(m), 2871(m), 1776(m), 1722(s), 1619(w), 1595(m), 1537(w), 1515(m), 1453(w), 1424(m), 1402(s), 1374(s), 1309(w), 1266(m), 1247(m), 1226(w), 1190(m), 1173(s), 1150(s), 1124(m), 1093(s), 1056(w), 1016(m), 991(m), 880(w), 839(m), 811(m), 750(m), 739(m), 711(m), 666(s), 608(m); HRMS m/z ($M + Na^+$) calcd 481.1193, found 481.1206. Anal. Calcd for $C_{26}H_{22}N_2O_4S$: C, 68.10; H, 4.84; N, 6.11. Found: C, 68.02; H, 5.03; N, 6.19.

7-(4-Phenoxyphenyl)-1-p-toluenesulfonyl-1H,7H-benzo[g]indole-6,8-dione (19). The general method with tetrahydroindole **13** and reflux for 3 d gave **19** (1.144 g, 75%) as yellow crystals: mp 216–217°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 8.12 (d, J = 3.6 Hz, 1H, 2-H), 8.00 (d, J = 7.8 Hz, 1H, 4-H), 7.94 (d, J = 8.1 Hz, 2H, Ts), 7.88 (d, J = 7.8 Hz, 1H, 5-H), 7.31–7.45 (m, 6H, Ts, PhOPh), 7.06–7.20 (m, 5H, PhOPh), 6.91 (d, J = 3.9 Hz, 1H, 3-H), 2.43 (s, 3H, Ts-CH_3); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 167.4, 164.7, 157.1, 156.6, 145.3, 138.6, 136.5, 134.7, 130.8, 130.3, 130.0, 129.9, 128.8, 128.1, 127.6, 127.4, 124.6, 119.8, 118.9, 118.8, 117.4, 109.4, 21.6; IR (KBr, cm^{-1}) 3159(m), 3114(m), 1773(w), 1716(s), 1587(w), 1536(w), 1506(s), 1487(m), 1454(w), 1428(m), 1398(m), 1365(s), 1320(w), 1266(m), 1233(s), 1178(m), 1147(m), 1121(m), 1093(m), 1017(m), 990(m), 938(w), 909(w), 864(w), 830(m), 806(m), 777(w), 740(m), 665(m); HRMS m/z ($M + Na^+$) calcd 531.0986, found 531.1006. Anal. Calcd for $C_{29}H_{20}N_2O_5S$: C, 68.49; H, 3.96; N, 5.51. Found: C, 68.57; H, 4.03; N, 5.33.

1-p-Toluenesulfonyl-1H-benzo[g]indole-6,9-dione (20). The general method with tetrahydroindole **8** and reflux for 24 h gave **20** (822 mg, 78%) as light-orange crystals: mp 186–187°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 8.08 (d, J = 8.08 Hz, 1H, 4-H), 7.91 (d, J = 3.9 Hz, 1H, 2-H), 7.89 (d, J = 8.4 Hz, 1H, 5-H), 7.89 (J = 8.7 Hz, 2H, Ts), 7.41 (d, J = 8.4 Hz, 2H, Ts), 6.97 (d, J = 10.2 Hz, 1H, 8-H), 6.90 (d, J = 10.2 Hz, 1H, 7-H), 6.83 (d, J = 3.9 Hz, 1H, 3-H), 2.49 (s, 3H, Ts-CH_3); ^{1}H NMR (300 MHz, acetone-d_6, δ) 8.11 (d, J = 3.9 Hz, 1H, 2-H), 8.08 (d, J = 8.4 Hz, 1H, 4-H), 8.04 (d, J = 8.1 Hz, 1H, 5-H), 7.94 (d, J = 8.4 Hz, 2H, Ts), 7.50 (d, J = 8.1 Hz, 2H, Ts), 7.09 (d, J = 10.2 Hz, 1H, 8-H), 7.04 (d, J = 3.6 Hz, 1H, 3-H), 7.01 (d, J = 10.5 Hz, 1H, 7-H), 2.45 (s, 3H, Ts-CH_3); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 185.3, 184.8, 145.3, 139.4, 138.0, 137.8, 136.9, 136.7, 131.6, 130.1, 129.5, 127.4, 127.3, 123.2, 122.5, 110.8, 21.6; IR (KBr, cm^{-1}) 3311(m), 3153(m), 3116(w), 3065(m), 1718(w), 1660(s), 1609(m), 1594(m), 1533(m), 1494(w), 1459(w), 1415(w), 1380(m), 1354(s), 1301(s), 1282(m), 1252(m), 1241(w), 1189(m), 1163(s), 1119(m), 1088(m), 1070(s), 997(m), 967(w), 956(w), 882(w), 860(w), 831(m), 810(m), 756(w), 720(m), 666(s), 622(w); HRMS m/z ($M + Na^+$) calcd 374.0458, found 374.0464. Anal. Calcd for $C_{19}H_{13}NO_4S$: C, 64.95; H, 3.73; N, 3.99. Found: C, 64.82; H, 4.10; N, 4.10.

1-p-Toluenesulfonyl-1H-naphtho[2,3-g]indole-6,11-dione (21). The general method with tetrahydroindole **9** and reflux for 24 h gave **21** (867 mg, 72%) as light-orange crystals: mp 139–140°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 8.1 (d, J = 8.1 Hz, 1H, 4-H), 8.26–8.28 (m, 1H, 8-H), 8.14–8.17 (m, 1H, 9-H), 7.91–7.95 (m, 4H, Ts, 2-H, 5-H), 7.77–7.81 (m, 2H, 7-H, 10-H), 7.43 (d, J = 7.8 Hz, 2H, Ts), 6.84 (d, J = 3.6 Hz, 1H, 3-H), 2.51 (s, 3H, Ts-CH_3); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 184.1, 182.6, 145.4, 137.8, 136.8, 135.1, 134.8, 134.7, 133.0, 132.1, 130.7, 130.1, 127.7, 127.6, 127.4, 127.0, 126.9, 125.2, 123.1, 110.8, 21.7; IR (KBr, cm^{-1}) 3180(m), 3066(m),

2915(w), 1668(s), 1593(m), 1529(w), 1458(w), 1412(w), 1379(w), 1352(m), 1324(m), 1286(s), 1258(m), 1195(w), 1172(m), 1130(w), 1095(m), 1044(w), 1014(m), 955(w), 884(w), 851(w), 811(w), 737(w), 715(m), 705(w), 669(m), 636(w); HRMS m/z ($M + Na^+$) calcd 424.0615, found 424.0622. Anal. Calcd for $C_{23}H_{15}NO_4S$: C, 68.81; H, 3.77; N, 3.49. Found: C, 68.70; H, 3.79; N, 3.51.

7-(4-Isopropylphenyl)-1H,7H-benzo[g]indole-6,8-dione (22). Forty mesh magnesium metal powder (245 mg, 101 mmol, 20 equiv.) was ground with a mortar and pestle by hand for 1 min, and then placed immediately in anhydrous methanol (20 mL, ≤0.100% water). The indole **18** (231 mg, 0.504 mmol) was added, and the mixture was stirred under reflux for 5 h, at which time TLC analysis indicated that the starting materials were completely converted. The mixture was cooled to rt, vacuum-filtered on a fritted-glass funnel, and the remaining solids were washed several times with dichloromethane (3 × 20 mL). The filtrate and washings were diluted with water (100 mL), and extracted with dichloromethane (3 × 20 mL). The dichloromethane was washed with saturated aqueous sodium bicarbonate (20 mL), water (20 mL), and brine (20 mL), and dried over anhydrous sodium sulfate. The solvent was removed using a rotating evaporator. The crude product was purified using MPLC with ethyl acetate/hexanes as eluent, and recrystallized from dichloromethane/petroleum ether, giving **22** (90 mg, 59%) as bright-yellow crystals: mp 185–186°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 9.48 (s, 1H, 1-H), 7.99 (d, J = 8.1 Hz, 1H, 4-H), 7.69 (d, J = 8.1 Hz, 1H, 5-H), 7.49 (dd, J = 3.0, 2.4 Hz, 1H, 2-H), 7.41 (d, J = 8.1 Hz, 2H, *i*PrPh), 7.38 (d, J = 8.1 Hz, 2H, *i*PrPh), 6.74 (dd, J = 3.3, 1.8 Hz, 1H, 3-H), 2.99 (septet, J = 7.1 Hz, 1H, —C*H*(CH_3)$_2$), 1.31 (d, J = 7.2 Hz, 6H, —CH(C*H*$_3$)$_2$); ^{1}H NMR (300 MHz, DMSO-d_6, δ) 2.19 (s, 1H, 1-H), 8.04 (d, J = 7.8 Hz, 1H, 4-H), 7.69 (dd, J = 2.9, 2.9 Hz, 1H, 2-H), 7.54 (d, J = 7.8 Hz, 1H, 5-H), 7.40 (d, J = 9.0 Hz, 2H, *i*PrPh), 7.37 (d, J = 9.0 Hz, 2H, *i*PrPh), 6.75 (dd J = 3.2, 1.7 Hz, 1H, 3-H), 2.96 (septet, J = 6.9 Hz, 1H, —C*H*(CH_3)$_2$), 1.25 (d, J = 6.9 Hz, 6H, —CH(C*H*$_3$)$_2$); ^{1}H NMR (300 MHz, acetone-d_6, δ) 11.22 (s, 1H, 1-H), 8.10 (d, J = 7.8 Hz, 1H, 4-H), 7.77 (d, J = 2.7, 2.7 Hz, 1H, 2-H), 7.60 (d, J = 7.8 Hz, 1H, 5-H), 7.46 (d, J = 9.0 Hz, 2H, *i*PrPh), 7.42 (d, J = 8.7 Hz, 2H, *i*PrPh), 6.82 (dd, J = 3.2, 2.0 Hz, 1H, 3-H), 3.02 (septet, J = 7.1 Hz, 1H, —C*H*(CH_3)$_2$), 1.31 (d, J = 6.9 Hz, 6H, —CH(C*H*$_3$)$_2$); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 169.0, 168.0, 148.5, 135.5, 132.3, 130.4, 129.3, 127.9, 127.3, 126.8, 125.6, 115.0, 114.0, 103.7, 33.8, 24.4; IR (KBr, cm^{-1}) 3392(bs), 3115(w), 3041(w), 2965(m), 2873(m), 1764(m), 1702(s), 1603(w), 1579(w), 1511(s), 1481(m), 1447(m), 1414(m), 1390(s), 1366(s), 1330(m), 1294(m), 1241(m), 1229(m), 1160(w), 1128(w), 1098(s), 1082(m), 971(w), 944(w), 888(w), 851(m), 825(m), 796(w), 762(m), 730(m), 670(m); HRMS m/z ($M + Na^+$) calcd 327.1105, found 327.1102. Anal. Calcd for $C_{19}H_{16}N_2O_2$: C, 74.98; H, 5.30; N, 9.20. Found: C, 74.78; H, 5.16; N, 9.21.

7-(4-Phenoxyphenyl)-1H,7H-benzo[g]indole-6,8-dione (23). Forty mesh magnesium metal powder (96 mg, 93 mmol, 20 equiv.) was ground with a mortar and pestle by hand for 1 min, and then placed immediately in anhydrous methanol (10 mL, ≤0.100% water). The indole **19** (100 mg, 0.196 mmol) was added, and the mixture was stirred under reflux for 5 h, at which time TLC analysis indicated complete conversion of the starting materials. The mixture was cooled to rt, vacuum-filtered on a fritted-glass funnel, and the remaining solids were washed with dichloromethane (3 × 10 mL). The filtrate and washings were diluted with water (50 mL), and extracted with dichloromethane (3 × 10 mL). The dichloromethane was washed with saturated aqueous sodium bicarbonate (10 mL), water (10 mL), and brine (10 mL), and dried over anhydrous sodium sulfate. The solvent was removed using a rotating evaporator. The crude product was purified by MPLC with ethyl acetate/hexanes as eluent, and recrystallized from dichloromethane/petroleum ether, giving **23** (38 mg, 55%) as yellow crystals: mp 206–207°C; ^{1}H NMR (300 MHz, DMSO-d_6, δ) 12.19 (s, 1H, 1-H), 8.05 (d, J = 7.8 Hz, 1H, 4-H), 7.70 (dd, J = 2.9, 2.9 Hz, 1H, 2-H), 7.56 (d, J = 8.1 Hz, 1H, 5-H), 7.42–7.51 (m, 4H, PhOPh), 7.09–7.23 (m, 5H, PhOPh), 6.76 (dd, J = 3.0, 1.8 Hz, 1H, 3-H); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 169.0, 167.9, 156.7, 135.5, 132.3, 130.8, 129.7, 129.4, 127.8, 126.8, 125.6, 124.5, 119.7, 119.0, 114.0, 105.0, 104.3, 103.7; IR (KBr, cm^{-1}) 3346(bs), 2960(m), 2922(s), 2853(m), 1761(m), 1698(s), 1590(w), 1509(m), 1486(m), 1447(m), 1392(m), 1368(m), 1332(w), 1291(w), 1245(m), 1159(w), 1109(m), 1074(m), 1009(w), 871(w), 828(w), 803(w), 756(w), 722(w); HRMS m/z ($M + Na^+$) calcd for $C_{22}H_{14}N_2O_3$: 377.0897, found 377.0891.

1H-Naphtho[2,3-g]indole-6,11-dione (25) [44]. A mixture of indole **21** (105 mg, 0.262 mmol), saturated aqueous sodium carbonate (10 mL), and methanol (10 mL) were stirred under reflux for 6 h, at which time TLC analysis indicated complete conversion of the starting materials. The mixture was cooled to rt, diluted with water (100 mL), and extracted with dichloromethane (3 × 20 mL). The dichloromethane was washed with saturated aqueous ammonium chloride (20 mL), and brine (20 mL), and dried over anhydrous sodium sulfate. The solvent was removed using a rotating evaporator, and the product was recrystallized from dichloromethane/petroleum ether, giving **25** (51 mg, 79%) as light-orange crystals: mp 205–206°C; ^{1}H NMR (300 MHz, $CDCl_3$, δ) 10.66 (s, 1H, 1-H), 8.07 (d, J = 8.4 Hz, 1H, 4-H), 8.00 (d, J = 8.1 Hz, 1H, 5-H), 8.23–8.34 (m, 2H, 8-H, 9-H), 7.75–7.81 (m, 2H, 7-H, 10-H), 7.57 (dd, J = 3.0, 2.4 Hz, 1H, 2-H), 6.68 (dd, J = 3.3, 1.8 Hz, 1H, 3-H); ^{13}C NMR (75 MHz, DMSO-d_6, δ) 185.0, 183.5, 135.0, 134.8, 134.70, 134.65, 133.8, 133.3, 132.8, 128.0, 127.6, 127.2, 126.7, 118.0, 117.8, 103.2; IR (KBr, cm^{-1}) 3095(w), 2960(m), 2923(m), 2852(w), 1719(w), 1668(s), 1660(m), 1590(m), 1572(w), 1545(w), 1487(m), 1445(w), 1405(w), 1329(m), 1289(s), 1235(w), 1199(w), 1158(m), 1090(s), 1048(m), 1008(m), 898(w), 844(w), 816(m), 724(s), 716(s), 638(w); HRMS m/z ($M + Na^+$) calcd 270.0526, found 270.0538. Anal. Calcd for $C_{16}H_9NO_2$: C, 77.72; H, 3.67; N, 5.67. Found: C, 77.74; H, 3.80; N, 5.49.

^{1}H and ^{13}C NMR spectra for **8**, **9**, **10**, **11**, **12**, **13**, **17**, **18**, **19**, **20**, **21**, **22**, **23**, and **25**. This material is available online free of charge (see Supporting Information).

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