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Reaction of indolin-2-ones with cerium(IV) ammonium nitrate

Carmen Escolano, Lluís Vallverdú and Keith Jones*

School of Chemical and Pharmaceutical Sciences, Kingston University, Penrhyn Road, Kingston-upon-Thames, Surrey KT1 2EE, UK

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Abstract—The reaction of indolin-2-ones with CAN is studied. When the reaction is carried out in an alcohol as solvent, 3-alkoxyindolin-2-ones are obtained in very good yields. If a non-nucleophilic solvent is used (THF, acetonitrile) 3-nitroxy derivatives are isolated. If the aromatic ring bears an electron-donating group, reactions are accompanied by aromatic ring nitration.

1. Introduction

During the last two decades our group has been interested in the preparation of indolin-2-one derivatives by intramolecular addition of aryl radicals to acrylamides.[1] During this work, we have found on occasion that the crude 3-substituted-indolin-2-ones spontaneously dimerise to produce 3,3′-leucoisoindigos such as **1**.[2] These oxindole dimers have been used as intermediates in the synthesis of calycanthine alkaloids such as folicanthine **2**.[3] In order to prepare such dimers in a satisfactory manner, we decided to explore the possible oxidative dimerisation of 3-substituted-indolin-2-ones with cerium(IV) ammonium nitrate (CAN). CAN is a versatile reagent for the oxidation of numerous functional groups in organic synthesis.[4] Most of the transformations mediated by CAN proceed under mild conditions and give high yields of products. In this paper we wish to report our systematic investigation of the chemistry associated with the functionalization of the C-3 position in indolin-2-ones by CAN (Fig. 1).

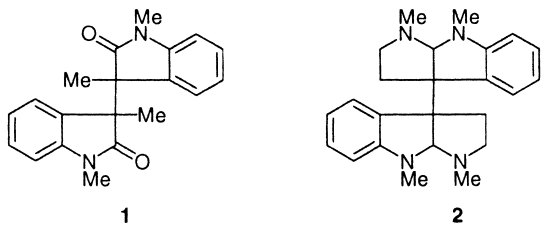
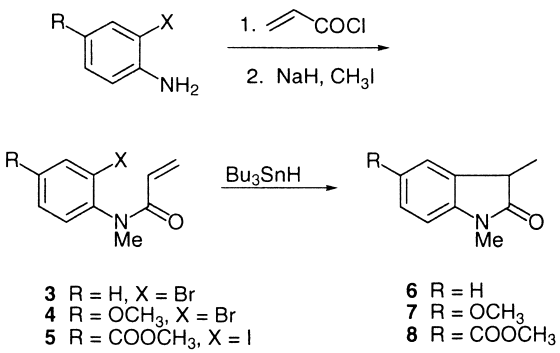


Figure 1.

2. Discussion

In order to study the effect of substituents with different electronic character, experiments were carried out using the 1,3-dimethylindolin-2-one, **6**, the methoxyderivative **7** and the methoxycarbonylderivative **8**. Compounds **6** and **7** are readily available from the corresponding 2-haloaniline using a three step sequence previously described by our group.[5] Reaction of 2-bromoaniline or 2-bromo-4-methoxyaniline with acryloyl chloride followed by N-alkylation and radical cyclization [tributyltin hydride (0.02 M) in refluxing toluene with a sub-stoichiometric amount of AIBN] led to **6** and **7** in good overall yields. Following this general procedure, compound **8**[6] was prepared from methyl 4-amino-3-iodobenzoate (Scheme 1).



Scheme 1.

Oxidation reactions of these compounds were performed at room temperature dissolving the starting material in different solvents and adding 2.2 equiv. of CAN (Scheme 2). Reacting **6** with CAN in methanol, ethanol or isopropanol gave the corresponding oxindole derivatives **9a**[7]**–c** in good yields. The ^{1}H NMR spectrum of **9a–c** showed a singlet at ~1.4 ppm and the ^{13}C NMR spectrum showed a quaternary carbon at ~79 ppm indicating that substitution at the 3-positon by an alkoxy group had occurred. When *tert*-butanol was used as a solvent only starting material was recovered. To study the scope of the

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* Corresponding author. Tel.: +44-20-8547-8450; fax: +44-20-8547-7562; e-mail: keith.jones@kingston.ac.uk

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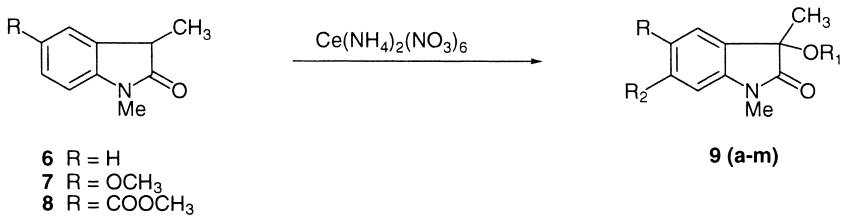


Scheme 2.

oxidation reaction in other nucleophilic solvents, isopropylamine was used. Reaction of **6** with CAN in isopropylamine as a solvent gave the 3-hydroxy derivative **9d**[8] with no products arising from the nucleophilic addition of isopropylamine being detected. In order to further explore the reaction, tetrahydrofuran (THF) and acetonitrile were chosen as non-nucleophilic solvents. When the reaction was carried out in THF or acetonitrile the nitrooxyoxindole **9e** was obtained in good yields (74 and 69%, respectively). The IR showed peaks at 1642 and 1616 cm^{-1} and in the ^{13}C NMR a signal at δ 83.5 ppm indicated substitution at C-3 by a nitrate group.

Next, reaction of the oxindole **7**, which bears an electron-donating group in the aromatic ring, was studied. Reactions in methanol, ethanol and isopropanol were performed with **9f–h** being isolated in good yields. As before, a singlet in the ^1H NMR at $\delta\sim1.5$ ppm and a quaternary carbon in the ^{13}C NMR at $\delta\sim79$ ppm indicates that substitution at the 3-position by an alkoxy group had occurred. Moreover, only two peaks in the aromatic region were observed, due to the nitration of the 6-position. When THF or acetonitrile was used as a solvent compound **9i** was obtained in good yield.

Table 1. Oxidation reactions of compounds **6–8** (Scheme 2)

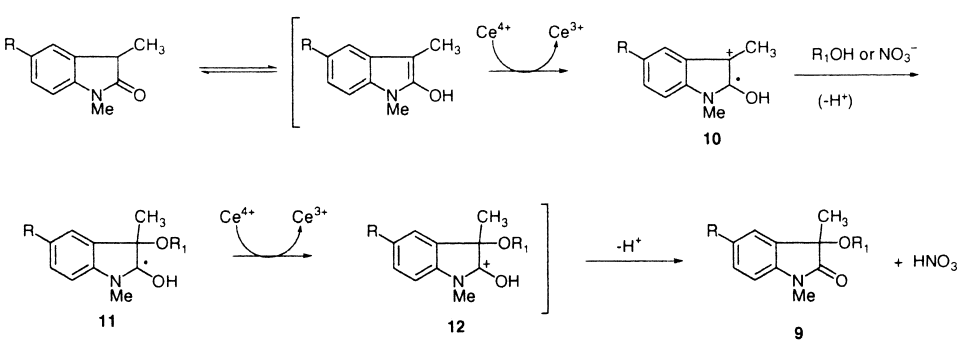
Compounds	R	R_1	R_2	Yield (%)
9a	H	CH_3	H	71
9b	H	CH_2CH_3	H	72
9c	H	$CH(CH_3)_2$	H	66
9d	H	H	H	68
9e	H	NO_2	H	74/69
9f	OCH_3	CH_3	NO_2	70
9g	OCH_3	CH_2CH_3	NO_2	64
9h	OCH_3	$CH(CH_3)_2$	NO_2	64
9i	OCH_3	NO_2	NO_2	57/60
9j	$COOCH_3$	CH_3	H	72
9k	$COOCH_3$	CH_2CH_3	H	88
9l	$COOCH_3$	$CH(CH_3)_2$	H	53
9m	$COOCH_3$	NO_2	H	80/84

Characteristic peaks at 1648 and 1353 cm^{-1} in the IR, only two aromatic protons and a quaternary carbon at δ 82.7 indicated that substitution at C-3 by a nitrate group and nitration in the 6-position had occurred. The nitration of the electron-rich aromatic ring was not unexpected, since CAN-mediated nitrations are well documented and several mechanisms have been proposed.[9]

Finally, the effect of an electron-withdrawing substituent was explored. When **8** was oxidised by CAN in methanol or ethanol, compounds **9j** (72%) and **9k** (88%), respectively, were obtained. Using isopropanol as a solvent a mixture of the expected **91** (53%) and **9m** (36%) was observed. As before, the structures of **9j–l** were deduced on the basis of the spectral data. As expected, reaction of **8** with CAN in THF or acetonitrile afforded the nitrooxy derivative **9m** in 80 and 84% yield, respectively. IR peaks (1651 and 1621 cm^{-1}) and a quaternary carbon at δ 82.8 ppm characteristic for the nitrooxy substitution at C-3 were observed. No nitration of the aromatic ring was observed owing to the deactivation of the benzene ring by the methoxycarbonyl group (Table 1).

Although further investigations are desirable in order to fully understand the mechanism of these reactions, we tentatively proposed the mechanism shown in Scheme 3.[10] Oxidation of indolin-2-one by CAN could lead to a radical-cation **10** which in the presence of a nucleophilic alcohol would give intermediate **11**. Further oxidation of **11** by the second equivalent of CAN would lead to the relatively stable cation **12** that would lose a proton giving **13** and nitric acid. The formation of nitric acid during the reaction would provide an explanation for the aromatic nitration of the electron-rich benzene ring in **7**.

In conclusion, oxidation reactions with cerium(IV) ammonium nitrate of indolin-2-ones substituted by different electronic character groups in the benzene ring, have been studied. When reactions are carried out in an alcohol as a



Scheme 3.

solvent (methanol, ethanol or isopropanol), 3-alkoxyindolin-2-ones are obtained in very good yield. If a non-nucleophilic solvent is used (THF or acetonitrile), 3-nitroxy derivatives are isolated. If the aromatic ring bears an electron-donating group, substitution at the C-3 position is accompanied by aromatic ring nitration. No trace of dimeric oxindole products were isolated in any reaction.

3. Experimental

3.1. General details

These were as previously reported.[6]

3.1.1. 1,3-Dimethyl-5-methoxycarbonylindolin-2-one, 8. A suspension of **5** (800 mg, 2.4 mmol) and a sub-stoichiometric amount of AIBN (ca. 10 mg) in toluene (160 mL) was heated to reflux. Then, tri-*n*-butyltin hydride (0.67 mL, 2.50 mmol) was added dropwise and the reaction mixture was stirred at this temperature for 1 h. After evaporation of the solvent the residue was chromatographed (SiO_2, hexane/ethyl acetate 1.5:1) to give the title compound **8** as a white solid (431 mg, 82%) mp 120–121°C (hexane/ethyl acetate 1:2) (Found: C, 65.69; H, 5.73; N, 6.09. $C_{12}H_{13}NO_3$ requires C, 65.74; H, 5.98; N, 6.39%). ν_{max}/cm^{-1} 1713 (s, ester C=O), 1617 (s, amide C=O); δ_H 1.40 (3H, d, J=7.6 Hz, CH_3), 3.15 (3H, s, NCH_3), 3.36 (1H, q, J=7.6 Hz, H-3), 3.82 (3H, s, OCH_3), 6.77 (1H, d, J=8.1 Hz, H-7), 7.82 (1H, s, H-4), 7.95 (1H, dd, J=8.1, 0.76 Hz, H-6); δ_C 15.0 (CH_3), 26.2 (NCH_3), 40.1 (CH), 51.9 (OCH_3), 107.3 (CH), 124.1 (C), 124.5 (CH), 130.2 (C), 130.5 (CH), 148.0 (C), 166.7 (ester C=O), 178.7 (amide C=O); *m/z* (EI) 219 (100, M^+), 188 (90, M^+-OCH_3), 160 (70).

3.2. General procedure for CAN oxidation

To a solution of oxindole (1 mmol) dissolved in the solvent (ca. 6 mL) CAN (2.2 mmol) was added slowly in four portions during 10 min and the mixture was stirred overnight. The solvent was evaporated in vacuo and the residue was dissolved in CH_2Cl_2. The organic layer was washed with water, dried and evaporated under reduced pressure.

3.2.1. 1,3-Dimethyl-3-methoxyindolin-2-one, 9a.[7] Oxindole **6** (50 mg, 0.31 mmol) in methanol (2 mL) and CAN (0.37 g, 0.68 mmol) gave a brown oil, **7a** (42 mg, 71%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.5). δ_H 1.47 (3H, s, CH_3), 2.92 (3H, s, OCH_3), 3.15 (3H, s, NCH_3), 6.78 (1H, d, J=7.6 Hz, ArH), 7.05 (1H, td, J=7.6, 1 Hz, ArH), 7.25 (2H, m, ArH); δ_C 23.8 (CH_3), 26.1 (NCH_3), 53.0 (OCH_3), 79.5 (C), 108.4 (CH), 123.1 (CH), 123.7 (CH), 128.5 (C), 129.3 (CH), 143.4 (C), 176.5 (amide C=O); *m/z* 191 (77, M^+), 175 (58), 160 (100), 132 (53), 77 (10).

3.2.2. 1,3-Dimethyl-3-ethoxyindolin-2-one, 9b. Oxindole **6** (20 mg, 0.12 mmol) in ethanol (1 mL) and CAN (0.15 g, 0.27 mmol) gave a colourless oil, **9b** (18.3 mg, 72%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.5). ν_{max}/cm^{-1} 2977 (m, C–H), 1724 (s, amide C=O), 1124 (m, C–O); δ_H 1.06 (3H, t, J=7 Hz, OCH_2CH_3), 1.48 (3H, s, CH_3), 3.03 (2q, 2H, J=7 Hz, OCH_2CH_3), 3.14 (3H, s, NCH_3), 6.77 (1H, dd, J=8.4, 0.85 Hz, ArH), 7.04 (1H, td, J=7.6, 0.85 Hz, ArH), 7.26 (2H, m, ArH); δ_C 15.3 (CH_2CH_3), 24.1 (CH_3), 26.0 (NCH_3), 60.9 (CH_2), 79.0 (C), 108.3 (CH), 123.0 (CH), 123.5 (CH), 129.3 (C), 129.5 (CH), 143.2 (C), 176.8 (amide C=O); *m/z* (EI) 177 (100, $M^+-C_2H_4$), 161 (58), 77 (19) (Found: M^+, 205.1103. $C_{12}H_{15}NO_2$ requires M 205.1116).

3.2.3. 1,3-Dimethyl-3-isoproxyindolin-2-one, 9c. Oxindole **6** (20 mg, 0.12 mmol) in isopropanol (1 mL) and CAN (0.15 g, 0.27 mmol) gave a white foam, **9c** (18 mg, 66%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.5). ν_{max}/cm^{-1} 2972 (m, C–H), 1725 (s, amide C=O), 1121 (m, C–O); δ_H 0.89 (3H, d, J=6 Hz, CH_3), 1.02 (3H, d, J=6 Hz, CH_3), 1.45 (3H, s, CH_3), 3.20 (3H, s, NCH_3), 3.22 (1H, sept., J=6 Hz, CH), 6.8–7.2 (4H, m, ArH); δ_C 23.4 (CH_3), 24.2 (CH_3), 25.0 (CH_3), 26.1 (NCH_3), 69.1 (CH), 78.6 (C), 108.3 (CH), 122.8 (CH), 123.9 (CH), 129.4 (CH), 130.2 (C),143.0 (C), 178.3 (amide C=O); *m/z* (EI) 219 (40, M^+), 207 (14), 167 (27) (Found: M^+, 219.1262. $C_{13}H_{17}NO_2$ requires M 219.1259).

3.2.4. 1,3-Dimethyl-3-hydroxyindolin-2-one, 9d.[8] Oxindole **6** (20 mg, 0.12 mmol) in isopropylamine (1 mL) and CAN (0.15 g, 0.27 mmol) gave a white foam, **9d** (15 mg, 68%) after chromatography (SiO_2, hexane/ethyl acetate 1:1) δ_C 24.8 (CH_3), 26.2 (NCH_3), 73.7 (C), 108.5 (CH), 123.2 (CH), 123.4 (CH), 129.6 (CH), 131.4 (C), 143.1 (C), 178.9 (amide C=O).

3.2.5. 1,3-Dimethyl-3-nitrooxyindolin-2-one, 9e. Oxindole **6** (40 mg, 0.25 mmol) in THF or acetonitrile (2 mL) and CAN (300 g, 0.54 mmol) gave a white foam, **9e** (41 mg, 74%; 38 mg, 69%, respectively) after chromatography (SiO_2, hexane/ethyl acetate 1:2). ν_{max}/cm^{-1} 1734 (s, amide C=O), 1642 and 1616 (s, ONO_2); δ_H (400 MHz) 1.62 (3H, s, CH_3), 3.25 (3H, s, NCH_3), 6.89 (1H, d, J=7.6 Hz, ArH), 7.10 (1H, t, J=7.6 Hz, ArH), 7.33 (1H, d, J=7.6 Hz, ArH), 7.38 (1H, td, J=7.6, 0.7 Hz, ArH); δ_C 21.4 (CH_3), 26.6 (NCH_3), 83.5 (C), 122.5 (CH), 123.3 (2×CH), 126.2 (C), 130.7 (CH),143.4 (C), 173.0 (amide C=O); *m/z* (EI) 223 (20, M^++1), 176 (32), 160 (100) (Found: M^++H, 223.0726. $C_{10}H_{11}N_2O_4$ requires M+H 223. 0719).

3.2.6. 3,5-Dimethoxy-1,3-dimethyl-6-nitroindolin-2-one, 9f. Oxindole **7** (91 mg, 0.47 mmol) in methanol (3 mL) and CAN (630 mg, 1.15 mmol) gave a yellow foam, **9f** (89 mg, 70%) after chromatography (SiO_2, hexane/ethyl acetate 3:1). ν_{max}/cm^{-1} 2945 (w, C–H), 1728 (s, amide C=O), 1526 (m, NO_2), 1352 (w, NO_2); δ_H 1.50 (3H, s, CH_3), 2.99 (3H, s, $COCH_3$), 3.18 (3H, s, NCH_3), 3.92 (3H, s, $ArOCH_3$), 7.09 (1H, s, ArH), 7.27 (1H, s, ArH); δ_C 23.9 (CH_3), 26.5 (NCH_3), 53.5 (OCH_3), 57.3 ($ArOCH_3$), 79.7 (C), 105.4 (CH), 110.3 (CH), 135.4 (C), 136.8 (C), 140.1 (C), 150.4 (C), 175.2 (amide C=O); *m/z* (EI) 266 (100, M^+), 236 (38), 223 (59), 176 (36), 160 (20), 77 (20) (Found: 266.0894. $C_{12}H_{14}N_2O_5$ requires M 266.0903).

3.2.7. 1,3-Dimethyl-3-ethoxy-5-methoxy-6-nitroindolin-2-one, 9g. Oxindole **7** (45 mg, 0.23 mmol) in ethanol (1.5 mL) and CAN (289 mg, 0.53 mmol) gave a yellow foam, **9g** (42 mg, 64%) after chromatography (SiO_2,

hexane/ethyl acetate 3:1). ν_{max}/cm^{-1} 2965 (w, C–H), 1726 (s, amide C═O), 1525 (m, NO_2), 1351 (w, NO_2); δ_H 1.09 (3H, t, J=7.0 Hz, CH_2CH_3), 1.50 (3H, s, CH_3), 2.98 and 3.11 (2H, m, CH_2CH_3), 3.16 (3H, s, NCH_3), 3.92 (3H, s, $ArOCH_3$), 7.08 (1H, s, ArH), 7.25 (1H, s, ArH); δ_C 15.3 (CH_2CH_3), 24.3 (CH_3), 26.5 (NCH_3), 57.3 (OCH_3), 61.5 (CH_2), 79.1 (C), 105.3 (CH), 110.2 (CH), 136.2 (2×C), 139.7 (C), 150.4 (C), 175.6 (amide C═O); *m/z* (EI) 280 (100, M^+), 251 (31, M^+), 236 (92, M^+), 223 (92), 176 (60), 160 (39), 77 (33) (Found: M^+, 280.1059. $C_{13}H_{16}N_2O_5$ requires *M* 280.1047).

3.2.8. 1,3-Dimethyl-3-isopropoxy-5-methoxy-6-nitroindolin-2-one, 9h. Oxindole **7** (91 mg, 0.48 mmol) in isopropanol (3 mL) and CAN (629 mg, 1.15 mmol) gave a yellow foam, **9h** (90 mg, 64%) after chromatography (SiO_2, hexane/ethyl acetate 3:1). ν_{max}/cm^{-1} 2975 (w, C–H), 1728 (s, amide C═O), 1526 (m, NO_2), 1350 (w, NO_2); δ_H 0.90 and 1.06 [6H, 2d, J=6.1 Hz, $CH(CH_3)_2$], 1.47 (3H, s, CH_3), 3.17 (3H, s, NCH_3), 3.25 [1H, m, $CH(CH_3)_2$], 3.92 (3H, s, OCH_3), 7.10 (1H, s, ArH), 7.26 (1H, s, ArH); δ_C 23.4 (CH_3), 24.2 (CH_3), 25.0 (CH_3), 26.5 (NCH_3), 57.4 (OCH_3), 69.9 (CH), 78.8 (C), 105.3 (CH), 110.5 (CH), 135.9 (C), 137.1 (C), 139.7 (C), 150.2 (C), 176.1 (amide C═O); *m/z* (EI) 294 (88, M^+), 251 (60, M^+), 236 (100, M^+), 223 (64), 176 (59.5), 77 (33) (Found: M^+, 294.1208. $C_{14}H_{18}N_2O_5$ requires *M* 294.1216).

3.2.9. 1,3-Dimethyl-5-methoxy-6-nitro-3-nitrooxyindolin-2-one, 9i. Oxindole **7** (86 mg, 0.45 mmol) in THF or acetonitrile (3 mL) and CAN (631 mg, 1.15 mmol) gave a yellow foam, **9i** (77 mg, 57%; 81 mg, 60%, respectively) after chromatography (SiO_2, hexane/ethyl acetate 3:1). ν_{max}/cm^{-1} 1736 (s, amide C═O), 1648 (s, ONO_2), 1528 (s, NO_2), 1353 (w, NO_2); δ_H 1.67 (3H, s, CH_3), 3.28 (3H, s, NCH_3), 3.98 (3H, s, OCH_3), 7.16 (1H, s, ArH), 7.38 (1H, s, ArH); δ_C 21.4 (CH_3), 27.0 (NCH_3), 57.4 (OCH_3), 82.7 (C), 106.1 (CH), 109.2 (CH), 132.3 (C), 136.2 (C), 140.4 (C), 150.3 (C), 170.2 (amide C═O); *m/z* (EI) 297 (72, M^+), 251 (89.6), 235 (67), 223 (89), 176 (100), 77 (46) (Found: M^+, 297.0605. $C_{11}H_{11}N_3O_7$ requires *M* 297.0597).

3.2.10. 1,3-Dimethyl-3-methoxy-5-methoxycarbonylindolin-2-one, 9j. Oxindole **8** (99 mg, 0.45 mmol) in methanol (3 mL) and CAN (559 mg, 1.01 mmol) gave a white foam, **9j** (81 mg, 72%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.2). ν_{max}/cm^{-1} 2930 (m, C–H), 1728 (s, amide C═O), 1712 (s, ester C═O); δ_H 1.50 (3H, s, CH_3), 2.95 (3H, s, OCH_3), 3.19 (3H, s, NCH_3), 3.85 (3H, s, $COOCH_3$), 6.84 (1H, d, J=8.3 Hz, H-7), 7.93 (1H, d, J=1.6 Hz, H-4), 8.03 (1H, dd, J=8.3, 1.6 Hz, H-6); δ_C 23.6 (CH_3), 26.3 (NCH_3), 52.1 ($COOCH_3$), 53.1 (OCH_3), 79.2 (C), 108.0 (CH), 125.0 (CH), 125.1 (C), 128.6 (C), 132.3 (CH), 147.4 (C), 166.6 (amide C═O), 176.8 (ester C═O); *m/z* (EI) 249 (40, M^+), 234 (41), 219 (100), 206 (32), 158 (28) (Found: M^+, 249.1001. $C_{13}H_{15}NO_4$ requires *M* 249.1001).

3.2.11. 1,3-Dimethyl-3-ethoxy-5-methoxycarbonylindolin-2-one, 9k. Oxindole **8** (50 mg, 0.22 mmol) in ethanol (1.5 mL) and CAN (279 mg, 0.5 mmol) gave a white foam, **9k** (53 mg, 88%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.2). ν_{max}/cm^{-1} 2979 (w, C–H), 1715 (s, amide and ester C═O); δ_H 1.06 (3H, t, J=6.9 Hz, CH_2CH_3), 2.98 and 3.03 (2H, 2q, J=6.9 Hz, CH_2CH_3), 3.18 (3H, s, N CH_3), 3.85 (3H, s, $COOCH_3$), 6.82 (1H, d, J=8.2 Hz, H-7), 7.92 (1H, d, J=1.6 Hz, H-4), 8.01 (1H, dd, J=8.2, 1.6 Hz, H-6); δ_C 15.3 (CH_2CH_3), 24.0 (CH_3), 26.3 (NCH_3), 52.1 ($COOCH_3$), 61.0 (CH_2), 78.6 (C), 107.9 (CH), 124.8 (CH), 125.0 (C), 129.4 (C), 132.2 (CH), 147.2 (C), 166.6 (amide C═O), 177.1 (ester C═O); *m/z* (EI) 263 (12.7, M^+), 234 (8), 219 (100), 188 (7), 158 (8) (Found: M^+, 263.1155. $C_{14}H_{17}NO_4$ requires *M* 263.1157).

3.2.12. 1,3-Dimethyl-3-isopropoxy-5-methoxycarbonylindolin-2-one, 9l. Oxindole **8** (101 mg, 0.46 mmol) in isopropanol (5 mL) and CAN (549 mg, 1 mmol) gave a white solid corresponding to a mixture of **9l** (68.6 mg, 53%) and **9m** (46 mg, 36%) after chromatography (SiO_2, hexane/ethyl acetate 1:1.2). Data for **9l**: δ_H 0.90 and 1.01 (6H, 2d, J=6.1 Hz, $CH(CH_3)_3$), 1.46 (3H, s, CH_3), 3.18 (3H, s, N CH_3), 3.25 (1H, m, $CH(CH_3)_3$), 3.84 (3H, s, OCH_3), 6.83 (1H, d, J=8.2 Hz, H-7), 7.94 (1H, d, J=1.6 Hz, H-4), 8.01 (1H, dd, J=8.2, 1.6 Hz, H-6); δ_C 23.4 (CH_3), 24.2 (CH_3), 24.8 (CH_3), 26.4 (NCH_3), 52.1 (OCH_3), 69.3 (CH), 78.2 (C), 108.0 (CH), 124.8 (C), 125.1 (CH), 130.1 (C), 132.1 (CH), 147.0 (C), 166.6 (amide C═O), 177.7 (ester C═O).

3.2.13. 1,3-Dimethyl-5-methoxycarbonyl-3-nitrooxyindolin-2-one, 9m. Oxindole **8** (103 mg, 0.47 mmol) in THF or acetonitrile (4 mL) and CAN (551 mg, 1 mmol) gave a white foam, **9m** (105 mg, 80%, 111 mg, 84%, respectively) after chromatography (SiO_2, hexane/ethyl acetate 1:1.2). ν_{max}/cm^{-1} 2947 (m, C–H), 1746 (s, ester C═O), 1715 (s, amide C═O), 1651 and 1621 (s, O–NO_2); δ_H 1.65 (3H, s, CH_3), 3.29 (3H, s, NCH_3), 3.90 (3H, s, OCH_3), 6.95 (1H, d, J=8.2 Hz, H-7), 8.01 (1H, d, J=1.6 Hz, H-4), 8.13 (1H, dd, J=8.2, 1.6 Hz, H-6); δ_C 21.2 (CH_3), 26.9 (NCH_3), 52.2 (OCH_3), 82.8 (C), 108.6 (CH), 123.9 (CH), 125.4 (C), 126.3 (C), 133.2 (CH), 147.3 (C), 166.1 (amide C═O), 177.2 (ester C═O); *m/z* (EI) 280 (80, M^+), 234 (98), 218 (68), 206 (100), 175 (43), 160 (42), 147 (20) (Found: M^+, 280.0693. $C_{12}H_{12}N_2O_6$ requires *M* 280.0695).

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References

1. (a) Jones, K.; Thompson, M.; Wright, C. *J. Chem. Soc., Chem. Commun.* **1986**, 115–116. (b) Jones, K.; Mc. Carthy, C. *Tetrahedron Lett.* **1989**, *30*, 2657–2660. (c) Clark, A. J.; Jones, K. *Tetrahedron Lett.* **1989**, *30*, 5485–5488. (d) Jones, K.; Storey, J. M. D. *J. Chem. Soc., Chem. Commun.* **1992**, 1766–1767. (e) Jones, K.; Wilkinson, J. *J. Chem. Soc., Chem. Commun.* **1992**, 1767–1768. (f) Clark, A. J.; Jones, K. *Tetrahedron* **1992**, *48*, 6875–6882. (g) Jones, K.; Brunton, S. A.; Gosain, R. *Tetrahedron Lett.* **1999**, *40*, 8935–8938.
2. Escolano, C. Unpublished results.

3. Fang, C.-L.; Horne, S.; Taylor, N.; Rodrigo, R. *J. Am. Chem. Soc.* **1994**, *116*, 9480–9486.
4. (a) Kagan, H. B.; Namy, J. L. *Tetrahedron* **1986**, *42*, 6573–6614. (b) Ho, T.-L. *Synthesis* **1973**, 347–354. (c) Baciocchi, E.; Ruzziconi, R. *Free Radicals in Synthesis and Biology*. Kluwer Academic: Dordrecht, 1989; pp 155–185. (d) Molander, G. A. *Chem. Rev.* **1992**, *92*, 29–68. (e) Rück, K.; Kunz, H. *J. Prakt. Chem.* **1994**, 470–472. (f) Nair, V.; Mathew, J.; Prabhakaran, J. *Chem. Soc. Rev.* **1997**, 127–132. (g) There has been a report on the use of CAN in the dimerisation of 4-hydroxyquinolin-2(1*H*)-ones Ye, J-H.; Ling, K.-Q.; Xu, J.-H. *Tetrahedron Lett.* **1999**, *40*, 1365–1368.
5. (a) Jones, K.; Thompson, M.; Wright, C. *J. Chem. Soc., Chem. Commun.* **1986**, 115–116. (b) Wright, C.; Shulkind, M.; Jones, K.; Thompson, M. *Tetrahedron Lett.* **1987**, *28*, 6389–6390.
6. Escolano, C.; Jones, K. *Tetrahedron* **2002**, *58*, 1453–1464.
7. (a) Kohn, M.; Ostersetzer, A. *Monastch. Chem.* **1911**, *32*, 912. (b) Wenkert, E.; Orr, J. C.; Garratt, S.; Hansen, J. H.; Wickberg, B.; Leicht, C. L. *J. Org. Chem.* **1963**, *27*, 4123–4126. (c) Janda, M.; Srogl, J.; Holy, P. *Coll. Czech. Chem. Commun.* **1981**, *46*, 3278–3284.
8. Giovannini, E.; Rosales, J. *Helv. Chim. Acta* **1963**, 1332–1338.
9. (a) Dinçtürck, S.; Ridd, J. H. *J. Chem. Soc., Perkin Trans. 2* **1982**, 965–969. Nitration of an electron-rich aromatic compound by CAN–SiO_2: (b) Chawla, H. M.; Mittal, R. S. *Synthesis* **1985**, 70–72. (c) Grenier, J.-L.; Catteau, J.-P.; Cotelle, P. *Synth. Commun.* **1999**, *29*, 1201–1208.
10. Mechanistic studies on the oxidation of alkylaromatic compounds by CAN have been published: (a) Baciocchi, E.; Mandolini, L.; Rol, C. *Tetrahedron Lett.* **1976**, *37*, 3343–3346. (b) Baciocchi, E.; Mei, S.; Rol, C. *J. Org. Chem.* **1978**, *43*, 2919–2921. (c) Baciocchi, E.; Rol, C.; Sebastiani, G. V.; Zampini, A. *J. Chem. Soc., Chem. Commun.* **1982**, 1045–1047. (d) Dinçtürk, S.; Ridd, J. H. *J. Chem. Soc., Perkin Trans. 2* **1982**, 961–964. (e) Baciocchi, E.; Rol, C.; Sabatiani, G. V.; Serena, B. *Tetrahedron Lett.* **1984**, *25*, 1945–1946. (f) Baciocchi, E.; Giacco, T.; Rol, C.; Sebatiani, G. V. *Tetrahedron Lett.* **1985**, *26*, 541–544. (g) Bacciochi, E.; Ruzziconi, R. *J. Org. Chem.* **1986**, *51*, 1645–1649. (h) Baciocchi, E.; Giacco, T.; Murgia, S. M.; Sebastiani, G. V. *J. Chem. Soc., Chem. Commun.* **1987**, 1246–1248. (i) Baciocchi, E.; Giacco, T.; Elisei, F. *J. Am. Chem. Soc.* **1993**, *115*, 12290–12295. (j) Polobelli, A.; Ceccherelli, P.; Pizzo, F. *J. Org. Chem.* **1995**, *60*, 4954–4958.