
Article:
Petersen, Wade F, Taylor, Richard J K orcid.org/0000-0002-5880-2490 and Donald, James R orcid.org/0000-0002-2176-4902 (2017) Photoredox-catalyzed procedure for carbamoyl radical generation:3,4-dihydroquinolin-2-one and quinolin-2-one synthesis. Organic and Biomolecular Chemistry. 5831–5845. ISSN 1477-0539

https://doi.org/10.1039/c7ob01274h

Organic & Biomolecular Chemistry

PAPER

Photoredox-catalyzed procedure for carbamoyl radical generation: 3,4-dihydroquinolin-2-one and quinolin-2-one synthesis

Wade F. Petersen, Richard J. K. Taylor and James R. Donald*

Received 00th January 20xx,
Accepted 00th January 20xx

DOI: 10.1039/x0xx00000x

www.rsc.org/

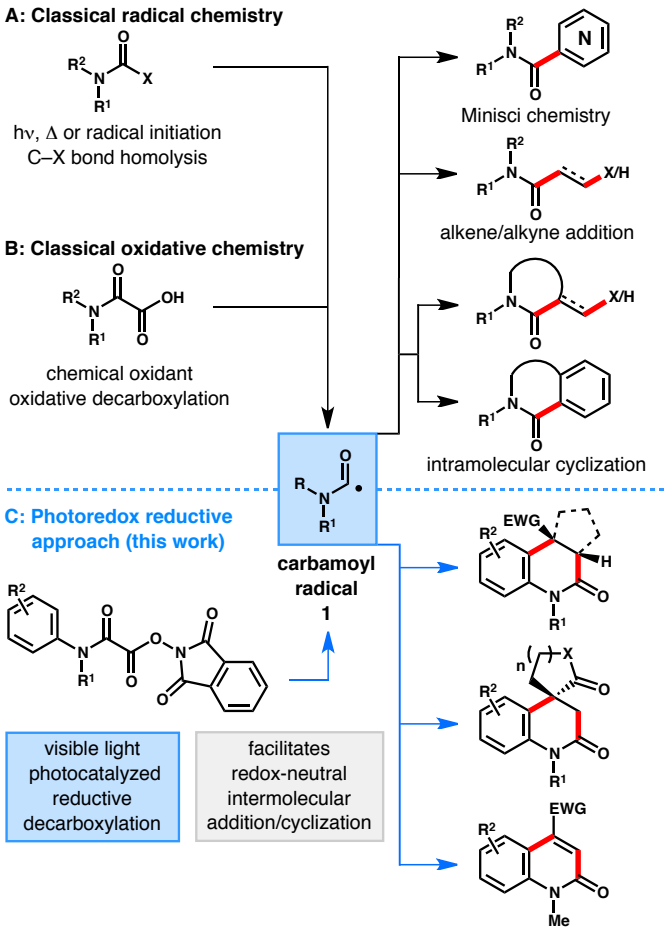
A reductive approach for carbamoyl radical generation from *N*-hydroxyphthalimido oxamides under photoredox catalysis is outlined. This strategy was applied to the synthesis of 3,4-dihydroquinolin-2-ones via the intermolecular addition/cyclization of carbamoyl radicals with electron deficient olefins in a mild, redox-neutral manner. Under a general set of reaction conditions, diversely substituted 3,4-dihydroquinolin-2-ones, including spirocyclic systems can be prepared. By using chlorine-substituted olefins, aromatic quinolin-2-ones can also be accessed.

Introduction

The growing application of photoredox catalysis in organic synthesis within the last decade has enabled the development of milder and less toxic alternatives to traditional radical chemistry and perhaps more importantly, facilitated the invention of entirely new, hitherto unattainable reactivity modes, made possible by the continual generation of strongly oxidizing and reducing species within the same pot.[1] Visible light photoexcitation of metal polypyridyl complexes or organic dyes at wavelengths to which common organic molecules are transparent generates excited-state species capable of selective radical formation in reaction substrates via single-electron transfer (SET) processes, thus triggering open-shell reactivity and initiating chemistry. Redox-neutral transformations are particularly desirable, removing the requirement for stoichiometric chemical oxidants or reductants, and by virtue of an 'electron borrowing' strategy, such processes occupy reactivity space complementary to electrochemistry.

Carbamoyl radicals **1** are versatile reactive intermediates, which generally display improved stability over their more heavily studied acyl and oxycarbonyl counterparts (which are prone to decarbonylation and decarboxylation, respectively), making them ideally suited to the synthesis of amide-containing compounds.[2] Major areas of application are Minisci chemistry,[3] intermolecular alkene/alkyne addition[4,5] and intramolecular cyclization to form lactams (Scheme 1),[3b,4g,6] while other uses include C–H abstraction to produce formamides,[6n,7] oxidation to isocyanates,[3b] addition to azo compounds,[8] alkynylation,[9] and in Pd-catalyzed processes, both as a coupling partner[10a] and as a carboxylate source.[10b]

The generation of carbamoyl radicals however, has been historically limited to two general strategies. These are (i) the use of classical radical chemistry, via homolytic C–X cleavage[11] of a suitably functionalized acyl precursor induced by either a radical initiator, heat, or UV light (Scheme 1A)[3c,d,4a–h,5,6a–q,s,7,8] and (ii) oxidative approaches via electron transfer from α-amidocarboxylates to stoichiometric single-electron chemical oxidants with subsequent loss of CO_2, usually conducted at



Scheme 1 Generation and application of carbamoyl radicals.

Department of Chemistry, University of York, Heslington, York, YO10 5DD, U.K.
Email: james.donald@york.ac.uk
Electronic Supplementary Information (ESI) available: See DOI: 10.1039/x0xx00000x

elevated temperatures (Scheme 1B).[3a,b,4i,j,9,10]

We proposed that a reductive approach to carbamoyl radicals might provide a basis for the development of chemistry not possible under existing modes of generation, in particular offering the possibility of overall redox-neutral transformations for processes terminated by an oxidative SET event. To this end, we recently reported[12] the first reductive approach to carbamoyl radicals from *N*-hydroxyphthalimido oxamides,[13,14] mediated under mild conditions by photoredox catalysis. The value of the strategy was demonstrated via trapping the intermediate carbamoyl radicals with electron deficient olefins in an intermolecular addition/cyclization to achieve a redox-neutral synthesis of 3,4-dihydroquinolin-2-ones (Scheme 1C). In this publication, we disclose full details of the reaction development, further probe the scope of the process, particularly in terms of aryl substituted radical acceptors and spirocycle formation and introduce an extension of the original approach to target the aromatic quinolin-2-one core under our standard reaction conditions.

The 3,4-dihydroquinolin-2-one bicyclic system comprises the core of several natural product families, representative examples include insecticidal yaequinolone E (**2**),[15] fused-spirocyclic (+)-meloscine (**3**)[16] and spirocyclic acetylcholinesterase inhibitor trigolutesin A (**4**) (Figure 1).[17] Notable synthetic 3,4-dihydroquinolin-2-ones are compound **5** which is an activator of the tumor cell specific M2 isoform of pyruvate kinase,[18] the HIV reverse transcriptase inhibitor and efavirenz analogue (**6**)[19] and the partial dopamine agonist aripiprazole (**7**) which is one of the top selling US pharmaceuticals, used to treat a range of mental disorders.[20]

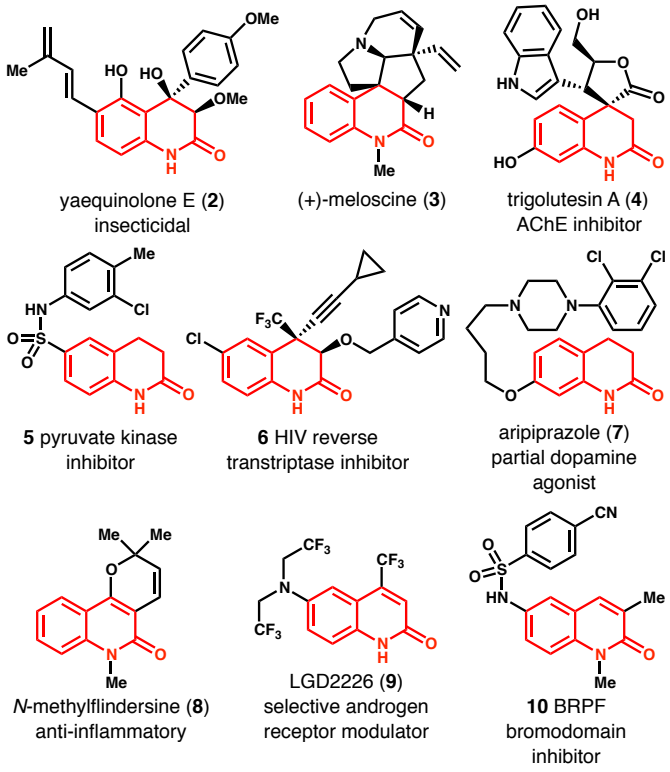


Figure 1 3,4-Dihydroquinolin-2-ones and quinolin-2-ones of medicinal interest.

Aromatic quinolin-2-ones are also frequently found in bioactive molecules and present an attractive core for pharmaceutical development.[21] Illustrative examples are the potent anti-inflammatory natural product *N*-methylflindersine (**8**),[22] the synthetic selective androgen receptor modulator LGD 2226 (**9**)[23] and compound **10**, derived from parent natural product *N*-methylquinolin-2-one[24] and optimized for inhibition of the bromodomain of bromodomain and PHD Finger-Containing (BRPF) proteins.[25]

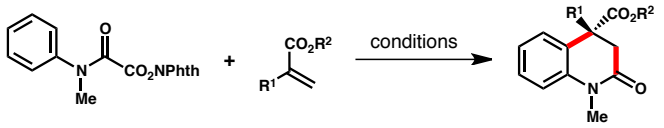
Consequently, we selected the synthesis of 3,4-dihydroquinolin-2-ones as the proving ground for our novel reductive carbamoyl radical generation in the hope of producing a diverse library of heterocyclic structures, in line with our program to develop new strategies for the synthesis of medicinally relevant nitrogen-containing ring systems.[26–29] Additionally, we also sought to access quinolin-2-ones, given their value to the biomedical arena.

Results and discussion

After some experimentation, a general route to access the requisite *N*-hydroxyphthalimido oxamide radical precursors on gram-scale was developed, via the acylation of anilines with chloro *N*-phthalimidoyl oxalate, readily prepared by Overman's method,[30] followed by successive aqueous washings with dilute aq. HCl and then saturated aq. $NaHCO_3$ to remove residual pyridine/anilines and *N*-hydroxyphthalimide respectively (see Experimental section). The resulting oxamides were found to be unstable to silica gel column chromatography, but were easily purified by recrystallization to afford bench-stable crystalline solids, which were stored in the dark as a precaution.

The addition-cyclization process was first evaluated for the formation of 3,4-dihydroquinolin-2-one **14** using oxamide **11** (derived from *N*-methylaniline) and ethyl acrylate (**12**) (Table 1). With 2 mol% $Ru(bpy)_3.6H_2O$ in MeCN, after 24 h irradiation with blue LEDs, we were pleased to observe the formation of the desired product **14** in 19% yield (determined by ^{1}H NMR spectroscopy with an internal standard, entry 1). Increasing the loading of the commercial acrylate **12** led to a slight improvement in yield at 2 eq., but further excess was found to be detrimental (entries 2 and 3). The inclusion of *i*-Pr_2NEt (1.0 eq.) in order to facilitate a reductive quenching cycle was non-beneficial (entry 4). Variation of the photocatalyst significantly influenced reaction efficiency, with *fac*-$Ir(ppy)_3$ found to be superior to both $Ru(bpy)_3.6H_2O$ and eosin Y, leading to a 27% yield (entries 5 and 6). Next, from a screen of solvents, toluene was found to be most suitable, affording lactam **14** in 37% yield (see entries 7–9). We investigated irradiation with a 30 W white compact fluorescent lamp (CFL) rather than the 60 W blue LEDs but these conditions were found to be inferior (entry 10). Finally, the effect of concentration was explored and higher dilution (0.04 M) was determined to be optimal (48% yield by ^{1}H NMR analysis), affording a 43% isolated yield of 3,4-dihydroquinolin-2-one **14** (entries 9, 11–13). Control

Table 1 Reaction Optimization.



oxamide 11 | **radical acceptor** R^1 = H, R^2 = Et, **12**; R^1 = R^2 = Me, **13** | **(±)-3,4-dihydro-quinolin-2-ones** R^1 = H, R^2 = Et, **14**; R^1 = R^2 = Me, **15**

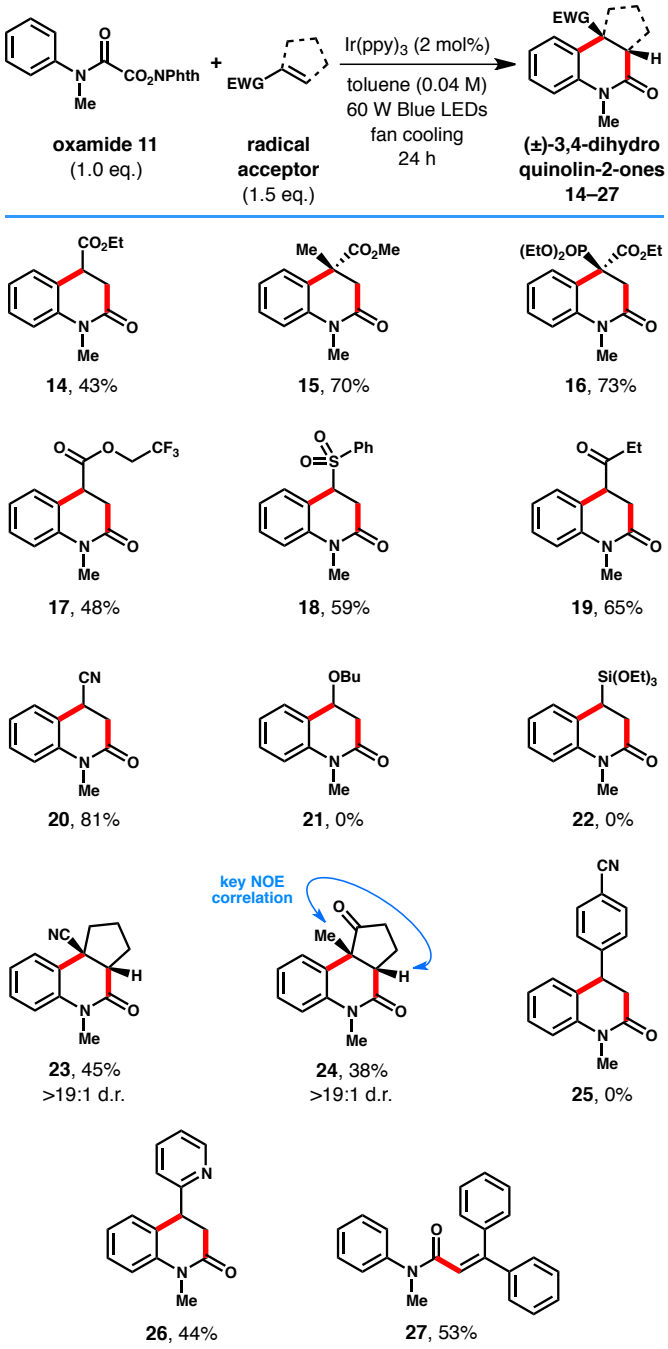
entry	**11**:**12**/**13**[a]	photocat. (2 mol%)	solvent (M)	yield (%)[b]
1[c]	1:1 (**12**)	$Ru(bpy)_3Cl_2$.[d]	MeCN (0.12)	19%
2[c]	1:2 (**12**)	$Ru(bpy)_3Cl_2$.[d]	MeCN (0.12)	25%
3[c]	1:5 (**12**)	$Ru(bpy)_3Cl_2$.[d]	MeCN (0.12)	12%
4[c,e]	1:1 (**12**)	$Ru(bpy)_3Cl_2$.[d]	MeCN (0.12)	7%
5[c]	1:1 (**12**)	*fac*-Ir(ppy)$_3$	MeCN (0.12)	27%
6[c]	1:1 (**12**)	Eosin Y	MeCN (0.12)	13%
7[c]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	CH_2Cl_2 (0.12)	26%
8[c]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	THF (0.12)	17%
9[c]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	PhMe (0.12)	37%
10[f]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	PhMe (0.12)	11%
11[c]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	PhMe (0.24)	25%
12[c]	**1:1.5 (12)**	***fac*-Ir(ppy)$_3$**	**PhMe (0.04)**	**48%, 43%**[g]
13[c]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	PhMe (0.02)	49%
14[c]	1:1.5 (**12**)	–	PhMe (0.04)	0%
15[h]	1:1.5 (**12**)	*fac*-Ir(ppy)$_3$	PhMe (0.04)	0%
16[c]	**1:1.5 (13)**	***fac*-Ir(ppy)$_3$**	**PhMe (0.04)**	**70%**[g]

[a]Reaction Stoichiometry. [b]Determined by ^{1}H NMR spectroscopy against an internal standard (BnOAc). [c]Irradiated with 60 W blue LEDs and fan cooling for 24 h. [d]Hexahydrate. [e]With *i*-Pr_2NEt (1.0 eq.). [f]Irradiated with a 30 W white CFL. [g]Isolated yield. [h]Reaction conducted in the dark.

experiments revealed that no product formation was observed either in the absence of photocatalyst or light (entries 14 and 15). Knowing that ethyl acrylate (**12**) might be a particularly challenging reaction partner, we applied the reaction conditions to methyl methacrylate (**13**), an acceptor anticipated to better stabilize the intermediate conjugate radical and have a lower propensity towards undesired oligomerization reactions. Gratifyingly, in this case 3,4-dihydroquinolin-2-one **15** was isolated in 70% yield (entry 16).

With the aforementioned exciting results in hand, we were now ready to explore the scope of our optimized conditions across a range of radical acceptors (Scheme 2). In addition to 3,4-dihydroquinolin-2-one **15**, a second quaternary substituted example **16** bearing a phosphonate ester was obtained in good yield. Mono-substituted, electron-deficient alkenes were found to be well tolerated in this reaction, offering 3,4-dihydroquinolin-2-ones **14** and **17–20** with pendent alkyl ester, active ester, sulfone, ketone and nitrile groups in 43–81% yield. The yield of the reaction was observed to mirror the electron-withdrawing and radical stabilizing nature of the alkene substituent. In contrast, no product formation (**21** or **22**) was observed when the more electon-rich butyl vinyl ether or triethoxyvinylsilane were employed. This reactivity is very much in line with the nucleophilic character displayed by carbamoyl radicals.[4b,31]

cis-Fused cyclopentanes **23** and **24** were isolated in modest yields under our general set of conditions, as single



Scheme 2 Radical acceptor scope.

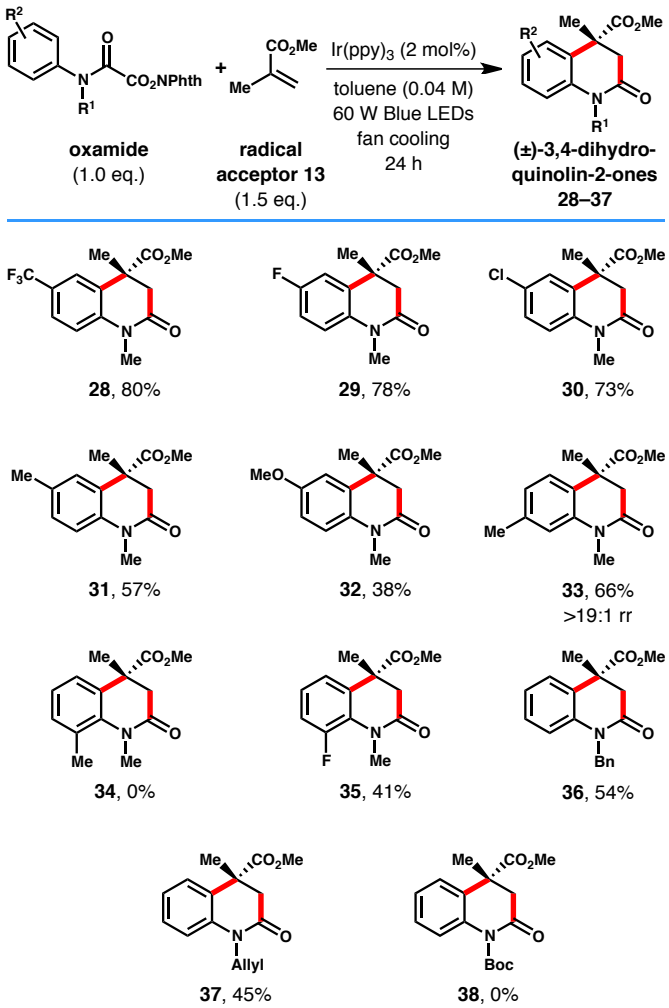
diastereomers, resulting from the attack on cyclopentenes bearing exo- and endocyclic electron-withdrawing groups respectively. The anticipated *cis*-fusion of cyclopentanone **24** was evidenced by an NOE correlation between the methyl group and the proton at the ring junction. Not only do these examples indicate that β-substitution is possible in this chemistry but they also contain the [6,6,5]-core of meloscine (**3**) and many of the other *melodinus* alkaloids, with useful handles for further synthetic manipulation.

Finally, we were interested to evaluate styrenyl-type olefins as radical acceptors. Under the reaction conditions, 4-cyano-styrene afforded a complex mixture of products, possibly due to competing oligomer and polymer forming

reactions. Pleasingly however, when 2-vinylpyridine was employed as the radical acceptor, 2-pyridyl-3,4-dihydroquinolin-2-one **26** was obtained, albeit in moderate yield. In the case of 1,1-diphenylethylene, with two aryl substituents on the alkene input, cyclization of the intermediate conjugate radical did not occur, likely due to reduced electrophilicity and increased stability. Instead, the doubly benzylic radical appears to have undergone single-electron oxidation and deprotonation to afford linear α,β-unsaturated amide **27**.

The oxamide inputs were then investigated in terms of scope using the radical acceptor methyl methacrylate (**13**) as the fixed variable. Five *p*-substituted *N*-methyl oxamides were subjected to the standard reaction conditions, affording 3,4-dihydroquinolin-2-ones **28**–**32** in 38–80% unoptimized yield with a range of electron-withdrawing and electron-donating substituents. Together with compound **15**, this series shows a distinct correlation of increasing yield with increasingly electron-withdrawing substituents on the oxamides.

Interestingly, the *m*-methyl substituted oxamide afforded lactam **33** in 66% yield as a single regioisomer, owing to steric directing effects. In contrast, none of the desired 3,4-dihydroquinolin-2-one **34** was observed when the *o*-methyl substituted oxamide was subjected to the process, possibly as a consequence of the non-planarity of the *o*-substituted anilide or due to undesired side reactions such as intramolecular benzylic C–H abstraction.[32] Pleasingly, the smaller and more electron-withdrawing *o*-fluoro substituent was compatible with the methodology, providing the 8-fluoro-3,4-dihydroquinolin-2-one **35** in 41% yield. This result offers potential access to further *o*-substituted derivatives as aryl fluorides present a useful functional handle through transition-metal catalyzed cross-coupling reactions.[33]



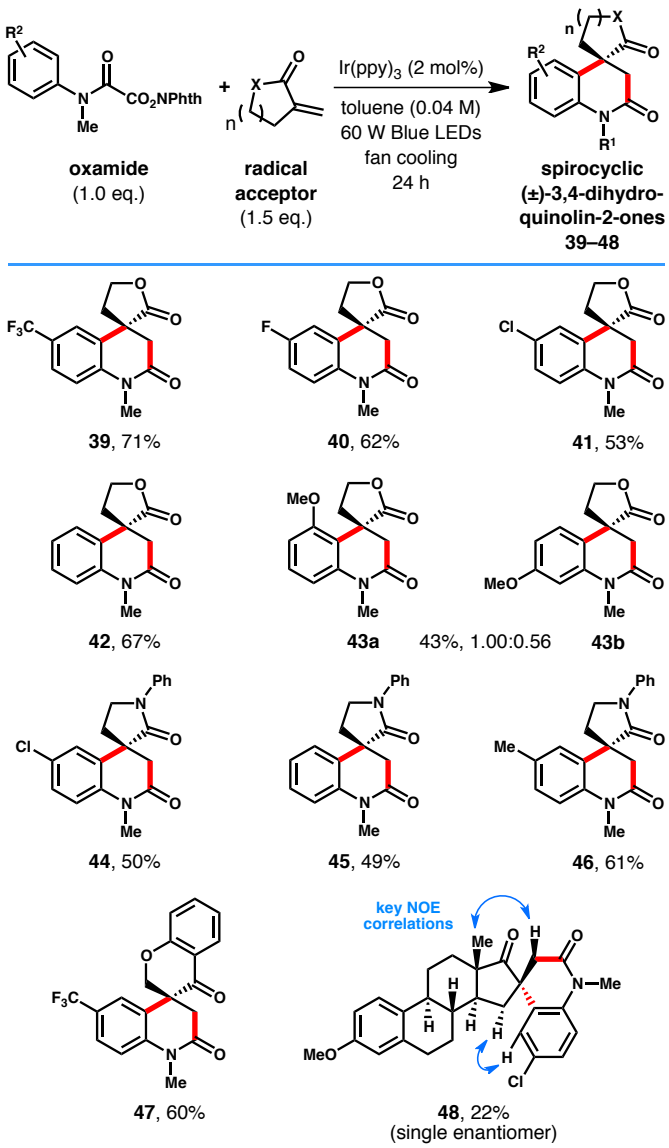
Scheme 3 Oxamide scope.

N-Benzyl and *N*-allyl 3,4-dihydroquinolin-2-ones **36** and **37** were isolated in 54% and 45% yields, respectively. These results are useful as the products bear removable *N*-protecting groups and noteworthy because the potential competing intramolecular cyclization of the carbamoyl radicals onto the pendant *N*-benzyl[3b,6m,6q] and *N*-allyl groups,[4g,6d,6g,6h,6l] was not observed in this work, but has been previously demonstrated in the literature. Unfortunately, no product formation was detected when an oxamide bearing an electron-withdrawing *N*-Boc substituent was used.

The Taylor group has a particular interest in the synthesis of spirocyclic natural products and spirocyclic scaffolds with which to explore chemical space.[26a–e,27a,c] Taking inspiration from the spirocyclic natural products (+)-meloscine (**3**) and trigolutesin A (**4**), we targeted spirocyclic 3,4-dihydroquinolin-2-ones through the use of radical acceptors bearing exocyclic alkenes. Pleasingly, the reaction of α-methylene-γ-butyrolactone with a range of oxamides produced a small library of spirocyclic lactone-lactam systems **39**–**43** in 43–71% yield (Scheme 4). Notably, in the case of the *m*-methoxy oxamide, the corresponding spirocycle was produced as a mixture of two inseparable *o*- and *m*-regioisomers **43a** and **43b** in a ratio of 1.00:0.56 respectively (43% combined yield). Interestingly, in this instance, steric effects seem to play a less significant role in controlling the regioselectivity, with orbital coefficients apparently dominating the position of aromatic substitution. It is anticipated that electronic and steric modification of the group on the phenolic oxygen atom might offer a means to favor formation of the regioisomer required for a synthesis of trigolutesin A (**4**).

When 3-methylidene-1-phenylpyrrolidin-2-one was used to trap the carbamoyl radical intermediates, spirorocyclic bislactams **44**–**46** were produced in 49–61% yield. Whilst there are single-example publications featuring the synthesis of similarly structured gem-difluoro cyclic imide/gem-difluoro lactone and oxindole- 3,4-dihydroquinolin-2-ones, a general method for the preparation of the simple parent systems and exploration of biological activity has not been reported.[34]

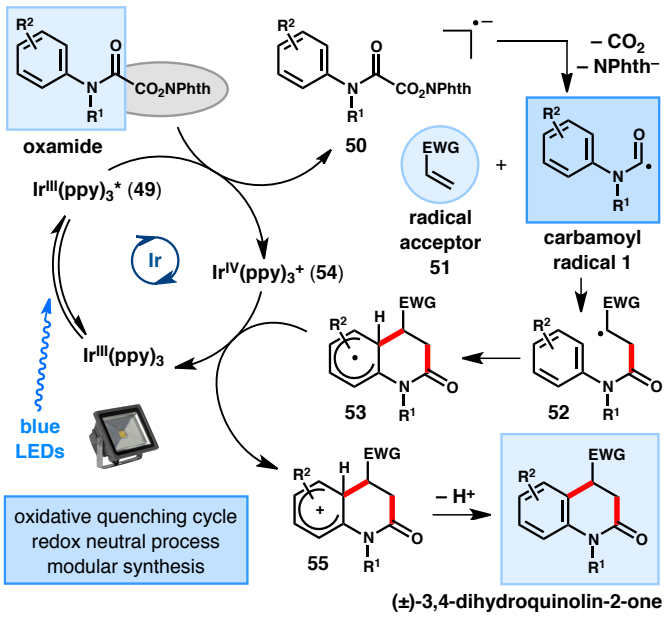
Spirocyclic cycloalkanone-lactam ring systems can also be accessed via this strategy as illustrated by the formation of the spirocyclic [6,6]-product **47** in 60% yield. As an example of a more complex and indeed more sterically hindered system, a radical acceptor derived from estrone was subjected to the reaction conditions, which afforded hexacyclic compound **48**, isolated as a single diastereomer in 22% yield. The relative



Scheme 4 Spirocyclic 3,4-dihydroquinolin-2-ones.

stereochemistry of modified steroid **48** was confirmed by the observation of NOE correlations between the α-keto methyl group and one of the α-amido protons, and one of the cyclopentanone methylene protons with the aryl proton *ortho*- to the chlorine atom.

The proposed mechanistic cycle for this reaction process is depicted in Scheme 5. Visible light irradiation of the Ir^{III} photocatalyst $Ir(ppy)_3$ would lead to the long-lived photoexcited state Ir^{III}* (**49**) [τ = 1.9 μs] which is a strong single-electron reductant [$E_{1/2}$ (Ir^{IV+}/Ir^{III*}) = –1.73 V vs Saturated Calomel Electrode (SCE)] well-capable of reducing the *N*-hydroxyphthalimido oxamide to the transient radical anion **50**, which can then undergo homolytic cleavage with the concomitant loss of CO_2 and phthalimide anion to afford carbamoyl radical intermediate **1**.[35] The nucleophilic carbamoyl radical **1** is then trapped by an electron-deficient alkene **51** generating the electrophilic conjugate radical **52** which can cyclize onto the anilide to produce cyclohexadienyl radical **53**. Oxidation of the electron-rich radical intermediate



Scheme 5 Proposed mechanism.

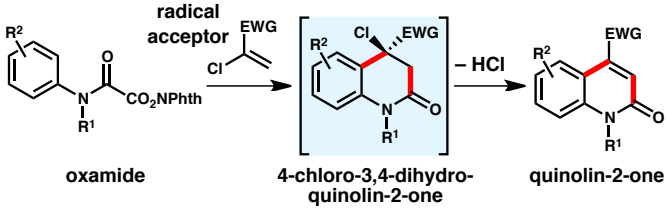
53 by the oxidized-state photocatalyst Ir^{IV+} (**57**) [$E_{1/2}(Ir^{IV+}/Ir^{III})$ = +0.77 V vs (SCE)] would regenerate the ground-state Ir^{III} photocatalyst and liberate cyclohexadienyl cation **55** which can rearomatize with loss of a proton (most likely to phthalimide anion) to afford the 3,4-dihydroquinolin-2-one product.[35]

Finally, after consideration of the reaction mechanism, we proposed an extension of the methodology to target aromatic qunolin-2-ones, important targets which can be considered as a privileged structure for lead synthesis in the pharmaceutical industry.[21–23,25] We hypothesized that by employing an α-chloro radical acceptor in the reaction process, elimination of HCl might be possible from the initially formed 4-chloro-3,4-dihydroquinolin-2-ones to provide access to quinolin-2-one products (Scheme 6).

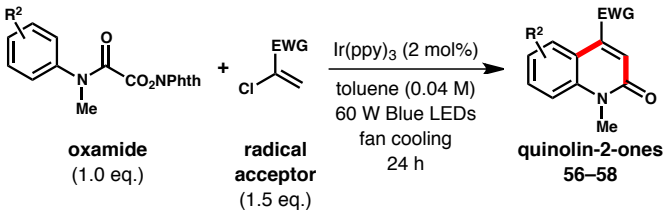
In the event, quinolin-2-ones **56–58** were isolated in 25–59% yield (Scheme 7). Whilst modest, these results highlight the structural diversity accessible under our standard set of reaction conditions.

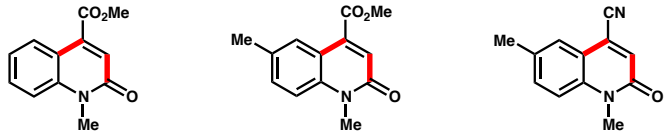
Conclusions

We have developed a novel reductive approach to access carbamoyl radicals from *N*-hydroxyphthalimido oxamides under photoredox catalysis. This strategy allows access to 3,4-dihydroquinolin-2-ones via an intermolecular addition/cyclization of carbamoyl radicals with electron



Scheme 6 Proposed quinolin-2-one synthesis.





Scheme 7 Quinoline-2-ones.

deficient olefins in a mild, redox-neutral manner. Functionality can be introduced at all positions of the 3,4-dihydroquinolin-2-one core and spirocyclic 3,4-dihydroquinolin-2-ones can be readily accessed. In addition, by using α-chloro radical acceptors, aromatic quinolin-2-ones can also be produced. It should be emphasized that all of the reported results were conducted under a standard set of reaction conditions and that optimization of the process should be possible on a case-by-case basis. We are currently exploring this methodology for applications in target synthesis, the results of which will be reported in due course. Finally, it is our hope that this reductive approach to access carbamoyl radicals will enable the development of new chemistry, particularly redox-neutral processes in the future.

Experimental

Except where stated, all reagents were purchased from commercial sources and used without further purification. Liquid electron-deficient olefins containing radical inhibitors were distilled prior to use and stored at –20 ˚C. THF and toluene were dried on an Innovative Technology Inc. PureSolv Solvent Purification System. ^{1}H NMR and ^{13}C NMR spectra were recorded on a JEOL ECX400 or JEOL ECS400 spectrometer, operating at 400 MHz and 100 MHz, respectively. All spectral data were acquired at 295 K. Chemical shifts are reported in parts per million (ppm, δ), downfield from tetramethylsilane (TMS, δ = 0.00 ppm) and are referenced to residual solvent ($CDCl_3$, δ = 7.26 ppm (^{1}H) and 77.16 ppm (^{13}C)). Coupling constants (*J*) are reported in Hertz (Hz). The multiplicity abbreviations used are: br broad, s singlet, d doublet, t triplet, q quartet, m multiplet, comp overlapping multiplet of magnetically non-equivalent nuclei, app apparent. Signal assignment was achieved by analysis of DEPT, COSY, HMBC and HSQC experiments where required. Infrared (IR) spectra were recorded on a PerkinElmer UATR 2 spectrometer, either as a compressed solid or a thin film dispersed from CH_2Cl_2 or $CDCl_3$. High-resolution mass-spectra were obtained by the University of York Mass Spectrometry Service, using electrospray ionization (ESI) on a Bruker Daltonics, Micro-tof spectrometer. Melting points were determined using Gallenkamp apparatus. Thin layer chromatography was carried out on Merck silica gel 60F_{254} pre-coated aluminum foil sheets and were visualized using UV light (254 nm) and stained with basic aqueous potassium permanganate. Column chromatography was carried out using Fluka silica gel (SiO_2), 35–70 μm, 60 Å, under a light positive pressure, eluting with the specified solvent system.

General experimental

General procedure A: for the synthesis of oxamides

Based upon the reported procedure,[14,36] oxalyl chloride (3.81 g, 2.54 mL, 30.0 mmol) was added drop-wise to a solution of *N*-hydroxyphthalimide (979 mg, 6.0 mmol) in THF (100 mL) at –78 ˚C. After the addition was complete, the reaction was stirred at rt for 18 h then concentrated under reduced pressure and dried under high vacuum (in the dark) for 1 h. The off-white residue was re-dissolved in THF (100 mL), cooled to –78 ˚C and a solution of the requisite aniline (6.0 mmol) and pyridine (475 mg, 485 mL, 6.0 mmol) in THF (5 mL) was added drop-wise and the reaction then allowed to warm to 0 ˚C. The reaction was stirred at 0 ˚C for 2 h and then at rt for the period noted before being concentrated under reduced pressure and the residue partitioned between EtOAc (400 mL) and HCl (10% aq, 100 mL). The organic layer was washed with sat. aq. $NaHCO_3$ (4 x 100 mL), dried ($MgSO_4$) and concentrated under reduced pressure and the residue purified by recrystallization from the solvent indicated to afford the corresponding oxamides which were found to be bench stable, but were stored in the dark as a precaution.

General procedure B: for the synthesis of 3,4-dihydroquinolin-2-ones 14–48 and quinolin-2-ones 56–58.

An 8 mL vial equipped with a PTFE septum and a magnetic stirrer bar was charged with the requisite oxamide (0.24 mmol), electron-deficient olefin (if solid, 0.36 mmol) and *fac*-tris[2-phenylpyridinato-C_2,*N*]iridium(III) [Ir(ppy)$_3$] (3.1 mg, 0.0048 mmol). The vial was purged with Ar, then toluene (6 mL) was added and the mixture was sparged with Ar for 10 min with stirring. After sparging was complete, the electron-deficient olefin (if liquid, 0.36 mmol) was added and the septum additionally sealed with paraffin film. The reaction was irradiated with a 60 W blue LED floodlight for 24 h, with stirring and cooling from a small fan to maintain an ambient temperature. The mixture was partitioned between EtOAc (3 x 50 mL) and sat. aq. NH_4Cl (50 mL) and the combined organic layers were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was purified by silica gel flash column chromatography, eluting with the solvents indicated to afford 3,4-dihydroquinolin-2-ones **14–48** and quinolin-2-ones **56–58**.

Compound synthesis

1,3-Dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (11). Prepared according to general procedure A using *N*-methylaniline (643 mg, 650 mL, 6.0 mmol) and stirring at rt for 2 h to afford oxamide **11** (1.47 g, 76%) as pale yellow needles after recrystallization from toluene: mp 156–158 ˚C;

^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.98–7.92 (m, 0.16H), 7.88–7.80 (comp, 2H), 7.78–7.72 (m, 1.84H), 7.52–7.46 (m, 2H), 7.46–7.40 (m, 1H), 7.40–7.34 (m, 2H), 3.61 (s, 0.24H), 3.46 (s, 2.76H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 158.2, 157.6, 140.3, 135.3 (minor), 135.0, 130.2, 129.6 (minor), 129.1, 128.8, 128.0 (minor), 126.6, 125.4 (minor), 124.4 (minor), 124.2, 38.8, 36.9; IR (film, ν_{max}/cm^{-1}) 1820, 1791, 1743, 1671, 1492, 1351, 1127, 1088, 1009; HRMS (ESI$^+$) *m/z* calcd. for $C_{17}H_{12}N_2NaO_5$ $[M+Na]^+$ 347.0638, found 347.0625.

1,3-Dioxoisoindolin-2-yl 2-(methyl(4-(trifluoromethyl) phenyl)amino)-2-oxoacetate. Prepared according to general procedure A using 4-(trifluoromethyl)-*N*-methylaniline (1.05 g, 848 mL, 6.0 mmol) and stirring at rt for 16 h to afford the oxamide (1.27 g, 54%) as colorless microcrystals after recrystallization from toluene: mp 148–150 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.99–7.93 (m, 0.26H), 7.89–7.82 (comp, 2H), 7.81–7.71 (comp, 3.74H), 7.56 (d, *J* = 8.3 Hz, 0.26H), 7.51 (d, *J* = 8.3 Hz, 1.74H), 3.65 (s, 0.39H), 3.49 (s, 2.61H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers, minor omitted for clarity) 160.9, 157.8, 157.2, 143.5 (m), 135.1, 130.9 (q, $J_{C\text{-}F}$ = 33.1 Hz), 128.7, 127.4 (q, $J_{C\text{-}F}$ = 3.7 Hz), 126.6, 124.3, 123.7 (q, $J_{C\text{-}F}$ = 272.4 Hz), 36.8; IR (film, ν_{max}/cm^{-1}) 1787, 1748, 1676, 1611, 1325, 1156, 1098, 1005; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{11}F_3N_2NaO_5$ $[M+Na]^+$ 415.0512, found 415.0496.

1,3-Dioxoisoindolin-2-yl 2-((4-fluorophenyl)(methyl)amino)-2-oxoacetate. Prepared according to general procedure A using 4-fluoro-*N*-methylaniline (751 mg, 722 mL, 6.0 mmol) and stirring at rt for 14 h to afford the oxamide (636 mg, 31%) as off-white plates after recrystallization from toluene: mp 138–140 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.98–7.93 (m, 0.16H), 7.88–7.81 (comp, 2H), 7.80–7.73 (m, 1.84H), 7.39–7.33 (m, 2H), 7.17 (app t, *J* = 8.5 Hz, 2H), 3.59 (s, 0.24H), 3.43 (s, 2.76H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 162.7 (d, $J_{C\text{-}F}$ = 249.5 Hz), 160.9, 158.1, 157.6, 136.3 (d, $J_{C\text{-}F}$ = 3.2 Hz), 135.3 (minor), 135.0, 134.6 (minor), 129.2 (minor), 128.8, 128.7 (d, $J_{C\text{-}F}$ = 9.0 Hz), 128.4 (minor), 124.5 (minor), 124.2, 117.3 (d, $J_{C\text{-}F}$ = 23.0 Hz), 37.1; IR (film, ν_{max}/cm^{-1}) 1817, 1790, 1743, 1671, 1507, 1350, 1226, 1158, 1128, 1088; HRMS (ESI$^+$) *m/z* calcd. for $C_{17}H_{11}FN_2NaO_5$ $[M+Na]^+$ 365.0544, found 365.0534.

1,3-Dioxoisoindolin-2-yl 2-((4-chlorophenyl)(methyl) amino)-2-oxoacetate. Prepared according to general procedure A using 4-chloro-*N*-methylaniline (850 mg, 726 mL, 6.0 mmol) and stirring at rt for 4 h to afford the oxamide (1.25 g, 58%) as colorless cubes after recrystallization from EtOAc: mp 166–168 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.86–7.82 (m, 2H), 7.79–7.74 (m, 2H), 7.46–7.41 (m, 2H), 7.35–7.29 (m, 2H), 3.59 (s, 0.30H) 3.43 (s, 2.70H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 157.9, 157.3, 138.9, 135.3 (minor), 135.0, 134.9, 130.4, 129.7 (minor), 128.7, 127.8, 126.6 (minor), 124.4 (minor), 124.2, 38.6 (minor), 36.9; IR (film, ν_{max}/cm^{-1}) 1816, 1789, 1743, 1491, 1467, 1350, 1091, 1015; HRMS (ESI$^+$) *m/z* calcd. for $C_{17}H_{11}{}^{35}ClN_2NaO_5$ $[M+Na]^+$ 381.0249, found 381.0247.

1,3-Dioxoisoindolin-2-yl 2-(methyl(p-tolyl)amino)-2-oxoacetate. Prepared according to general procedure A using *N*-methyl-*p*-toluidine (727 mg, 759 mL, 6.0 mmol) and stirring at rt for 2.5 h to afford the oxamide (1.46 g, 72%) as colorless needles after recrystallization from toluene: mp 152–154 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.97–7.92 (m, 0.15H), 7.87–7.80 (comp, 2H), 7.78–7.72 (m, 1.85H), 7.29–7.23 (comp, 4H), 3.58 (s, 0.23H), 3.43 (s, 2.77H), 2.39 (s, 2.77H), 2.38 (s, 0.23H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 161.0, 158.2, 157.6, 139.2, 137.8, 135.3 (minor), 134.9, 134.6 (minor), 130.8, 130.2 (minor), 128.9, 126.2, 125.2 (minor), 124.4 (minor), 124.2, 123.7 (minor), 38.9 (minor), 37.0, 21.3; IR (film, ν_{max}/cm^{-1}) 3132, 1785, 1739, 1675, 1463, 1181, 1131, 1190, 1006; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{14}N_2NaO_5$ $[M+Na]^+$ 361.0795, found 361.0789.

1,3-Dioxoisoindolin-2-yl 2-((4-methoxyphenyl)(methyl) amino)-2-oxoacetate. Prepared according to general procedure A using 4-methyoxy-*N*-methylaniline (823 mg, 6.0 mmol) and stirring at rt for 18 h to afford the oxamide (829 mg, 39%) as fine white needles after recrystallisation from EtOAc: mp 135–137 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.95–7.92 (m, 0.15H), 7.84–7.79 (comp, 1.95H), 7.78–7.73 (m, 1.90H), 7.31–7.26 (m, 2H), 6.99–6.94 (m, 2H), 3.85 (s, 2.70H), 3.82 (s, 0.30H), 3.57 (s, 0.30H), 3.40 (s, 2.70H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 160.0, 159.3, 157.7, 135.3 (minor), 134.9, 133.0, 128.8, 128.0, 126.7 (minor), 124.4 (minor), 124.1, 115.3, 114.8 (minor), 55.7, 37.1; IR (film, ν_{max}/cm^{-1}) 1816, 1788, 1743, 1672, 1511, 1249, 1103; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{14}N_2NaO_6$ $[M+Na]^+$ 377.0744, found 377.0736.

1,3-Dioxoisoindolin-2-yl 2-(methyl(*m*-tolyl)amino)-2-oxoacetate. Prepared according to general procedure A using *N*-methyl-*m*-toluidine (727 mg, 760 mL, 6.0 mmol) and stirring at rt for 30 min to afford the oxamide (1.59 g, 79%) as off-white microcrystals after recrystallization from toluene: mp 120-123 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.98–7.92 (m, 0.17H), 7.88–7.80 (comp, 2H), 7.78–7.72 (m, 1.83H), 7.36 (app t, *J* = 8.2 Hz, 1H), 7.25–7.14 (comp, 3H), 3.59 (s, 0.25H), 3.44 (s, 2.75H), 2.43 (s, 2.75H), 2.40 (s, 0.25H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 160.9, 158.2, 157.6, 140.6, 140.3, 134.9, 130.0, 129.8, 128.9, 127.0, 124.2, 123.3, 36.9, 21.4; IR (film, ν_{max}/cm^{-1}) 1807, 1782, 1737, 1669, 1589, 1184, 1156, 1130, 1097, 1027; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{14}N_2NaO_5$ $[M+Na]^+$ 361.0795, found 361.0793.

1,3-Dioxoisoindolin-2-yl 2-(methyl(*o*-tolyl)amino)-2-oxoacetate. Prepared according to general procedure A using *N*-methyl-*o*-toluidine (727 mg, 741 mL, 6.0 mmol) and stirring at rt for 16 h to afford the oxamide (1.10 g, 54%) as pale yellow microcrystals after recrystallization from toluene: mp 123–125 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.97–7.93 (m, 0.15H), 7.88–7.77 (comp, 2H), 7.77–7.71 (m, 1.85H), 7.41–7.25 (comp, 4H), 3.53 (s, 0.23H), 3.35 (s, 2.77H), 2.36 (s, 2.77H), 2.29 (s, 0.23H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 157.9 (2C), 138.8, 136.5, 135.3 (minor), 134.9, 131.8, 130.4 (minor), 130.0, 129.2 (minor), 128.8, (2C), 127.7, 124.5 (minor), 124.2, 36.1, 17.5; IR (film, ν_{max}/cm^{-1}) 1819, 1790, 1744, 1678, 1492, 1349, 1185, 1157, 1131, 1077, 1004; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{14}N_2NaO_5$ $[M+Na]^+$ 361.0795, found 361.0794.

1,3-Dioxoisoindolin-2-yl 2-((2-fluorophenyl)(methyl) amino)-2-oxoacetate. Prepared according to general procedure A using *N*-(2-fluorophenyl)-*N*-methylamine (751 mg, 6.0 mmol) and stirring at rt for 18 h to afford the oxamide (1.38 g, 67%) as colorless microcrystals after recrystallization from toluene: mp 134–136 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.98–7.92 (m, 0.20H), 7.88–7.79 (comp, 2H), 7.78–7.72 (m, 1.80H), 7.49–7.33 (comp, 2H), 7.30–7.19 (comp, 2H), 3.59 (s, 0.30H), 3.42 (s, 2.70H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 161.3 (minor), 160.8, 158.2 (d, $J_{C\text{-}F}$ = 252.0 Hz), 157.6 (2C), 135.3 (minor), 135.0, 131.4 (d, $J_{C\text{-}F}$ = 7.9 Hz), 130.4 (d, $J_{C\text{-}F}$ = 8.0 Hz) (minor), 129.6, 129.1 (minor), 128.8 (minor), 128.7, 128.4 (d, $J_{C\text{-}F}$ = 20.2 Hz) (minor), 127.9 (d, $J_{C\text{-}F}$ = 12.9 Hz), 125.5 (d, $J_{C\text{-}F}$ = 4.1 Hz), 125.1 (d, $J_{C\text{-}F}$ = 3.6 Hz) (minor), 124.4 (minor), 124.2, 117.2 (d, $J_{C\text{-}F}$ = 19.5 Hz), 117.2 ($J_{C\text{-}F}$ = 19.6 Hz) (minor), 38.6 (d, $J_{C\text{-}F}$ = 2.0 Hz) (minor), 36.4 (d, $J_{C\text{-}F}$ = 2.0 Hz); IR (film, ν_{max}/cm^{-1}) 1819, 2789, 1743, 1686, 1499, 1185, 1163, 1134, 1111, 1078, 1006; HRMS (ESI$^+$) *m/z* calcd. for $C_{17}H_{11}FN_2NaO_5$ [M+Na]$^+$ 365.0544, found 365.0528.

1,3-Dioxoisoindolin-2-yl 2-(benzyl(phenyl)amino)-2-oxoacetate. Prepared according to general procedure A using *N*-benzylaniline (1.00 g, 1.04 mL, 6.0 mmol) and stirring at rt for 4 h to afford the oxamide (1.65 g, 69%) as colorless cubes after recrystallization from EtOAc: mp 131–133 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.83–7.78 (m, 2H), 7.77–7.71 (m, 2H), 7.42–7.37 (comp, 3H), 7.33–7.28 (comp, 3H), 7.28–7.23 (m, 2H), 7.21–7.16 (m, 2H), 5.11 (s, 0.10H), 5.03 (s, 1.90H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 158.1, 157.7, 138.6, 135.3, 135.2 (minor), 134.9, 130.0, 129.5 (minor), 129.3, 129.0, 128.8, 128.8, 128.5 (minor), 128.2, 127.9, 127.1 (minor), 124.4 (minor), 124.1, 53.1; IR (film, ν_{max}/cm^{-1}) 1815, 1788, 1743, 1672, 1595, 1494, 1113, 1077; HRMS (ESI$^+$) *m/z* calcd. for $C_{23}H_{16}N_2NaO_5$ [M+Na]$^+$ 423.0951, found 423.0967.

1,3-Dioxoisoindolin-2-yl-2-(allyl(phenyl)amino)-2-oxoacetate. Prepared according to general procedure A using *N*-allylaniline (799 mg, 814 mL, 6.0 mmol) and stirring at rt for 4 h to afford the oxamide (1.20 g, 57%) as colorless cubes after recrystallization from EtOAc: mp 138–140 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.96–7.92 (m, 0.10H), 7.86–7.79 (comp, 2H), 7.77–7.72 (m, 1.90H), 7.50–7.41 (comp, 3H), 7.36–7.34 (m, 2H), 5.90 (ddt, *J* = 17.2, 9.8, 6.3 Hz, 1H), 5.27–5.10 (comp, 2H), 4.55–4.51 (m, 0.10H), 4.46 (dt, *J* = 6.3, 1.2 Hz, 1.90H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 158.0, 157.4, 138.9, 135.3 (minor), 135.0, 131.1, 130.1, 129.6 (minor), 129.2, 128.8, 127.6, 126.8 (minor), 124.4 (minor), 124.2, 119.8, 52.2; IR (film, ν_{max}/cm^{-1}) 1815, 1788, 1743, 1672, 1596, 1494, 1185, 1106; HRMS (ESI$^+$) *m/z* calcd. for $C_{19}H_{14}N_2NaO_5$ [M+Na]$^+$ 373.0795, found 373.0778.

1,3-Dioxoisoindolin-2-yl 2-((*tert*-butoxycarbonyl)(phenyl) amino)-2-oxoacetate. Based upon the reported procedure,[14,32] oxalyl chloride (3.81 g, 2.54 mL, 30.0 mmol) was added drop-wise to a solution of *N*-hydroxyphthalimide (979 mg, 6.0 mmol) in THF (100 mL) at –78 ˚C. After the addition was complete, the reaction was stirred at rt for 18 h then concentrated under reduced pressure and dried under high vacuum (in the dark) for 1 h to provide an off-white residue.

A solution of *tert*-butyl phenylcarbamate[37] (1.16 g, 6.0 mmol) in THF (5 mL) was added drop-wise to a suspension of sodium hydride (60% dispersion in mineral oil, 0.480 g, 7.2 mmol) in THF (40 mL) at 0 °C and the reaction was stirred for 30 min at this temperature. The resultant solution was then transferred via cannula drop-wise into a solution of chloro *N*-phthalimidoyl oxalate in THF (100 mL), at –78 ˚C and the reaction then allowed to warm to 0 ˚C. The reaction was stirred at 0 ˚C for 2 h and then at rt for 2 h before being concentrated under reduced pressure and the residue partitioned between EtOAc (400 mL) and critic acid solution (10% aq, 100 mL). The organic layer was washed with sat. aq. $NaHCO_3$ (4 x 100 mL), dried ($MgSO_4$) and concentrated under reduced pressure and the residue purified by recrystallization from EtOAc to afford the oxamide (0.730 g, 30%) as white needles which were stored in the dark as a precaution: mp 124–125 ˚C (sublimes); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.95-7.89 (m, 2H), 7.84-7.79 (m, 2H), 7.50-7.40 (m/comp, 3H), 7.25-7.20 (m, 2H), 1.48 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 161.1, 159.3, 157.3, 151.7, 135.1, 134.6, 129.4, 129.3, 128.9, 128.0, 124.3, 86.9, 27.8; IR (film, ν_{max}/cm^{-1}) 1825, 1792, 1741, 1713, 1294, 1147, 1052; HRMS (ESI$^+$) *m/z* calcd. for $C_{21}H_{18}N_2NaO_7$ [M+Na]$^+$ 433.1006, found 433.1007.

1,3-Dioxoisoindolin-2-yl-2-((3-methoxyphenyl)(methyl) amino)-2-oxoacetate. Prepared according to general procedure A using 3-methyoxy-*N*-methylaniline (823 mg, 6.0 mmol) and stirring at rt for 18 h to afford the oxamide (590 mg, 28%) as a white powder after recrystallization from Et_2O: mp 101–103 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (rotamers) 7.96–7.92 (m, 0.15H), 7.87–7.79 (comp, 1.95H), 7.78–7.72 (m, 1.90H), 7.31–7.26 (m, 2H), 7.38 (t, *J* = 8.1 Hz, 1H), 6.99–6.93 (comp, 2H), 6.84 (t, *J* = 2.2 Hz, 1H), 3.85 (s, 2.70H), 3.82 (s, 0.30H), 3.59 (s, 0.30H), 3.44 (s, 2.70H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) (rotamers) 160.9, 160.8, 158.1, 157.5, 141.4, 135.3 (minor), 134.9, 130.9, 130.3 (minor), 128.8, 124.4 (minor), 124.2, 118.7, 117.4 (minor), 115.3, 111.8, 111.3 (minor), 55.6, 38.8 (minor), 36.9; IR (film, ν_{max}/cm^{-1}) 1816, 1788, 1742, 1672, 1602; HRMS (ESI$^+$) *m/z* calcd. for $C_{18}H_{14}N_2NaO_6$ [M+Na]$^+$ 377.0744, found 377.0734.

Ethyl 1-methyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carboxylate (14). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and ethyl acrylate (**12**) (36.0 mg, 39.3 mL, 0.36 mmol) and eluting with 3:2 hexanes/EtOAc to give 3,4-dihydroquinolin-2-one **14** (24 mg, 43%) as a pale yellow solid: R_f 0.15 (3:2 hexanes/EtOAc); mp 67-69 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.32 (app t, *J* = 7.9 Hz, 1H), 7.28–7.25 (m, 1H), 7.06 (app t, *J* = 7.9 Hz, 1H), 7.01 (d, *J* = 7.9 Hz, 1H), 4.24–4.06 (m, 2H), 3.85 (dd, *J* = 6.1, 4.7 Hz, 1H), 3.36 (s, 3H), 3.03 (dd, *J* = 16.2, 4.7 Hz, 1H), 2.79 (dd, *J* = 16.2, 6.1 Hz, 1H), 1.22 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 171.7, 168.3, 140.4, 128.9, 128.6, 123.1, 122.9, 115.3, 61.6, 42.3, 33.9, 29.7, 14.2; IR (film, ν_{max}/cm^{-1}) 2919, 1719, 1667, 1597, 1464, 1414, 1367, 1193, 1142, 1018; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{15}NNaO_3$ [M+Na]$^+$ 256.0944, found 256.0940.

Methyl 1,4-dimethyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carboxylate (15). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 1:1 hexanes/Et_2O to give 3,4-dihydro-1*H*-quinolin-2-one **15** (39 mg, 70%) as a pale yellow solid: R_f 0.12 (1:1 hexanes/Et_2O); mp 83–84 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.35–7.28 (comp, 2H), 7.09 (app td, *J* = 7.7, 1.2 Hz, 1H), 7.01 (d, *J* = 7.7 Hz, 1H), 3.69 (s, 3H), 3.37 (s, 3H), 3.14 (d, *J* = 16.0 Hz, 1H), 2.57 (d, *J* = 16.0 Hz, 1H), 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.4, 168.3, 139.8, 128.7, 128.1, 126.1, 123.4, 115.3, 52.9, 44.6, 41.7, 29.6, 23.4; IR (film, ν_{max}/cm^{-1}) 2921, 1729, 1674, 1598, 1469, 1359, 1268, 1196, 1160, 1136, 1102, 1055; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{15}NNaO_3$ $[M+Na]^+$ 256.0944, found 256.0940.

Ethyl 4-(diethoxyphosphoryl)-1-methyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carboxylate (16). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and ethyl 2-(diethoxyphosphoryl)acrylate[38] (85.0 mg, 76.1 mL, 0.36 mmol) and eluting with 1:9 hexanes/EtOAc to give 3,4-dihydro-1*H*-quinolin-2-one **16** (65 mg, 73%) as a pale yellow oil which solidified on standing: R_f 0.18 (1:9 hexanes/EtOAc); mp 32-33 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.70 (d, *J* = 8.0 Hz, 1H), 7.34 (app t, *J* = 8.0 Hz, 1H), 7.08 (app t, *J* = 8.0 Hz, 1H), 7.01 (d, *J* = 8.0 Hz, 1H) 4.28 (q, *J* = 7.0 Hz, 2H), 4.19–3.99 (comp, 4H), 3.41 (dd, *J* = 24.9, 16.5 Hz, 1H), 3.34 (s, 3H), 3.14 (dd, *J* = 16.5, 11.2 Hz, 1H), 1.27 (t, *J* = 7.0 Hz, 6H), 1.20 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 169.1 (d, $J_{C\text{-}P}$ = 1.5 Hz), 166.8 (d, $J_{C\text{-}P}$ = 6.6 Hz), 140.4 (d, $J_{C\text{-}P}$ = 7.0 Hz), 129.4 (d, $J_{C\text{-}P}$ = 2.5 Hz), 129.0 (d, $J_{C\text{-}P}$ = 4.8 Hz), 123.1 (d, $J_{C\text{-}P}$ = 2.4 Hz), 120.0 (d, $J_{C\text{-}P}$ = 6.4 Hz), 115.6 (d, $J_{C\text{-}P}$ = 1.4 Hz), 63.6 (d, $J_{C\text{-}P}$ = 7.1 Hz), 63.5 (d, $J_{C\text{-}P}$ = 7.2 Hz), 62.8, 51.7 (d, $J_{C\text{-}P}$ = 143.6 Hz), 36.1 (d, $J_{C\text{-}P}$ = 4.3 Hz), 29.7, 16.4 (2C, d, $J_{C\text{-}P}$ = 6.2 Hz; d, $J_{C\text{-}P}$ = 6.0 Hz), 14.1; IR (film, ν_{max}/cm^{-1}) 2982, 2934, 1732, 1675, 1597, 1462, 1364, 1247, 1215, 1039, 1015; HRMS (ESI$^+$) *m/z* calcd. for $C_{17}H_{25}NO_6P$ $[M+H]^+$ 370.1414, found 370.1417.

2,2,2-Trifluoroethyl 1-methyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (17). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and 2,2,2-trifluoroethyl acrylate (55.5 mg, 45.6 mL, 0.36 mmol) and eluting with 3:2 hexanes/Et_2OAc to give 3,4-dihydro-1*H*-quinolin-2-one **17** (33 mg, 48%) as an off-white solid: R_f 0.23 (3:2 hexanes/EtOAc); mp 93-95 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.35 (app t, *J* = 7.8 Hz, 1H), 7.28 (d, *J* = 7.8 Hz, 1H), 7.08 (app t, *J* = 7.8 Hz, 1H), 7.03 (d, *J* = 7.8 Hz, 1H), 4.56–4.38 (comp, 2H), 3.98 (dd, *J* = 6.3, 3.9 Hz, 1H), 3.36 (s, 3H), 3.06 (dd, *J* = 16.2, 3.9 Hz, 1H), 2.85 (dd, *J* = 16.2, 6.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 170.2, 167.6, 140.4, 129.5, 128.8, 124.2, 123.4, 121.4, 115.5, 61.0 (q, *J* = 36.7 Hz), 41.9, 33.6, 29.7; IR (film, ν_{max}/cm^{-1}) 2923, 1736, 1660, 1597, 1465, 1419, 1382, 1297, 1164; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{12}F_3NNaO_3$ $[M+Na]^+$ 310.0661, found 310.0657.

1-Methyl-4-(phenylsulfonyl)-3,4-dihydroquinolin-2(1*H*)-one (18). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and phenyl vinyl sulfone (60.6 mg, 0.36 mmol) and eluting with 7:3→0:1 hexanes/Et_2O to give 3,4-dihydro-1*H*-quinolin-2-one **18** (43 mg, 59%) as a pale yellow solid. R_f 0.25 (7:3 hexanes/Et_2O); mp 154–155 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.58 (tt, *J* = 7.5, 1.3 Hz, 1H), 7.54–7.49 (m, 2H), 7.46–7.36 (comp, 4H), 7.13 (app t, *J* = 7.3 Hz, 1H), 6.81 (d, *J* = 8.3 Hz, 1H), 4.33 (d, *J* = 7.7 Hz, 1H), 3.42 (d, *J* = 17.7 Hz, 1H) 3.02 (dd, *J* = 17.7, 7.7 Hz, 1H), 2.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 165.1, 141.0, 136.0, 134.3, 131.8, 130.9, 129.6, 128.9, 123.3, 116.2, 115.2, 63.2, 32.0, 29.2; IR (film, ν_{max}/cm^{-1}) 2924, 1668, 1595, 1478, 1373, 1303, 1291, 1138, 1080; HRMS (ESI$^+$) *m/z* calcd. for $C_{16}H_{15}NNaO_3S$ $[M+Na]^+$ 324.0665, found 324.0651.

1-Methyl-4-propionyl-3,4-dihydroquinolin-2(1*H*)-one (19). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and ethyl vinyl ketone (30.3 mg, 35.6 mL, 0.36 mmol) and eluting with 1:4 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **19** (34 mg, 65%) as a pale yellow solid. R_f 0.20 (1:4 hexanes/Et_2O); mp 93–95 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.33–7.25 (comp, 2H), 7.06 (t, *J* = 7.9 Hz, 1H), 6.98 (d, *J* = 7.9 Hz, 1H), 3.82 (dd, *J* = 6.1, 2.8 Hz, 1H), 3.30 (s, 3H), 3.02 (dd, *J* = 16.1, 2.8 Hz, 1H), 2.68 (dd, *J* = 16.1, 6.1 Hz, 1H), 2.59–2.41 (comp, 2H), 0.96 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 208.2, 168.8, 140.5, 128.9 (2C), 123.1 (2C), 115.3, 49.0, 33.4, 33.1, 29.5, 7.6; IR (film, ν_{max}/cm^{-1}) 2933, 1702, 1670, 1595, 1462, 1413, 1371, 1279, 1187, 1144, 1115; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{15}NNaO_2$ $[M+Na]^+$ 240.0995, found 240.0996.

1-Methyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carbonitrile (20). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and acrylonitrile (19.1 mg, 23.7 mL, 0.36 mmol) and eluting with 3:7 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **20** (36 mg, 81%) as a pale yellow solid: R_f 0.15 (2:3 hexanes/Et_2O); mp 88–90 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.48 (dt, *J* = 7.6, 1.0 Hz, 1H), 7.44–7.38 (m, 1H), 7.16 (td, 7.6, 1.0 Hz, 1H), 7.06 (dd, *J* = 8.2, 0.6 Hz, 1H), 4.18 (dd, *J* = 10.6, 5.4 Hz, 1H), 3.38 (s, 3H), 3.02 (dd, *J* = 16.0, 5.4 Hz, 1H), 2.93 (dd, *J* = 16.0, 10.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 166.4, 139.7, 130.0, 127.0, 123.9, 119.5, 118.2, 115.7, 34.9, 30.0, 28.4; IR (film, ν_{max}/cm^{-1}) 2924, 2247, 1742, 1728, 1670, 1600, 1472, 1459, 1359, 1272, 1135; HRMS (ESI$^+$) *m/z* calcd. for $C_{11}H_{10}N_2NaO$ $[M+Na]^+$ 209.0685, found 209.0686.

5-Methyl-4-oxo-1,2,3,3a,4,5-hexahydro-9b*H*-cyclopenta[*c*] quinolone-9b-carbonitrile (23). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate **11** (77.8 mg, 0.24 mmol) and 1-cyclopentenecarbonitrile (33.5 mg, 35.5 mL, 0.36 mmol) and eluting with 1:1 hexanes/Et_2O to give 3,4-dihydro-1*H*-quinolin-2-one **23** (20 mg, 45%) as a white solid: R_f 0.39 (2:3 hexanes/Et_2O); mp 112–114 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.60 (dd, *J* = 7.6, 1.5 Hz, 1H), 7.43–7.36 (m, 1H), 7.17 (td, *J* = 7.6, 1.1 Hz, 1H), 7.05 (dd, *J* = 8.2, 0.8 Hz, 1H), 3.40 (s, 3H), 3.23 (dd, *J* = 8.2, 4.3 Hz, 1H), 2.54–2.32 (comp, 3H), 2.14–1.93 (comp, 2H), 1.87–1.74 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ

(ppm) 168.0, 138.1, 129.9, 127.6, 123.9, 122.0, 121.0 115.5, 49.2, 45.4, 39.3, 30.2, 28.4, 21.6; IR (film, ν_{max}/cm^{-1}) 2236, 1743, 16667, 1600, 1457, 1356, 1273, 1124; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{15}N_2O$ $[M+H]^+$ 227.1179, found 227.1180.

5,9b-Dimethyl-3,3a,5,9b-tetrahydro-1*H*-cyclopenta[*c*] quinoline-1,4(2*H*)-dione (24). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and 2-methyl-2-cyclopenten-1-one (34.6 mg, 35.3 mL, 0.36 mmol) and eluting with 1:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **24** (21 mg, 38%) as a pale yellow solid: R_f 0.24 (3:5 hexanes/Et_2O); mp 92–94 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.31 (td, *J* = 8.1, 1.6 Hz, 1H), 7.27–7.22 (m, 1H), 7.09–7.02 (comp, 2H), 3.43 (s, 3H), 2.94 (dd, *J* = 12.1, 6.7 Hz, 1H), 2.44–2.21 (comp, 3H), 1.80–1.63 (m, 1H), 1.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 216.0, 169.5, 138.7, 128.9, 127.4, 123.8, 122.4, 115.3, 51.9, 50.1, 50.1, 35.3, 29.7, 23.0; IR (film, ν_{max}/cm^{-1}) 2923, 1738, 1666, 1597, 1453, 1362; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{16}NO_2$ $[M+H]^+$ 230.1176, found 230.1172.

1-Methyl-4-(pyridin-2-yl)-3,4-dihydroquinolin-2(1*H*)-one *(26).* Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and 2-vinylpyridine (37.9 mg, 38.8 mL, 0.36 mmol). Brine (50 mL) was used in place of sat. aq. (NH_4Cl) in the work up and the column was eluted with Et_2O to give 3,4-dihydro-1*H*-quinolin-2-one **26** (25 mg, 44%) as a pale yellow gum: R_f 0.26 (Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.60–8.57 (m, 1H), 7.59 (app td, *J* = 7.7, 2.1 Hz, 1H), 7.30 (ddd, *J* = 8.5, 6.3, 2.7 Hz, 1H), 7.15 (dd, *J* = 7.7, 4.4 Hz, 1H), 7.08–6.96 (comp, 4H), 4.37 (app t, *J* = 6.5 Hz, 1H), 3.37 (s, 3H), 3.26 (dd, *J* = 16.0, 6.5 Hz, 1H), 2.96 (dd, *J* = 16.0, 6.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 169.5, 160.7, 150.0, 140.5, 136.9, 128.4, 128.2, 127.7, 123.1, 122.2 (2C), 115.1, 43.7, 37.2, 29.6; IR (film, ν_{max}/cm^{-1}) 2923, 1670, 1600, 1590, 1470, 1366, 1129, 1136; HRMS (ESI$^+$) *m/z* calcd. for $C_{15}H_{15}N_2O$ $[M+H]^+$ 239.1179, found 239.1179.

***N*-methyl-*N*,3,3-triphenylacrylamide (27).** Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and 1,1-diphenylethylene (64.9 mg, 63.6 mL, 0.36 mmol) and eluting with 1:1 hexanes\$Et_2O$ to give *N*-methyl-*N*,3,3-triphenylacrylamide **27** (40 mg, 53%) as a pale yellow gum which solidified upon standing: R_f 0.18 (1:1 hexanes\$Et_2O$); mp 78–80 ˚C (lit.[39] 81-83 ˚C); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.38–7.28 (comp, 4H), 7.28–7.15 (comp 5H), 7.10–6.98 (comp, 4H), 6.87 (d, *J* = 7.5 Hz, 2H), 6.18 (s, 1H), 3.23 (s, 3H); HRMS (ESI$^+$) *m/z* calcd. for $C_{22}H_{20}NO$ $[M+H]^+$ 314.1539, found 314.1542. All data were in agreement with those reported in the literature.[39]

Methyl-1,4-dimethyl-2-oxo-6-(trifluoromethyl)-1,2,3,4-tetrahydroquinoline-4-carboxylate (28). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(4-(trifluoromethyl)phenyl)amino)-2-oxoacetate (94.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **28** (57 mg, 80%) as a colorless oil: R_f 0.19 (2:3 hexanes/Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.61–7.53 (comp, 2H), 7.08 (d, *J* = 8.5 Hz, 1H), 3.68 (s, 3H), 3.37 (s, 3H), 3.17 (d, *J* = 16.1 Hz, 1H), 2.57 (d, *J* = 16.1 Hz, 1H), 1.64 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 173.7, 168.2, 142.8, 128.6, 126.1 (q, $J_{C\text{-}F}$ = 3.6 Hz), 125.4 (q, $J_{C\text{-}F}$ = 33.2 Hz), 124.1 (q, $J_{C\text{-}F}$ = 271.0 Hz), 123.4 (q, $J_{C\text{-}F}$ = 3.6 Hz), 115.4, 53.1, 44.5, 41.4, 29.8, 23.3; IR (film, ν_{max}/cm^{-1}) 2956, 1731, 1686, 1617, 1333, 1275, 1115, 1087; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{14}F_3NNaO_3$ $[M+Na]^+$ 324.0818, found 324.0804.

Methyl 6-fluoro-1,4-dimethyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (29). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-((4-fluorophenyl)(methyl)amino)-2-oxoacetate (82.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 3:7 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **29** (47 mg, 78%) as a pale yellow solid: R_f 0.14 (3:7 hexanes/Et_2O); mp 102–104 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.06–6.98 (comp, 2H), 6.95 (dd, *J* = 8.8, 4.8 Hz, 1H), 3.70 (s, 3H), 3.34 (s, 3H), 3.13 (d, *J* = 16.2 Hz, 1H), 2.54 (d, *J* = 16.2 Hz, 1H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 173.9, 167.9, 158.9 (d, $J_{C\text{-}F}$ = 243.0 Hz), 136.2 (d, $J_{C\text{-}F}$ = 2.7 Hz), 130.1 (d, $J_{C\text{-}F}$ = 7.1 Hz), 116.5 (d, $J_{C\text{-}F}$ = 8.1 Hz), 115.1 (d, $J_{C\text{-}F}$ = 22.4 Hz), 113.5 (d, $J_{C\text{-}F}$ = 24.2 Hz), 53.1, 44.6, 41.5, 29.9, 23.4; IR (film, ν_{max}/cm^{-1}) 2953, 1720, 1670, 1503, 1432, 1354, 1267, 1150, 1105; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{14}FNNaO_3$ $[M+Na]^+$ 274.0850, found 274.0853.

Methyl-6-chloro-1,4-dimethyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (30). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((4-chlorophenyl)(methyl) amino)-2-oxoacetate (86.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **30** (47 mg, 73%) as a colorless oil: R_f 0.14 (2:3 hexanes/Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.28–7.24 (comp, 2H), 6.91 (d, *J* = 9.3 Hz, 1H), 3.67 (s, 3H), 3.31 (s, 3H), 3.10 (d, *J* = 16.0 Hz, 1H), 2.52 (d, *J* = 16.0 Hz, 1H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 173.8, 167.9, 138.5, 129.7, 128.7, 128.6, 126.3, 116.5, 53.1, 44.5, 41.4, 29.7, 23.3; IR (film, ν_{max}/cm^{-1}) 2953, 1729, 1677, 1493, 1411, 1354, 1266, 1246, 1197, 1100; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{14}{}^{35}ClNNaO_3$ $[M+Na]^+$ 290.0554, found 290.0552.

Methyl 1,4,6-trimethyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carboxylate (31). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(*p*-tolyl)amino)-2-oxoacetate (81.2 mg, 0.24 mmol) and methyl methacrylate (**13**) (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **31** (34 mg, 57%) as a yellow solid: R_f 0.20 (2:3 hexanes/EtOAc); mp 61–63 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.10 (d, *J* = 8.3 Hz, 1H), 7.07 (s, 1H), 6.89 (d, *J* = 8.3 Hz, 1H), 3.68 (s, 3H), 3.33 (s, 3H), 3.11 (d, *J* = 15.9 Hz, 1H), 2.53 (d, *J* = 15.9 Hz, 1H), 2.32 (s, 3H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.5, 168.2, 137.4, 132.9, 129.1, 127.9, 126.6, 115.2, 52.9, 44.6, 41.8, 29.6, 23.4, 20.9; IR (film, ν_{max}/cm^{-1}) 2955, 2922, 1726, 1674, 1505, 1471, 1359, 1268, 1140, 1105; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{17}NNaO_3$ $[M+Na]^+$ 270.1101, found 270.1098.

Methyl-6-methoxy-1,4-dimethyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (32). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((4-methoxyphenyl)(methyl)amino)-2-oxoacetate (85.0 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydro-1*H*-quinolin-2-one **32** (24 mg, 38%) as a pale yellow solid: R_f 0.40 (1:9 hexanes/Et_2O); mp 97–99 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) d (ppm) 6.92 (d, *J* = 8.6 Hz, 1H), 6.89–6.78 (comp, 2H), 3.80 (s, 3H), 3.68 (s, 3H), 3.33 (s, 3H), 3.10 (d, *J* = 15.9 Hz, 1H), 2.53 (d, *J* = 15.9 Hz, 1H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) d (ppm) 174.3, 168.0, 155.7, 133.5, 129.6, 116.2, 112.8, 112.7, 55.7, 52.9, 44.8, 41.7, 29.8, 23.4; IR (film, ν_{max}/cm^{-1}) 2953, 1728, 1668, 1505, 1430, 1295, 1230; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{17}NNaO_4$ $[M+Na]^+$ 286.1050, found 286.1043.

Methyl 1,4,7-trimethyl-2-oxo-1,2,3,4-tetrahydroquinoline-4-carboxylate (33). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(*m*-tolyl)amino)-2-oxoacetate (81.2 mg, 0.24 mmol) and methyl methacrylate (**13**) (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 1:1 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **33** (39 mg, 66%) as a yellow solid: R_f 0.24 (1:1 hexanes/Et_2O); mp 112–114 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.17 (d, *J* = 7.7 Hz, 1H), 6.90 (d, *J* = 7.7 Hz, 1H), 6.82 (s, 1H), 3.67 (s, 3H), 3.35 (s, 3H), 3.11 (d, *J* = 16.0 Hz, 1H), 2.53 (d, *J* = 16.0 Hz, 1H), 2.36 (s, 3H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.6, 168.5, 139.7, 138.7, 125.9, 125.2, 124.0, 116.1, 52.8, 44.3, 41.8, 29.6, 23.5, 21.5; IR (film, ν_{max}/cm^{-1}) 2918, 1722, 1671, 1607, 1408, 1348, 1269, 1248, 1196, 1137, 1101; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{17}NNaO_3$ $[M+Na]^+$ 270.1101, found 270.1103.

Methyl 8-fluoro-1,4-dimethyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (35). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-((2-fluorophenyl)(methyl)amino)-2-oxoacetate (82.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 3:2 hexanes/Et_2O to afford crude material which was repurified by silica gel flash column chromatography, eluting with 1:1 hexanes/EtOAc to give 3,4-dihydroquinolin-2-one **35** (25 mg, 41%) as a colorless solid: R_f 0.29 (7:3 hexanes/Et_2O); mp 61–63 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.10–7.01 (comp, 3H), 3.70 (s, 3H), 3.41 (d, *J* = 6.6 Hz, 3H), 3.07 (d, *J* = 15.7 Hz, 1H), 2.53 (d, *J* = 15.7 Hz, 1H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 173.9, 169.1, 152.3 (d, $J_{C\text{-}F}$ = 247.8 Hz), 133.0 (d, $J_{C\text{-}F}$ = 1.5 Hz), 128.9 (d, $J_{C\text{-}F}$ = 8.1 Hz), 124.7 (d, $J_{C\text{-}F}$ = 8.4 Hz), 121.2 (d, $J_{C\text{-}F}$ = 3.0 Hz), 116.9 (d, $J_{C\text{-}F}$ = 22.0 Hz), 53.0, 45.2, 42.1, 33.7 (d, $J_{C\text{-}F}$ = 11.7 Hz), 23.0; IR (film, ν_{max}/cm^{-1}) 2954, 1732, 1685, 1479, 1354, 1243, 1101; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{14}FNNaO_3$ $[M+Na]^+$ 274.0850, found 274.0845.

Methyl-1-benzyl-4-methyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (36). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(benzyl(phenyl)amino)-2-oxoacetate (96.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **36** (40 mg, 54%) as a yellow oil: R_f 0.37 (2:3 hexanes/Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.33–7.26 (comp, 3H), 7.24–7.19 (comp, 3H), 7.19–7.13 (m, 1H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.92 (d, *J* = 8.1 Hz, 1H), 5.27 (d, *J* = 16.2 Hz, 1H), 5.13 (d, *J* = 16.2 Hz, 1H), 3.68 (s, 3H), 3.25 (d, *J* = 15.8 Hz, 1H), 2.71 (d, *J* = 15.8 Hz, 1H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.3, 168.5, 138.9, 136.9, 128.8, 128.7, 128.2, 127.2, 126.7, 126.2, 123.5, 116.1, 52.9, 45.8, 44.7, 41.8, 23.5; IR (film, ν_{max}/cm^{-1}) 2952, 1728, 1676, 1599, 1496, 1454, 1375, 1268, 1103; HRMS (ESI$^+$) *m/z* calcd. for $C_{19}H_{19}NNaO_3$ $[M+Na]^+$ 332.1257, found 332.1249.

Methyl-1-allyl-4-methyl-2-oxo-1,2,3,4-tetrahydro quinoline-4-carboxylate (37). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-(allyl(phenyl)amino)-2-oxoacetate (84.1 mg, 0.24 mmol) and methyl methacrylate (**13**) (36.0 mg, 38.5 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give 3,4-dihydroquinolin-2-one **37** (28 mg, 45%) as a white solid: R_f 0.32 (2:3 hexanes/Et_2O); mp 81–83 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.31–7.23 (comp, 2H), 7.07 (td, *J* = 8.2, 1.1 Hz, 1H), 7.00 (dd, *J* = 8.2, 1.0 Hz, 1H), 5.85 (ddt, *J* = 17.2, 10.4, 4.8 Hz, 1H), 5.18 (ddd, *J* = 10.4, 2.8, 1.8 Hz, 1H), 5.14 (ddd, *J* = 17.2, 2.8, 1.8 Hz, 1H), 4.60 (ddt, *J* = 16.8, 4.8, 1.8 Hz, 1H), 4.55 (ddt, *J* = 16.8, 4.8, 1.8 Hz, 1H), 3.68 (s, 3H), 3.15 (d, *J* = 15.8 Hz, 1H), 2.61 (d, *J* = 15.8 Hz, 1H), 1.61 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.3, 168.0, 139.0, 132.5, 128.7, 128.2, 126.1, 123.5, 116.7, 116.1, 52.9, 44.9, 44.8, 41.8, 23.4; IR (film, ν_{max}/cm^{-1}) 2952, 1728, 1676, 1599, 1458, 1373, 1225, 1103; HRMS (ESI$^+$) *m/z* calcd. for $C_{15}H_{17}NNaO_3$ $[M+Na]^+$ 282.1101, found 282.1092.

1'-Methyl-6'-(trifluoromethyl)-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (39). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(4-(trifluoro methyl)phenyl)amino)-2-oxoacetate (94.1 mg, 0.24 mmol) and α-methylene-γ-butyrolactone (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with Et_2O to give spiro-3,4-dihydroquinolin-2-one **39** (51 mg, 71%) as a white solid: R_f 0.26 (Et_2O); mp 135–137 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.63 (dd, *J* = 8.6, 1.5 Hz, 1H), 7.31 (d, *J* = 1.5 Hz, 1H), 7.17 (d, *J* = 8.6 Hz, 1H), 4.48 (ddd, *J* = 9.6, 7.9, 4.6 Hz, 1H), 4.36 (dt, *J* = 9.6, 7.4 Hz, 1H), 3.43 (s, 3H), 3.10 (d, *J* = 16.1 Hz, 1H), 2.76 (d, *J* = 16.1 Hz, 1H), 2.50 (dt, *J* = 13.1, 7.9 Hz, 1H), 2.34 (ddd, *J* = 13.1, 7.4, 4.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 177.0, 167.0, 142.3, 126.6 (q, $J_{C\text{-}F}$ = 3.7 Hz), 126.4, 125.8 (q, $J_{C\text{-}F}$ = 33.5 Hz), 123.8 (q, $J_{C\text{-}F}$ = 271.5 Hz), 122.6 (q, $J_{C\text{-}F}$ = 3.7 Hz), 116.0, 65.2, 46.0, 39.1, 35.5, 30.0; IR (film, ν_{max}/cm^{-1}) 2922, 1768, 1683, 1618, 1337, 1281, 1168, 1140, 1115, 1089; HRMS (ESI$^+$) *m/z* calcd. for $C_{14}H_{12}F_3NNaO_3$ $[M+Na]^+$ 322.0661, found 322.0664.

6'-Fluoro-1'-methyl-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (40). Prepared according to general procedure B using oxamide 1,3-dioxoisoindolin-2-yl 2-((4-fluorophenyl)(methyl)amino)-2-oxoacetate (82.1 mg, 0.24 mmol) and α-methylene-γ-butyrolactone (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with Et_2O to give spiro-3,4-dihydro-1*H*-quinolin-2-one **40** (37 mg, 62%) as a white solid: R_f 0.18 (Et_2O); mp 120–122 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.09–7.00 (comp, 2H), 6.83 (dd, *J* = 8.5, 0.5 Hz, 1H), 4.45 (ddd, *J* = 9.5, 8.0, 4.5 Hz, 1H), 4.34 (ddd, *J* = 9.5, 8.0, 7.1 Hz, 1H), 3.38 (s, 3H), 3.06 (d, *J* = 16.0 Hz, 1H), 2.69 (d, *J* = 16.0 Hz, 1H), 2.47 (dt, *J* =

13.0, 8.0 Hz, 1H), 2.30 (ddd, *J* = 13.0, 7.1, 4.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 177.2, 166.8, 158.8 (d, $J_{C\text{-}F}$ = 245.1 Hz), 135.8 (d, $J_{C\text{-}F}$ = 2.7 Hz), 127.6 (d, $J_{C\text{-}F}$ = 7.3 Hz), 117.2 (d, $J_{C\text{-}F}$ = 7.9 Hz), 115.6 (d, $J_{C\text{-}F}$ = 22.3 Hz), 113.0 (d, $J_{C\text{-}F}$ = 24.5 Hz), 65.2, 46.0, 39.1, 35.5, 30.0; IR (film, ν_{max}/cm^{-1}) 2922, 1766, 1672, 1504, 1364, 1185, 1122, 1023; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{13}H_{12}FNNaO_3$ [M+Na]$^+$ 272.0693, found 272.0687.

6'-Chloro-1'-methyl-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (41). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((4-chlorophenyl)(methyl)amino)-2-oxoacetate (86.1 mg, 0.24 mmol) and α-methylene-γ-butyrolactone (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 1:3 hexanes/Et_2O to give spiro-3,4-dihydroquinolin-2-one **41** (34 mg, 53%) as a yellow solid: R_f 0.47 (Et_2O); mp 142–144 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.32 (dd, *J* = 8.7, 2.3 Hz, 1H), 7.07 (d, *J* = 2.3 Hz, 1H), 7.00 (d, *J* = 8.7 Hz, 1H), 4.46 (ddd, *J* = 9.4, 8.0, 4.3 Hz, 1H), 4.35 (ddd, *J* = 9.4, 8.0, 7.1 Hz, 1H), 3.38 (s, 3H), 3.07 (d, *J* = 16.0 Hz, 1H), 2.70 (d, *J* = 16.0 Hz, 1H), 2.47 (dt, *J* = 13.0, 8.0 Hz, 1H), 2.30 (ddd, *J* = 13.0, 7.1, 4.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 177.1, 166.9, 138.2, 129.2, 129.1, 127.5, 125.6, 117.1, 65.2, 46.0, 39.2, 35.6, 29.9; IR (film, ν_{max}/cm^{-1}) 1767, 1674, 1597, 1495, 1413, 1356, 1170, 1023; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{13}H_{12}{}^{35}ClNNaO_3$ [M+Na]$^+$ 288.0398, found 288.0401.

1'-Methyl-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (42). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**7**) (77.8 mg, 0.24 mmol) and α-methylene-γ-butyrolactone (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with Et_2O to give spiro-3,4-dihydroquinolin-2-one **42** (37 mg, 67%) as a pale yellow solid: R_f 0.33 (Et_2O); mp 107–109 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.36 (dd, *J* = 7.2, 1.6 Hz, 1H), 7.15–7.05 (comp, 3H), 4.45 (ddd, *J* = 9.1, 8.4, 3.8 Hz, 1H), 4.32 (ddd, *J* = 9.1, 8.4, 6.9 Hz, 1H), 3.41 (s, 3H), 3.12 (d, *J* = 16.0 Hz, 1H), 2.69 (d, *J* = 16.0 Hz, 1H), 2.46 (app dt, *J* = 13.0, 8.4 Hz, 1H), 2.30 (ddd, *J* = 13.0, 8.4, 6.9 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 177.8, 167.4, 139.5, 129.3, 125.8, 125.4, 123.8, 115.9, 65.2, 46.1, 39.6, 35.9, 29.8; IR (film, ν_{max}/cm^{-1}) 2958, 2923, 1773, 1665, 1597, 1470, 1361, 1176, 1140, 1023; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{13}H_{13}NNaO_3$ [M+Na]$^+$ 254.0788, found 254.0787.

5'-Methoxy-1'-methyl-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (43a) *and* **7'-Methoxy-1'-methyl-4,5-dihydro-1'*H*,2*H*-spiro[furan-3,4'-quinoline]-2,2'(3'*H*)-dione (43b).** Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((3-methoxyphenyl)(methyl)amino)-2-oxoacetate (85.0 mg, 0.24 mmol) and α-methylene-γ-butyrolactone (35.3 mg, 31.6 mL, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give an inseparable mixture of spiro-3,4-dihydroquinolin-2-ones **43a** and **43b** (27 mg, 43%) as a yellow oil (**43a**:**43b** 1.00:0.56). R_f 0.26 (1:9 hexanes/Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (**43a** major) 7.29 (t, *J* = 8.3 Hz, 1H), 6.73–6.68 (m, 2H), 4.49–4.33 (m, 2H), 3.82 (s, 3H), 3.37 (s, 3H), 3.01 (d, *J* = 15.7 Hz, 1H), 2.70 (d, *J* = 15.7 Hz, 1H), 2.46–2.31 (m, 2H); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) (**43b** minor) 6.98 (d, *J* = 8.3 Hz, 1H), 6.65–6.57 (m, 2H), 4.40–4.25 (m, 2H), 3.82 (s, 3H), 3.37 (s, 3H), 3.07 (d, *J* = 15.9 Hz, 1H), 2.67 (d, *J* = 15.9 Hz, 1H), 2.36–2.22 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 179.8, 178.0, 167.6, 166.7, 160.3, 155.8, 141.2, 140.7, 129.7, 126.2, 118.1, 115.5, 108.9, 107.6, 107.2, 103.7, 65.6, 65.2, 56.2, 55.7, 45.5, 42.9, 40.3, 39.8, 36.0, 34.8, 30.4, 30.1; IR (film, ν_{max}/cm^{-1}) 2923, 1766, 1673, 1595, 1474, 1356, 1259, 1216, 1144, 1026; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{14}H_{15}NNaO_4$ [M+Na]$^+$ 284.0893, found 284.0901.

6'-Chloro-1'-methyl-1-phenyl-1'*H*-spiro[pyrrolidine-3,4'-quinoline]-2,2'(3'*H*)-dione (44). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((4-chlorophenyl)(methyl) amino)-2-oxoacetate (86.1 mg, 0.24 mmol) and 3-methylidene-1-phenylpyrrolidin-2-one[40] (48.0 mg, 0.36 mmol) and eluting with Et_2O to give spiro-3,4-dihydro-1*H*-quinolin-2-one **44** (41 mg, 50%) as a pale yellow solid: R_f 0.28 (Et_2O); mp 125–127 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.72 (d, *J* = 7.9 Hz, 2H), 7.44 (dd, *J* = 7.9, 7.5 Hz, 2H), 7.29 (dd, *J* = 8.5, 2.3 Hz, 1H), 7.24 (t, *J* = 7.5 Hz, 1H), 7.04 (d, *J* = 2.3 Hz, 1H), 6.99 (d, *J* = 8.5 Hz, 1H), 3.92–3.86 (comp, 2H), 3.40 (s, 3H), 3.17 (d, *J* = 16.0 Hz, 1H), 2.71 (d, *J* = 16.0 Hz, 1H) 2.36 (app dt, J = 12.9, 7.6 Hz, 1H), 2.27–2.19 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 173.2, 167.9, 138.8, 138.5, 129.6, 129.2, 128.9, 128.6, 125.6 (2C), 120.3, 116.9, 48.7, 45.1, 39.7, 32.1, 29.8; IR (film, ν_{max}/cm^{-1}) 2924, 1675, 1596, 1494, 1397, 1356, 1301, 1228, 1139; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{19}H_{18}{}^{35}ClN_2O_2$ [M+H]$^+$ 341.1051, found 341.1032.

1'-Methyl-1-phenyl-1'*H*-spiro[pyrrolidine-3,4'-quinoline]-2,2' (3'*H*)-dione (45). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and 3-methylidene-1-phenylpyrrolidin-2-one[40] (48.0 mg, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give spiro-3,4-dihydro-1*H*-quinolin-2-one **45** (37 mg, 49%) as a colourless oil: R_f 0.18 (2:3 hexanes/Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.79–7.70 (m, 2H), 7.48–7.39 (m, 2H), 7.35–7.29 (m, 1H), 7.25–7.19 (m, 1H), 7.10–7.01 (comp, 3H), 3.90–3.84 (m, 2H), 3.42 (s, 3H), 3.21 (d, *J* = 16.0 Hz, 1H), 2.70 (d, *J* = 16.0 Hz, 1H), 2.34 (dt, *J* = 12.8, 8.0 Hz, 1H), 2.28–2.18 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.0, 168.4, 139.7, 139.0, 129.2, 128.7, 127.8, 125.6, 125.3, 123.6, 120.1, 115.7, 48.7, 45.1, 40.1, 32.3, 29.7; IR (film, ν_{max}/cm^{-1}) 2925, 2247, 1671, 1597, 1497, 1395, 1361, 1300, 1227; HRMS (ESI$^+$) *m*/*z* calcd. for $C_{19}H_{18}N_2NaO_2$ [M+Na]$^+$ 329.1260, found 329.1251.

1',6'-Dimethyl-1-phenyl-1'*H*-spiro[pyrrolidine-3,4'-quinoline]-2,2'(3'*H*)-dione (46). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(*p*-tolyl)amino)-2-oxoacetate (81.2 mg, 0.24 mmol) and 3-methylidene-1-phenylpyrrolidin-2-one[40] (48.0 mg, 0.36 mmol) and eluting with 2:3 hexanes/Et_2O to give spiro-3,4-dihydroquinolin-2-one **46** (41 mg, 61%) as a pale yellow solid: R_f 0.21 (2:3 hexanes/Et_2O); mp 138–140 ˚C; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.78–7.71 (m, 2H), 7.47–7.41 (m, 2H), 7.25–7.19 (m, 1H), 7.11 (dd, *J* = 8.3, 1.4 Hz, 1H), 6.96 (d, *J* = 8.3 Hz, 1H), 6.83 (d, *J* = 1.4 Hz, 1H), 3.88 (dd, *J* = 7.9, 5.6 Hz, 2H), 3.40 (s, 3H), 3.18 (d, *J* = 15.9 Hz, 1H), 2.68 (d, *J* = 15.9 Hz, 1H), 2.34 (dt, *J* = 12.7, 7.9 Hz, 1H), 2.27 (s, 3H), 2.20 (dt, *J* = 12.7, 5.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 174.1, 168.2, 139.1,

137.3, 133.3, 129.2, 129.1, 127.8, 125.9, 125.3, 120.2, 115.6, 48.8, 45.1, 40.2, 32.3, 29.7, 20.9; IR (film, ν_{max}/cm^{-1}) 2923, 1670, 1597, 1499, 1396, 1364, 1141; HRMS (ESI$^+$) *m/z* calcd. for $C_{20}H_{20}N_2NaO_2$ $[M+Na]^+$ 343.1417, found 343.1400.

1'-Methyl-6'-(trifluoromethyl)-1'*H*-spiro[chroman-3,4'-quinoline]-2',4(3'*H*)-dione (47). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(4-(trifluoromethyl)phenyl)amino)-2-oxoacetate (94.1 mg, 0.24 mmol) and 3-methylenechroman-4-one[41] (57.7 mg, 0.36 mmol) and eluting with 3:2 hexanes\Et$_2$O to give spiro-3,4-dihydro-1*H*-quinolin-2-one **47** (52 mg, 60%) as a colorless gum: R_f 0.19 (Et$_2$O); ^{1}H NMR (400 MHz, CDCl$_3$) d (ppm) 7.97 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.63–7.54 (comp, 2H), 7.50–7.47 (m, 1H), 7.18–7.19 (comp, 2H), 7.04 (d, J = 8.4 Hz, 1H), 4.56 (d, *J* = 11.8 Hz, 1H), 4.39 (d, *J* = 11.8 Hz, 1H), 3.44 (s, 3H), 3.04 (d, *J* = 16.3 Hz, 1H), 2.79 (d, *J* = 16.3 Hz, 1H); ^{13}C NMR (100 MHz, CDCl$_3$) d (ppm) 191.6, 167.0, 161.1, 137.1, 128.3, 126.7 (q, J_{C-F} = 3.7 Hz), 125.5 (q, J_{C-F} = 33.3 Hz), 124.4, 124.2 (q, J_{C-F} = 3.8 Hz), 123.9 (q, J_{C-F} = 271.9 Hz), 122.7, 119.9, 118.2, 115.8, 72.7, 47.5, 35.6, 29.9; IR (film, ν_{max}/cm^{-1}) 2925, 1683, 1605, 1478, 1465, 1325, 1284, 1117, 1089, 1050; HRMS (ESI$^+$) *m/z* calcd. for $C_{19}H_{15}F_3NO_3$ $[M+H]^+$ 362.0999, found 362.1005.

(4'*R*,8*R*,9*S*,13*S*,14*S*)-6'-chloro-3-methoxy-1',13-dimethyl-7,8,9,11,12,13,14,15-octahydro-1'*H*-spiro[cyclopenta[*a*]phenanthrene-16,4'-quinoline]-2',17 (3'*H*,6*H*)-dione (48). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl-2-((4-chlorophenyl)(methyl)amino)-2-oxoacet ate (86.1 mg, 0.24 mmol) and (8*R*,9*S*,13*S*,14*S*)-3-methoxy-13-methyl-16-methylene-7,8,9,11,12,13,15,16-octahydro-6*H*-cyclopenta[*a*]phenanthren-17(14*H*)-one[42] (107 mg, 0.36 mmol) and eluting with 19:1 CH_2Cl_2/Et$_2$O to afford crude material which was repurified by silica gel flash column chromatography, eluting with 3:7 hexanes/Et$_2$O to give spiro-3,4-dihydro-1*H*-quinolin-2-one **48** (25 mg, 22%) as a colorless solid: R_f 0.23 (3:7 hexanes/Et$_2$O); $[\alpha]_D^{22}$ +1.2 (c 1.25, CHCl$_3$); mp 185–187 ˚C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm) 7.27 (dd *J* = 8.7, 2.4 Hz, 1H), 7.20 (d, *J* = 8.6 Hz, 1H), 6.98 (d, *J* = 8.7 Hz, 1H), 6.75–6.71 (comp, 2H), 6.63 (d, *J* = 2.7 Hz, 1H), 3.78 (s, 3H), 3.39 (s, 3H), 3.04 (d, *J* =15.6 Hz, 1H), 2.90–2.83 (comp, 2H), 2.57 (d, *J* = 15.6 Hz, 1H), 2.51–2.43 (m, 1H), 2.41–2.31 (m, 1H), 2.10 (dd, *J* = 12.6, 5.3 Hz, 1H), 1.96 (app t, *J* = 12.6 Hz, 1H), 1.90–1.82 (m, 1H), 1.80–1.54 (comp, 5H), 1.43–1.30 (m, 1H), 1.05 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm) 221.0, 168.0, 157.8, 138.7, 137.7, 132.3, 131.8, 128.4, 128.1, 126.4, 126.3, 116.9, 114.0, 111.7, 55.3, 52.2, 49.7, 46.9, 44.0, 42.5, 37.8, 36.6, 31.7, 29.9, 29.6, 26.7, 25.8, 15.4; IR (film, ν_{max}/cm^{-1}) 2928, 1738, 1676, 1608, 1493, 1410, 1356, 1255, 1138, 1044; HRMS (ESI$^+$) *m/z* calcd. for $C_{28}H_{31}{}^{35}ClNO_3$ $[M+H]^+$ 464.1987, found 464.1966.

Methyl 1-methyl-2-oxo-1,2-dihydroquinoline-4-carboxylate (56). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(phenyl)amino)-2-oxoacetate (**11**) (77.8 mg, 0.24 mmol) and methyl a-chloroacrylate (43.4 mg, 36.5 mL, 0.36 mmol) and eluting with 1:1 hexanes/EtOAc to give 3,4-dihydro-1*H*-quinolin-2-one **56** (31 mg, 59%) as a pale yellow solid: R_f 0.21 (1:1 hexanes/EtOAc); mp 111–113 ˚C [lit.[43] 117-119 ˚C (hexane/ether)]; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm) 8.35 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.66–7.58 (m, 1H), 7.42 (d, *J* = 8.5 Hz, 1H), 7.30 (t, J = 8.1 Hz, 1H), 7.22 (s, 1H), 3.99 (s, 1H), 3.75 (s, 3H); all ^{1}H NMR data were consistent with those previously reported in the literature;[43] ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm) 166.0, 161.5, 140.5, 138.6, 131.3, 127.4, 124.6, 122.9, 117.6, 114.7, 53.0, 30.0; IR (film, ν_{max}/cm^{-1}) 2923, 1727, 1660, 1589, 1426, 1246, 1194, 1072, 1017; HRMS (ESI$^+$) *m/z* calcd. for $C_{12}H_{11}NNaO_3$ $[M+Na]^+$ 240.0631, found 240.0627.

Methyl 1,6-dimethyl-2-oxo-1,2-dihydroquinoline-4-carboxylate (57). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(*p*-tolyl)amino)-2-oxoacetate (81.2 mg, 0.24 mmol) and methyl a-chloroacrylate (43.4 mg, 36.5 mL, 0.36 mmol) and eluting with 1:1 Et$_2$O to give 3,4-dihydro-1*H*-quinolin-2-one **57** (22 mg, 40%) as a yellow solid: R_f 0.24 (Et$_2$O); mp 152–154 ˚C; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm) 8.10 (s, 1H), 7.42 (br d, *J* = 8.7 Hz, 1H), 7.29 (d, *J* = 8.7 Hz, 1H), 7.17 (s, 1H), 3.98 (s, 3H), 3.71 (s, 3H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm) 166.1, 161.2, 138.5, 138.4, 132.6, 132.5, 126.9, 124.3, 117.5, 114.5, 53.0, 29.9, 21.0; IR (film, ν_{max}/cm^{-1}) 2921, 1717, 1651, 1580, 1441, 1238, 1157, 1074, 1037; HRMS (ESI$^+$) *m/z* calcd. for $C_{13}H_{13}NNaO_3$ $[M+Na]^+$ 254.0788, found 254.0782.

1,6-Dimethyl-2-oxo-1,2-dihydroquinoline-4-carbonitrile (58). Prepared according to general procedure B using 1,3-dioxoisoindolin-2-yl 2-(methyl(*p*-tolyl)amino)-2-oxoacetate (81.2 mg, 0.24 mmol) and 2-chloroacrylonitrile (31.5 mg, 28.7 mL, 0.36 mmol) and eluting with Et$_2$O to give 3,4-dihydro-1*H*-quinolin-2-one **58** (12 mg, 25%) as a pale brown solid: R_f 0.38 (Et$_2$O); mp 191–193 ˚C [lit.[44] 197-198 ˚C (EtOH)]; ^{1}H NMR (400 MHz, CDCl$_3$) δ (ppm) 7.71 (br s, 1H), 7.52 (dd, *J* = 8.7, 1.6 Hz, 1H), 7.33 (d, *J* = 8.7 Hz, 1H), 7.13 (s, 1H), 3.72 (s, 3H), 2.48 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm) ^{13}C NMR (100 MHz, CDCl$_3$) δ (ppm) 160.0, 138.1, 134.1, 133.6, 128.7, 126.5, 122.5, 117.3, 114.9, 114.7, 30.1, 20.8; IR (film, ν_{max}/cm^{-1}) 3036, 2922, 2238, 1741, 1651, 1590, 1562, 1452, 1415, 1316, 1072; HRMS (ESI$^+$) *m/z* calcd. for $C_{12}H_{10}N_2NaO$ $[M+Na]^+$ 221.0685, found 221.0675.

Acknowledgements

We thank the South African National Research Foundation (NRF/95404, W.F.P.) and Elsevier (J.R.D.) for financial support.

Notes and references

1 For recent reviews, see: (a) J.-R. Chen, X.-Q. Hu, L.-Q. Lu, W.-J. Xiao, *Acc. Chem. Res.*, 2016, **49**, 1911; (b) D. Staveness, I. Bosque and C. R. J. Stephenson, *Acc. Chem. Res.*, 2016, **49**, 2295; (c) T. P. Yoon, *Acc. Chem. Res.*, 2016, **49**, 2307; (d) J. J. Douglas, M. J. Sevrin and C. R. J. Stephenson, *Org. Process Res. Dev.*, 2016, **20**, 1134. (e) M. H. Shaw, J. Twilton and D. W. C. MacMillan, *J. Org. Chem.*, 2016, **81**, 6898. (f) N. A. Romero and D. A. Nicewicz, *Chem. Rev.*, 2016, **116**, 10075. (g) E. Meggers, *Chem. Commun.*, 2015, **51**, 3290.

2 For a review of acyl radical chemistry including carbamoyl radicals, see: C. Chatgilialoglu, D. Crich, M. Komatsu and I. Ryu, *Chem. Rev.*, 1999, **99**, 1991.

3 (a) F. Coppa, F. Fontana, E. Lazzarini and F. Minisci, *Heterocycles*, 1993, **36**, 2687; (b) F. Minisci, F. Fontana, F. Coppa and Y. M. Yan, *J. Org. Chem.*, 1995, **60**, 5430; (c) F. Minisci, F. Recupero, C. Punta, C. Gambarotti, F. Antonietti, F. Fontanab and G. F. Pedullic, *Chem. Commun.*, 2002, 2496; (d) T. Caronna, C. Gambarotti, L. Palmisano, C. Puntab and F. Recupero, *Chem. Commun.*, 2003, 2350.

4 (a) L. Friedman and H. Shechter, *Tetrahedron Lett.*, 1961, **2**, 238; (b) D. Elad and J. Rokach, *J. Org. Chem.*, 1964, **29**, 1855; (c) R. Dowbenko, *Tetrahedron*, 1964, **20**, 1843; (d) D. Elad and J. Rokach, *J. Chem. Soc.*, 1965, 800; (e) D. Elad and J. Rokach, *J. Org. Chem.*, 1965, **30**, 3361; (f) J. Rokach and D. Elad, *J. Org. Chem.*, 1966, **31**, 4210; (g) G. B. Gill, G. Pattenden and S. J. Reynolds, *J. Chem. Soc., Perkin Trans. 1*, 1994, 369; (h) D. Ravelli, S. Montanaro, M. Zema, M. Fagnoni and A. Albini, *Adv. Synth. Catal.*, 2011, **353**, 3295; (i) W.-P. Mai, G.-C. Sun, J.-T. Wang, G. Song, P. Mao, L.-R. Yang, J.-W. Yuan, Y.-M. Xiao and L.-B. Qu, *J. Org. Chem.*, 2014, **79**, 8094; (j) Q. Jiang, J. Jia, B. Xu, A. Zhao and C.-C. Guo, *J. Org. Chem.*, 2015, **80**, 3586.

5 S. Fujiwara, Y. Shimizu, T. Shin-ike and N. Kambe, *Org. Lett.*, 2001, **3**, 2085.

6 (a) G. Pattenden and S. J. Reynolds, *J. Chem. Soc. Perkin Trans. 1*, 1994, 379; (b) J. H. Rigby, D. M. Danca and J. H. Homer, *Tetrahedron Lett.*, 1998, **39**, 8413; (c) L. V. Jackson and J. C. Walton, *Chem. Commun.*, 2000, 2327; (d) E. M. Scanlan and J. C. Walton, *Chem. Commun.*, 2002, 2086; (e) A. F. Bella, L. V. Jackson and J. C. Walton, *J. Chem. Soc., Perkin Trans. 2*, 2002, 1839; (f) A. F. Bella, L. V. Jackson and J. C. Walton, *Org. Biomol. Chem.*, 2004, **2**, 421; (g) E. M. Scanlan, A. M. Z. Slawin, and J. C. Walton, *Org. Biomol. Chem.*, 2004, **2**, 716; (h) R. S. Grainger, and P. Innocenti, *Angew. Chem., Int. Ed.*, 2004, **116**, 3527; (i) L. Benati, G. Bencivenni, R. Leardini, M. Minozzi, D. Nanni, R. Scialpi, P. Spagnolo and G. Zanardi, *J. Org. Chem.*, 2006, **71**, 3192; (j) E. M. Scanlan, and J. C. Walton, *Helv. Chim. Acta*, 2006, **89**, 2133; (k) R. S. Grainger and E. J. Welsh, *Angew. Chem., Int. Ed.*, 2007, **119**, 5473; (l) R. S. Grainger and P. Innocenti, *Heteroat. Chem.*, 2007, **18**, 568; (m) G. López-Valdez, S. Olguín-Uribe and L. D. Miranda, *Tetrahedron Lett.*, 2007, **48**, 8285; (n) G. Bencivenni, T. Lanza, R. Leardini, M. Minozzi, D. Nanni, P. Spagnolo and P. Zanardi, *J. Org. Chem.*, 2008, **73**, 4721; (o) S. Fujiwara, Y. Shimizu, Y. Imahori, M. Toyofuku, T. Shin-ike and N. Kambe, *Tetrahedron Lett.*, 2009, **50**, 3628; (p) G. Rousseau, F. Robert and Y. Landais, *Chem. Eur. J.*, 2009, **15**, 11160; (q) G. López-Valdez, S. Olguín-Uribe, A. Millan-Ortíz, R. Gamez-Montaño and L. D. Miranda, *Tetrahedron*, 2011, **67**, 2693; (r) M. Yuan, L. Chen, J. Wang, S. Chen, K. Wang, Y. Xue, G. Yao, Z. Luo and Y. Zhang, *Org. Lett.*, 2015, **17**, 346; (s) A. Millán-Ortiz, G. López-Valdez, F. Cortez-Guzmán and L. D. Miranda, *Chem. Commun.*, 2015, **51**, 8345.

7 A. G. M. Barrett, H. Kwonband and E. M. Wallace, *J. Chem. Soc., Chem. Commun.*, 1993, 1760.

8 R. M. Fantazier and J. E. Herweh, *J. Org. Chem.*, 1973, **8**, 2560.

9 H. Wang, L.-N. Guo, S. Wang and X.-H. Duan, *Org. Lett.*, 2015, **17**, 3054.

10 (a) M. Li, C. Wang, P. Fang and H. Ge, *Chem. Commun.*, 2011, **47**, 6587; (b) Y. Wu, C. Jiang, D. Wu, Q. Gu, Z.-Y. Luo and H.-B. Luo, *Chem. Commun.*, 2016, **52**, 1286.

11 For leading references categorized by the nature of the C–X bond see ref 12.

12 W. F. Petersen, R. J. K. Taylor and J. R. Donald, *Org. Lett.*, 2017, **19**, 874.

13 For a review of tertiary alkyl radical generation by this method, see: C. R. Jamison and L. E. Overman, *Acc. Chem. Res.*, 2016, **49**, 1578.

14 For this method applied to methoxycarbonyl radicals, see: Y. Slutskyy and L. E. Overman, *Org. Lett.*, 2016, **18**, 2564.

15 (a) R. Uchida, R. Imasato, Y. Yamaguchi, R. Masuma, K. Shiomi, H. Tomoda and S. Ōmura, *J. Antibiot.*, 2006, **59**, 646; (b) R. Uchida, R. Imasato, H. Tomoda and S. Ōmura, *J. Antibiot.*, 2006, **59**, 652.

16 K. Bernauer, G. Englert, W. Wetter and E. Weiss, *Helv. Chim. Acta*, 1969, **52**, 1886.

17 S.-S. Ma, W.-L. Mei, Z.-K. Guo, S.-B. Liu, Y.-X. Zhao, D.-L. Yang, Y.-B. Zeng, B. Jiang and H.-F. Dai, *Org. Lett.*, 2003, **15**, 1492.

18 M. J. Walsh, K. R. Brimacombe, H. Veith, J. M. Bougie, T. Daniel, W. Leister, L. C. Cantley, W. J. Israelsen, M. G. Vander Heiden, M. Shen, D. S. Auld, C. J. Thomas and M. B. Boxer, *Bioorg. Med. Chem. Lett.*, 2011, **21**, 6322.

19 M. Patel, R. J. McHugh Jr., B. C. Cordova, R. M. Klabe, L. T. Bacheler, S. Erickson-Viitanen and J. D. Rodgers, *Bioorg. Med. Chem. Lett.*, 2001, **11**, 1943.

20 For a review, see: M. A. Davies, D. J. Sheffler and B. L. Roth, *CNS Drug Rev.*, 2004, **10**, 317.

21 For a review, see: T. Tashima, *Bioorg. Med. Chem. Lett.*, 2015, **25**, 3415.

22 J.-J. Chen, P.-H. Chen, C.-H. Liao, S.-Y. Huang and I.-S. Chen, *J. Nat. Prod.*, 2007, **70**, 1444.

23 A. van Oeveren, M. Motamedi, N. S. Mani, K. B. Marschke, F. J. López, W. T. Schrader, A. Negro-Vilar and L. Zhi, *J. Med. Chem.*, 2006, **49**, 6143.

24 (a) E. Späth and J. Pikl, *Monatsh. Chem.*, 1930, **55**, 352; (b) P. J. Houghton, T. Z. Woldemariam, Y. Watanabe and M. Yates, *Planta Med.*, 1999, **65**, 250.

25 N. Igoe, E. D. Bayle, O. Fedorov, C. Tallant, P. Savitsky, C. Rogers, D. R. Owen, G. Deb, T. C. P. Somervaille, D. M. Andrews, N. Jones, A. Cheasty, H. Ryder, P. E. Brennan, S. Müller, S. Knapp and P. V. Fish, *J. Med. Chem.*, 2017, **60**, 668.

26 For recent examples see: (a) A. K. Clarke, M. J. James, P. O'Brien, R. J. K. Taylor and W. P. Unsworth, *Angew. Chem., Int. Ed.*, 2016, **55**, 13798; (b) S. J. Chambers, G. Coulthard, W. P. Unsworth, P. O'Brien and R. J. K. Taylor, *Chem. Eur. J.*, 2016, **22**, 6496; (c) J. T. R. Liddon, M. J. James, A. K. Clarke, P. O'Brien, R. J. K. Taylor and W. P. Unsworth, *Chem. Eur. J.*, 2016, **22**, 8777; (d) M. J. James, R. E. Clubley, K. Y. Palate, T. J. Procter, A. C. Wyton, P. O'Brien, R. J. K. Taylor and W. P. Unsworth, *Org. Lett.*, 2015, ***17***, 4372; (e) M. J. James, J. D. Cuthbertson, P. O'Brien, R. J. K. Taylor and W. P. Unsworth, *Angew. Chem., Int. Ed.*, 2015, **54**, 7640.

27 For selected examples featuring radical cyclization see: (a) P. Drouhin, T. E. Hurst, A. C. Whitwood and R. J. K. Taylor, *Tetrahedron*, 2015, **71**, 7124; (b) P. Drouhin and R. J. K. Taylor, *Eur. J. Org. Chem.*, 2015, 2333; (c) P. Drouhin, T. E. Hurst, A. C. Whitwood and R. J. K. Taylor, *Org. Lett.*, 2014, **16**, 4900; (d) T. E. Hurst, R. M. Gorman, P. Drouhin, A. Perry and R. J. K. Taylor, *Chem. Eur. J.*, 2014, **20**, 14063; (e) J. E. M. N. Klein, A. Perry, D. S. Pugh and R. J. K. Taylor, *Org. Lett.*, 2010, **12**, 3446; (f) A. Perry and R. J. K. Taylor, *Chem. Commun.*, 2009, 3249.

28 For related radical cyclizations to form 3,4-dihydroquinolin-2-ones, see: (a) W.-P. Mai, G.-C. Sun, J.-T. Wang, G. Song, P. Mao, L.-R. Yang, J.-W. Yuan, Y.-M. Xiao and L.-B. Qu, *J. Org. Chem.*, 2014, ***79***, 8094. (b) Y.-L. Zhu, B. Jiang, W.-J. Hao, A.-F. Wang, J.-K. Qiu, P. Wei, D.-C. Wang, G. Li and S.-J. Tu, *Chem. Commun.*, 2016, **52**, 1907. (c) A.-F. Wang, Y.-L. Zhu, S.-L. Wang, W.-J. Hao, G. Li, S.-J. Tu and B. Jiang, *J. Org. Chem.*, 2016, **81**, 1099. (d) Y.-L. Zhu, D.-C. Wang, B. Jiang, W.-J. Hao, P. Wei, A.-F. Wang, J.-K. Qiu and S.-J. Tu, *Org. Chem. Front.*, 2016, **3**, 385. (e) C.-G. Li, G.-Q. Xu and P.-F. Xu, *Org. Lett.*, 2017, **19**, 512.

29 For related cyclizations to form 1,2,3,4-tetrahydroquinolines under photoredox catalysis, see: (a) S. Zhu, A. Das, L. Bui, H. Zhou, D. P. Curran and M. Rueping, *J. Am. Chem. Soc.*, 2013,

135, 1823. (b) L. Chen, C. S. Chao, Y. Pan, S. Dong, Y. C. Teo, J. Wang and C.-H. Tan, *Org*. *Biomol*. *Chem*., 2013, **11**, 5922. (c) D. Lenhart and T. Bach, *Beilstein J*. *Org*. *Chem*., 2014, **10**, 890. (d) Z. Liang, S. Xu, W. Tian and R. Zhang, *Beilstein J*. *Org*. *Chem*., 2015, **11**, 425.

30 G. L. Lackner, K. W. Quasdorf and L. E. Overman, *J*. *Am*. *Chem*. *Soc*., 2013, **135**, 15342.

31 Similar reactivity was observed by Overman for related methoxycarbonyl radicals; see ref 14.

32 Whilst we were unable to isolate the desired product **34** from the reaction, masses corresponding to **34**, and the products of C–H abstraction by the carbamoyl and intermediate conjugate radicals were observed by HRMS analysis of the crude reaction mixture after work up.

33 For a recent example, see: F. Zhu and Z.-X. Wang, *J*. *Org*. *Chem*., 2014, **79**, 4285; and references cited therein.

34 (a) R. H. Snell, M. J. Durbin, R. L. Woodward and M. C. Willis, *Chem*. *Eur*. *J*., 2012, **18**, 16754; (b) J.-S. Yu, F.-M. Liao, W.-M. Gao, K. Liao, R.-L. Zuo and J. Zhou, *Angew*. *Chem*., *Int*. *Ed*., 2015, **54**, 7381.

35 L. Flamigni, A. Barbieri, C. Sabatini, B. Ventura and F. Barigelletti, *Top*. *Curr*. *Chem*., 2007, **281**, 143.

36 G. L. Lackner, K. W. Quasdorf, G. Pratsch and L. E. Overman, *J*. *Org*. *Chem*., 2015, **80**, 6012.

37 A. Millet and O. Baudoin, *Org*. *Lett*., 2014, **16**, 3998.

38 A. T. Biju, M. Padmanaban, N. E. Wurz and F. Glorious, *Angew*. *Chem*., *Int*. *Ed*., 2011, **50**, 8412.

39 L.; Liu, H. Lu, H. Wang, C. Yang, X. Zhang, D. Zhang-Negrerie, Y. Du and K. Zhao, *Org*. *Lett*., 2013, **15**, 2906.

40 M. Fu, L. Chen, Y. Jiang, Z.-X. Jiang and Z. Yang, *Org*. *Lett*., 2016, **18**, 348.

41 Y.-M. Li, S.-J. Lou, Q.-H. Zhou, L.-W. Zhu, L.-F. Zhu and L. Li, *Eur*. *J*. *Org*. *Chem*., 2015, 3044.

42 E. Mernyáka, E. Kozmaa, A. Hetényi, L. Márkc, G. Schneidera and J. Wölfling, *Steroids*, 2009, **74**, 520.

43 C. Kaneko, T. Naito, M. Hashiba, H. Fujii and M. Somei, *Chem*. *Pharm*. *Bull*., 1979, **27**, 1813.

44 A. Kaufmann, A. Albertini, *Chem*. *Ber*., 1909, **42**, 3776.