Synthesis of 2-aryl-1*H*-benzimidazoles and 2-aryl-1*H*-perimidines using arylidene Meldrum's acid as a source of the aryl group and oxidant

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Arylidene Meldrum's acid is employed as a source of the aryl group and oxidant for the synthesis of 2-aryl-1*H*–benzimidazoles by a condensation reaction with 1,2-phenylenediamine in refluxing ethanol with good to high yields. Arylidene Meldrum's acids were also used as a source of the aryl group and oxidant for the synthesis of 2-aryl-1*H*-perimidines by a condensation reaction with 1,8-diaminonaphthalene in refluxing ethanol with high yields.

Keywords: arylidene Meldrum's acid, 2-aryl-1*H*-benzimidazoles, 2-aryl-1*H*-perimidines

Multinuclear *N*-heterocyclic compounds such as perimidines and benzimidazoles are of wide interest because they exhibit a diverse range of biological activities.[1,2] Differently substituted benzimidazoles have been associated with an extensive range of biological activities, including antiviral, antifungal, antimicrobial, antiprotozoal, anti-inflammatory, anticancer, antioxidant, anticoagulant, antidiabetic and antihypertensive activities.[3–7]

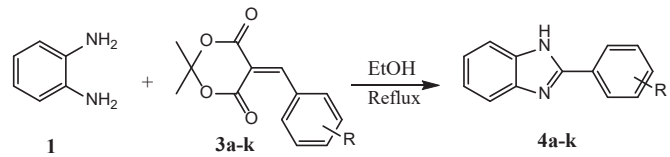
In view of the biological importance of benzimidazoles and perimidines there has been growing interest in the development of synthetic methods for the preparation of these heterocycles. For the synthesis of 2-substituted benzimidazoles the condensation of 1,2-phenylenediamine and aldehydes with subsequent oxidation has been studied using various oxidative reagents such as nitrobenzene (high-boiling point oxidant/solvent),[8–10] I_2,[11] Fe(III)/Fe(II),[12] $In(OTf)_3$,[13] $PhI(OAc)_2$,[14] $Sc(OTf)_3$,[15,16] $Yb(OTf)_3$,[17] heteropoly acids,[18] thionyl chloride treatment,[19] MnO2,[20] $Pb(OAc)_4$,[21] oxone,[22] $NaHSO_3$,[23] H_2O_2/HCl,[24] $Na_2S_2O_5$,[25] potassium persulfate–$CuSO_4$,[26] potassium ferricyanide,[27] H_2O_2/CAN,[28] $H_2O_2/Fe(NO_3)_3$,[29] cobalt(III)–salen complex supported on activated carbon[30] and Cu(II) complex.[31] The most commonly used method for the preparation of 2-substituted perimidines is the condensation reaction of 1,8-diaminonaphthalene with a carbonyl group, which requires a special reagent or forced reaction conditions.[32–38] Although all of these methods are widely employed they all suffer from one or other disadvantage, such as the formation of by-products, tedious work-up procedures or the use of expensive, toxic and air-sensitive oxidative reagents. In addition, in most synthetic routes, the first step is the preparation of 2,3-dihydro-perimidine or 2,3-dihydro- benzimidazole using acid catalysis, and in a subsequent step dehydrogenation is effected using an oxidant reagent. Thus, there is still a need to search for better oxidants and a procedure with operational simplicity.

Given these considerations, here we report a simple and efficient method for the synthesis of 2-aryl-1*H*-benzimidazoles and 2-aryl-1*H*-perimidines through reaction of 1,2-phenylenediamine or 1,8-diaminonaphthalene with two equivalents of arylidene Meldrum's acid, not only as the aryl group donor, but also as the organic oxidant.

Results and discussion

The optimised conditions for the condensation of 1,2-phenylenediamine **1** and benzylidene Meldrum's acid **3a** are 1,2-phenylenediamine (1.0 mmol) and benzylidene Meldrum's acid (2.0 mmol) in ethanol (10.0 mL) under reflux conditions. To explore the scope and generality of this method the synthesis of 2-substituted benzimidazoles **4a–k** was carried out under the same reaction conditions through the reaction of 1,2-phenylenediamine **1** and a wide variety of arylidene Meldrum's acids **3a–k** with high yields (Table 1). In addition, under the optimised reaction conditions, a series of 2-substituted perimidines **5a–i** were synthesised. To explore the scope of this novel transformation, various arylidene Meldrum's acids **3a–i** with 1,8-diaminonaphthalene **2** were utilised under the same reaction conditions (Table 2).

Table 1 Synthesis of 2-aryl-1*H*-benzimidazoles

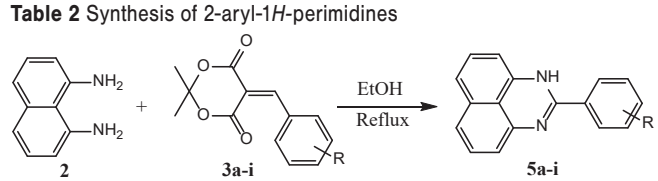


1 **3a-k** **4a-k**

Product	R	Time (h)	Yield (%)[a]	M.p. (°C)
4a	H	4	90	292–294 (289–291)[14]
4b	3-Cl	3	78	230–232 (235–237)[39]
4c	4-Cl	4	90	295–296 (292–294)[14]
4d	4-F	2	92	252–254 (249–251)[40]
4e	4-Br	4	80	292–294 (298)[41]
4f	4-CH_3	5	75	272–274 (277)[11]
4g	4-CF_3	2	85	264–266
4h	4-$N(CH_3)_2$	5	70	210–212 (215)[42]
4i	2-CH_3	5	72	211–214
4j	2-NO_2	4	85	269–271 (263–265)[39]
4k	2-Cl	3	83	228–230 (233–234)[39]

[a]Yields are given for the isolated products

Table 2 Synthesis of 2-aryl-1*H*-perimidines



2 **3a-i** **5a-i**

Product	R	Time (h)	Yield (%)[a]	M.p. (°C)
5a	4-Cl	4.5	92	176–178 (179–181)[43]
5b	4-CH_3	5.5	80	159–161 (160–162)[44]
5c	2,3-$(OCH_3)_2$	6.5	77	139–141
5d	4-NO_2	4.0	87	177–179
5e	3-NO_2	4.0	88	161–163 (162–164)[43]
5f	4-OCH_3	5.5	78	122–125 (120–122)[44]
5g	2,4-$(OCH_3)_2$	7.0	80	151–150
5h	2-Cl	4.5	84	149–150
5i	4-F	4.0	86	163–161

[a]Yields are given for the isolated products

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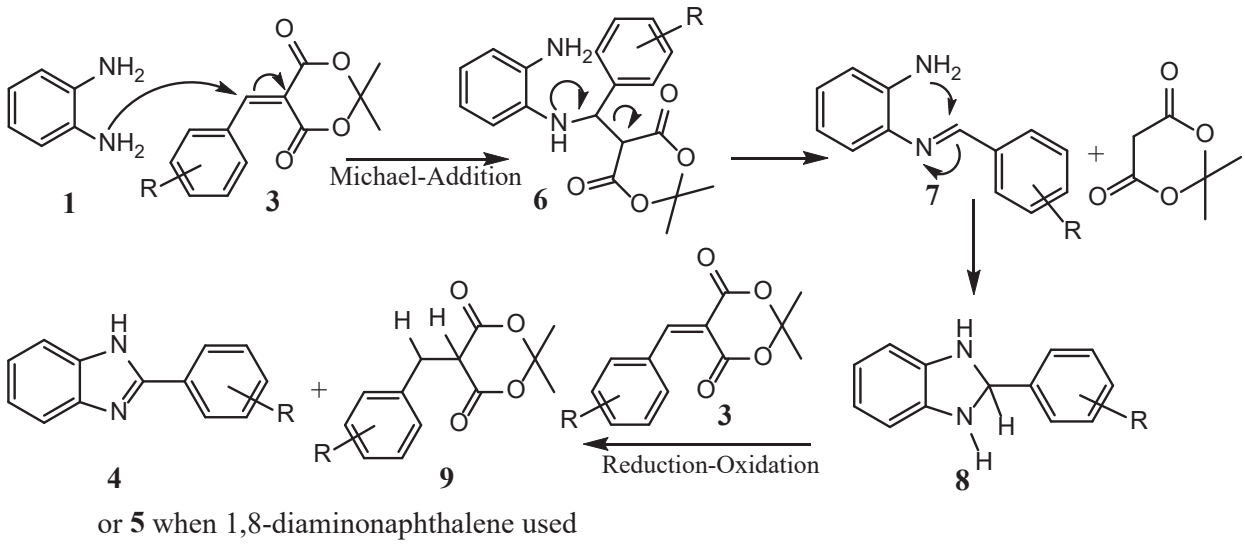

Scheme 1 Proposed mechanism for the synthesis of 2-aryl-1*H*-benzimidazoles **4** and 2-aryl-1*H*-perimidines **5**.

As can be seen from Tables 1 and 2, electronic effects and the nature of substituents on the aromatic ring resulted in products with different reaction times and yields. When aromatic aldehydes containing electron-donating groups (such as methyl, methoxy or dimethylamino) were employed, a longer reaction time and lower yield was required than for those of electron-withdrawing groups (such as trifluoromethyl, nitro or halides) on the aromatic rings.

The known compounds were identified by comparison of their melting points with those reported in the literature (see references in Tables 1 and 2). In addition a number of these compounds were characterised by ^{1}H and ^{13}C NMR, IR and CHN analysis.

A possible mechanism for the synthesis of 2-substituted benzimidazoles **4** and 2-substituted perimidines **5** is illustrated in Scheme 1. This conversion involves the initial reaction of the 1,2-phenylenediamine **1** with arylidene Meldrum's acid **3** to form the intermediate **6** *via* a Michael addition reaction. This intermediate is then converted to Schiff base **7** by eliminating Meldrum's acid as a good leaving group. Continuing, the amine group in Schiff base **7** undergoes an intramolecular nucleophilic addition to the imine group, generating dihydro-benzimidazole **8**. Finally, the benzimidazole **4** is formed through a simple and efficient intermolecular hydrogen transfer between intermediate **8** as a reductant and arylidene Meldrum's acid **3** as an oxidant. Aryldihydro Meldrum's acid **9** was isolated and characterised by spectroscopic techniques. For example, the ^{1}H NMR spectrum of compound **9a** consisted of a singlet at δ 0.54 ppm for the two methyl protons. Two doublets occurred at δ 3.32 and 3.45 ppm with coupling constants of 4.5 and 14.1 Hz, respectively, for the methylene protons. In addition, a doublet and a doublet at δ 4.01 ppm that integrated for one hydrogen, with coupling constants of 14.1 and 4.5 Hz, respectively, for the methine proton were also observed. A multiplet at δ 6.92–7.27 ppm for the aromatic protons of the phenyl ring was also observed. The ^{1}H-decoupled ^{13}C NMR spectrum of compound **9a** showed 11 distinct signals, in agreement with the proposed structure. Partial assignments of these resonances and those of compound **9b** are given in the experimental section.

Conclusions

In summary, we have developed an efficient synthesis that is high-yielding under mild conditions for the synthesis of 2-aryl-1*H*–benzimidazoles and 2-aryl-1*H*-perimidines using arylidene Meldrum's acid. This method offers several advantages, compared with those reported in the literature: (1) it uses a new, readily available and inexpensive reagent, (2) it uses the reagent not only as the source of the aryl group but also as the oxidant, (3) it has short reaction times, and (4) the product is easily isolated and purified, making it a useful and attractive strategy for the synthesis of these products.

Experimental

All chemicals were of high-grade quality and were purchased from either Aldrich or Merck and used without further purification. All melting points were obtained on a Bamslead Electrothermal 9200 apparatus and are uncorrected. The reactions were monitored by thin-layer chromatography (TLC) and all yields refer to isolated products. ^{1}H and ^{13}C NMR spectra were recorded in DMSO on a Bruker 300 and 400 MHz spectrometer. Infrared spectra were recorded on a Bruker FT-IR Equinax-55 spectrophotometer in KBr with absorption maxima quoted in cm^{-1}. Elemental analyses were performed using a Carlo Erba EA 1108 instrument.

Representative experimental procedure

To a magnetically stirred solution of 1,2-phenylenediamine **1** (1.0 mmol) or 1,8-diaminonaphthalene **2** (1.0 mmol) in ethanol (5 mL) was added dropwise arylidene Meldrum's acid **3** (2.0 mmol) in ethanol (5 mL) at room temperature over 5 min. The reaction mixture was then stirred at reflux conditions for an appropriate time. After completion of the reaction, determined by TLC, the solvent was removed under reduced pressure and the resulting crude product was recrystallised from water to give the pure compounds **4a–k** and **5a–i**. For the preparation of **4e** and **5a,** after removal of the solvent, the mixture of products was separated by chromatography on silica gel plates using hexane/ethyl acetate (2:1) to give **9a** and **9b** as well as **4e** and **5a**.

Physical and spectroscopic data for compounds **4a–k** *and* **5a–i**

*2-Phenyl-1*H*-benzimidazole* (**4a**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3048, 2966, 2853, 1621, 1494, 1384, 1180, 1028, 970; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.20 (d, 2H, *J* = 4.8 Hz, ArH), 7.44–7.56 (m, 4H, ArH), 7.67 (br s, 1H, ArH), 8.20 (d, 2H, *J* = 7.2 Hz, ArH), 12.94 (s, 1H, NH).

*2-(3-Chlorophenyl)-1*H*-benzimidazole* (**4b**): IR (KBr) (ν_{max}/cm^{-1}): 3442, 3047, 2965, 1602, 1442, 1384, 1362, 1285, 1124, 1080, 977; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.17–7.26 (m, 2H, ArH), 7.52–7.60 (m, 3H, ArH), 7.67 (d, 1H, *J* = 7.5 Hz, ArH), 8.13 (d, 1H, J = 6.9 Hz, ArH), 8.21 (s, 1H, ArH), 13.02 (s, 1H, NH).

*2-(4-Chlorophenyl)-1*H*-benzimidazole* (**4c**): IR (KBr) (ν_{max}/cm^{-1}): 3442, 3052, 2995, 2955, 1881, 1622, 1471, 1448, 1384, 1320, 1225, 1119, 963. ^{1}H-NMR (300 MHz, DMSO-d_6): δ (ppm) 7.17–7.35 (m, 2H, ArH), 7.60 (d, 4H, *J* = 8.4 Hz, ArH), 8.20 (d, 2H, *J* = 8.4 Hz, ArH), 12.92 (br s, 1H, NH).

*2-(4-Fluorophenyl)-1*H*-benzimidazole* (**4d**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3053, 2964, 1623, 1498, 1452, 1397, 1228, 1156, 1110, 968; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.16–7.22 (m, 2H, ArH), 7.39 (t, 2H, *J* = 8.7 Hz, ArH), 7.58 (br s, 2H, ArH), 8.18–8.23 (dd, 2H, *J* = 8.4 and 5.4 Hz, ArH), 12.91 (br s, 1H, NH).

*2-(4-Bromophenyl)-1*H*-benzimidazole* (**4e**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3051, 2950, 1622, 1470, 1428, 1320, 1274, 1113, 1070, 963; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm)7.16–7.25 (m, 2H, ArH), 7.52 (d, 1H, *J* = 7.2 Hz, ArH), 7.65 (d, 1H, *J* = 7.2 Hz, ArH), 7.75 (d, 2H, *J* = 8.4 Hz, ArH), 8.11 (d, 2H, *J* = 8.4 Hz, ArH), 12.98 (s, 1H, NH).

*2-(4-Methylphenyl)-1*H*-benzimidazole* (**4f**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3053, 3026, 2965, 2917, 1621, 1588, 1447, 1398, 1274, 1154, 1041, 964; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 2.36 (s, 3H, CH_3), 7.17–7.18 (m, 2H, ArH), 7.34 (d, 2H, *J* = 8.1 Hz, ArH), 7.51–7.62 (m, 2H, ArH), 8.07 (d, 2H, *J* = 8.1 Hz, ArH), 12.82 (s, 1H, NH).

*2-(4-Trifluoromethylphenyl)-1*H*-benzimidazole* (**4g**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3053, 2964, 1623, 1498, 1452, 1397, 1228, 1156, 1110, 968; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.19–7.28 (m, 2H, ArH), 7.56 (d, 1H, *J* = 7.8 Hz, ArH), 7.70 (d, 1H, *J* = 7.8 Hz, ArH), 7.92 (d, 2H, *J* = 8.1 Hz, ArH), 8.38 (d, 2H, *J* = 8.1 Hz, ArH), 13.16 (s, 1H, NH); ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 122.32, 123.17, 128.15, 129.06, 134.52, 150.19; Anal. calcd for $C_{14}H_9F_3N_2$ (262.24): C, 64.12; H, 3.46; N, 10.68; found: C, 64.19; H, 3.48; N, 10.65%.

*2-(4-Dimethylaminophenyl)-1*H*-benzimidazole* (**4h**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3061, 2965, 2906, 1606, 1549, 1528, 1491, 1367, 1165; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 3.0 (s, 6H, NMe_2), 6.84 (d, 2H, *J* = 9.0 Hz, ArH), 7.13–7.16 (m, 2H, ArH), 7.49–7.52 (m, 2H, ArH), 7.98 (d, 2H, *J* = 9.0 Hz, ArH), 12.89 (s, 1H, NH).

*2-(2-Methylphenyl)-1*H*-benzimidazole* (**4i**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3061, 2967, 2920, 2877, 2789, 2673, 1589, 1490, 1403, 1384, 1277, 1207, 1011, 975; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 2.40 (s, 3H, CH_3), 7.14–7.22 (m, 2H, ArH), 7.29 (d, 1H, *J* = 7.5 Hz, ArH), 7.42 (t, 1H, *J* = 7.8 Hz, ArH), 7.51 (d, 1H, *J* = 7.5 Hz, ArH), 7.64 (d, 1H, *J* = 7.2 Hz, ArH), 7.95 (d, 1H, *J* = 7.8 Hz, ArH), 8.01 (s, 1H, ArH), 12.86 (s, 1H, NH); ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 24.52, 122.21, 127.39, 129.98, 130.32, 131.15, 131.64, 132.07, 149.10; Anal. calcd for $C_{14}H_{12}N_2$ (208.26): C, 80.74; H, 5.81; N, 13.45; found: C, 80.69; H, 5.78; N, 13.40%.

*2-(2-Nitrophenyl)-1*H*-benzimidazole* (**4j**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3064, 2864, 2655, 1611, 1574, 1446, 1379, 1348, 1278, 1140, 1078; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.25 (br s, 2H, ArH), 7.69 (br s, 2H, ArH), 7.73 (t, 1H, *J* = 7.8 Hz, ArH), 7.84 (t, 1H, *J* = 7.5 Hz, ArH), 7.98 (d, 1H, *J* = 7.8 Hz, ArH), 8.02 (d, 1H, *J* = 7.8 Hz, ArH), 13.08 (s, 1H, NH).

*2-(2-Chlorophenyl)-1*H*-benzimidazole* (**4k**): IR (KBr) (ν_{max}/cm^{-1}): 3447, 3048, 1936, 1622, 1590, 1443, 1404, 1231, 1110, 1026; ^{1}H NMR (300 MHz, DMSO-d_6): δ (ppm) 7.20–7.26 (m, 2H, ArH), 7.47–7.55 (m, 2H, ArH), 7.62–7.65 (m, 3H, ArH), 7.89–7.92 (m, 1H, ArH), 12.74 (s, 1H, NH).

*2-(4-Chlorophenyl)-1*H*-perimidine* (**5a**): IR (KBr) (ν_{max}/cm^{-1}): 3298, 2995, 2850, 1635, 1598, 1447, 1426, 1414; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 6.54 (d, 2H, *J* = 7.2 Hz, ArH), 6.96 (d, 2H, *J* = 7.2 Hz, ArH), 7.99 (m, 4H, ArH), 7.62 (d, 2H, *J* = 8. Hz, ArH), 8.04 (d, 2H, *J* = 8.8 Hz, 2H, ArH), 10.71(s, 1H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 107.8, 122.0, 124.2, 125.2, 128.7, 128.9, 129.0, 129.1, 132.5, 135.5, 136.2, 141.3, 143.7, 152.1.

*2-(4-Methylphenyl)-1*H*-perimidine* (**5b**): IR (KBr) (ν_{max}/cm^{-1}): 3287, 3048, 2920, 1635, 1601, 1509, 1444, 1372; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 2.31 (s, 3H, CH_3), 6.62 (m, 2H, *J* = 8.4 Hz, ArH), 7.03 (d, 2H, *J* = 8.4 Hz, ArH), 7.14 (m, 2H, *J* = 8.4 Hz, ArH), 7.34 (d, 2H, *J* = 8.4 Hz, ArH), 7.93 (d, 2H, *J* = 8.4 Hz, ArH), 10.61 (s, 1H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 21.48, 109.0, 118.9, 119.0, 120.4, 121.9, 127.2, 128.8, 128.9, 131.0, 135.5, 139.6, 141.4, 152.9.

*2-(2,3-Dimethoxyphenyl)-1*H*-perimidine* (**5c**): IR (KBr) (ν_{max}/cm^{-1}): 3343, 2990, 2857, 1611, 1594, 1447, 1422, 1411, 1594; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.85 (s, 3H, OCH_3), 3.90 (s, 3H, OCH_3), 6.49–7.23 (m, 10H, ArH and NH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 56.0, 56.4, 98.9, 105.3, 105.9, 112.6, 114.8, 118.5, 121.9, 127.1, 128.9, 131.6, 135.6, 153.0, 158.9, 162.8; Anal. calcd for $C_{19}H_{16}N_2O_2$ (304.35): C, 74.98; H, 5.30; N, 9.20; found: C, 75.09; H, 5.33; N, 9.14%.

*2-(4-Nitrophenyl)-1*H*-perimidine* (**5d**): IR (KBr) (ν_{max}/cm^{-1}): 3364, 2983, 1601, 1513, 1420, 1350; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 5.54 (s, 1H, NH), 6.52 (d, 2H, *J* = 7.2 Hz, ArH), 7.00 (m, 2H, *J* = 8.8 Hz, ArH), 7.18 (m, 2H, *J* = 7.2 Hz, ArH), 7.84 (d, 2H, *J* = 8.8 Hz, ArH), 8.30 (m, 2H, ArH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 65.3, 105.0, 107.9, 112.8, 116.0, 119.9, 123.8, 127.4, 128.7, 129.5, 134.7, 142.5, 144.6, 147.8, 150.3; Anal. calcd for $C_{17}H_{11}N_3O_2$ (289.29): C, 70.58; H, 3.83; N, 14.53; found: C, 70.52; H, 3.79; N, 14.48%.

*2-(3-Nitrophenyl)-1*H*-perimidine* (**5e**): IR (KBr) (ν_{max}/cm^{-1}): 3345, 3038, 1602, 1528, 1416, 1351; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 5.50 (s, 1H, NH), 6.52 (d, 1H, *J* = 6.8 Hz, ArH), 7.01 (m, 3H, *J* = 7.6 Hz, ArH), 7.18 (m, 2H, *J* = 8.0 Hz, ArH), 7.73 (m, 1H, *J* = 8.0 Hz, ArH), 8.0 (m, 1H, *J* = 7.6 Hz, ArH), 8.28 (m, 1H, *J* = 6.8 Hz, ArH), 8.46 (m, 1H, ArH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 65.2, 105.0, 116.1, 122.0, 122.3, 123.0, 123.7, 127.4, 129.0, 130.3, 130.7, 133.8, 135.0, 135.4, 142.6, 145.0, 148.3.

*2-(4-Methoxyphenyl)-1*H*-perimidine* (**5f**): IR (KBr) (ν_{max}/cm^{-1}): 3446, 3037, 2924, 2838, 1611, 1598, 1512, 1465, 1437; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.86 (s, 3H, OCH_3), 6.62 (s, 1H, NH), 6.62–8.03 (m, 10H, ArH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 55.9, 114.1, 117.3, 118.7, 121.8, 125.9, 127.3, 128.9, 131.0, 135.5, 137.5, 140.0, 141.9, 152.6, 154.4, 162.0.

*2-(2,4-Dimethoxyphenyl)-1*H*-perimidine* (**5g**): IR (KBr) (ν_{max}/cm^{-1}): 3348, 3044, 2998, 1600, 1517, 1485, 1414; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.78 (s, 3H, CH_3), 3.79 (s, 3H, CH_3), 5.35 (s, 1H, NH), 6.49 (m, 2H, ArH), 6.69 (m, 2H, ArH), 6.99 (m, 2H, *J* = 7.6 Hz, ArH), 7.14 (m, 2H, *J* = 7.6 Hz, ArH), 7.23 (m, 2H, ArH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 56.1, 56.2, 104.7, 111.6, 111.8, 115.6, 119.3, 120.6, 120.8, 127.3, 128.9, 134.5, 134.8, 135.3, 143.7, 148.9, 149.1, 149.5; Anal. calcd for $C_{19}H_{16}N_2O_2$ (304.35): C, 74.98; H, 5.30; N, 9.20; found: C, 74.88; H, 5.29; N, 9.16%.

*2-(2-Chlorophenyl)-1*H*-perimidine* (**5h**): IR (KBr) (ν_{max}/cm^{-1}): 3386, 3048, 2924, 2853, 1635, 1596, 1477, 1371; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 7.08–7.64 (m, 10H, ArH), 10.90 (s, 1H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 119.2, 122.1, 123.9, 126.8, 127.1, 127.9, 128.9, 130.1, 130.8, 131.6, 131.8, 134.9, 135.6, 142.3, 153.4; Anal. calcd for $C_{17}H_{11}ClN_2$ (278.74): C, 73.25; H, 3.98; N, 10.05; found: C, 73.17; H, 3.96; N, 10.01%.

*2-(4-Fluorophenyl)-1*H*-perimidine* (**5i**): IR (KBr) (ν_{max}/cm^{-1}): 3313, 2987, 2853, 1636, 1595, 1442, 1425; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 6.63 (m, 2H, ArH), 7.05 (d, 2H, *J* = 8.0 Hz, ArH), 7.17 (d, 2H, *J* = 8.0 Hz, ArH), 7.39 (d, 2H, *J* = 8.8 Hz, ArH), 8.10 (d, 2H, *J* = 8.8 Hz, ArH), 10.70 (s, 1H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 114.4, 115.7, 115.9, 119.0, 121.9, 128.9, 129.8, 129.8, 130.3, 130.3, 131.9, 132.0, 135.5, 152.2, 165.4; Anal. calcd for $C_{17}H_{11}FN_2$ (262.29): C, 77.85; H, 4.23; N, 10.68; found: C, 77.83; H, 4.19; N, 10.64%.

5-(4-Bromobenzyl)-2,2-dimethyl-1,3-dioxane-4,6-dione (**9a**): M.p. 127–129 °C; Yield 83%; IR (KBr) (ν_{max}/cm^{-1}): 1758, 1731, 1605, 1587, 1491, 1391, 1377, 1303, 1285, 1114; ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 0.54 (s, 6H, $2CH_3$), 3.32 (d, *J* = 4.5 Hz, 1H, CH_2), 3.45 (d, *J* = 14.1 Hz, 1H, CH_2), 4.01 (dd, *J* = 14.1 and 4.5 Hz, 1H, CH), 6.92–7.27 (m, 4H, ArH); ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 20.95, 42.32, 48.73, 105.90, 128.73, 129.00, 137.36, 138.21, 167.51; Anal. calcd for $C_{13}H_{13}BrO_4$ (313.15): C, 49.86; H, 4.18; found: C, 49.97; H, 4.21%.

5-(4-Chlorobenzyl)-2,2-dimethyl-1,3-dioxane-4,6-dione (**9b**): M.p. 147–149 °C; Yield 80%; IR (KBr) (ν_{max}/cm^{-1}): 1754, 1725, 1514, 1394, 1382, 1362, 1287, 1194; ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 0.53 (s, 6H, $2CH_3$), 3.33 (d, *J* = 4.3 Hz, 1H, CH_2), 3.46 (d, *J* = 14.1 Hz, 1H, CH_2), 4.00 (dd, *J* = 14.1 and 4.3 Hz, 1H, CH), 7.02 (d, *J* = 7.8 Hz, 2H, ArH), 7.16 (d, *J* = 7.8 Hz, 2H, ArH); ^{13}C NMR (75 MHz, $CDCl_3$):

δ (ppm) 20.50, 42.36, 48.42, 105.85, 128.04, 129.42, 134.27, 137.81, 167.61; Anal. calcd for $C_{13}H_{13}ClO_4$ (268.69): C, 58.11; H, 4.88; found: C, 58.19; H, 4.91%.

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