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RESEARCH ARTICLE

Low Temperature Intramolecular [4+2] Cycloaddition of Allenes with Arenes for the Synthesis of Diene Ligands

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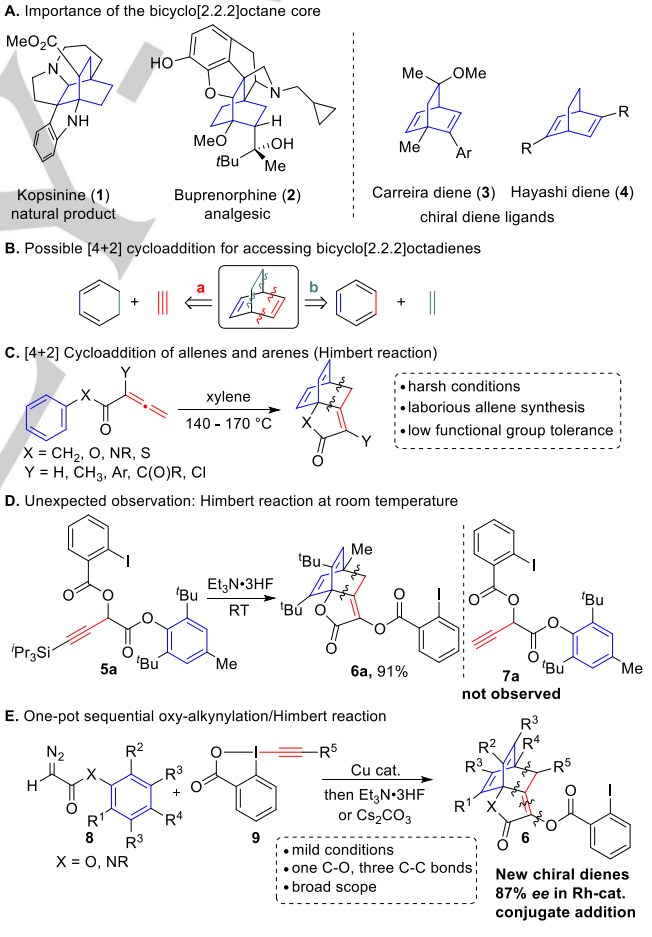
Abstract: The intramolecular [4+2] cycloaddition between arenes and allenes first reported by Himbert gives rapid access to rigid polycyclic scaffolds, but requires high reaction temperatures (140 -170 °C) and several steps to access the starting materials. Herein, we report a one-pot oxyalkynylation/cycloaddition reaction proceeding under mild conditions (23-90 °C) and providing complex polycyclic architectures with high efficiency, atom and step economy. The bicyclo[2.2.2]octadiene products were obtained with a wide variety of useful functional groups and were successfully applied as chiral ligands for metal catalysis. Computational studies gave a first rationalization of the low activation energy for the cycloaddition based on counter-intuitive favourable dispersive interactions in the transition state.

Introduction

The development of multiple bond-forming transformations to increase molecular complexity and diversity from simple precursors is a constant quest in synthetic chemistry with important applications in the pharmaceutical and agrochemical industry (industries?).[1] Among multiple bond-forming transformations, cycloadditions occupy a privileged position.[2,3] They have found applications in the synthesis of natural products,[4] organic materials,[5] and pharmaceutical agents.[6] In particular, the Diels-Alder reaction has been investigated extensively.[7] When using cyclic dienes, it gives access after reduction to bicyclo[2.2.2]octane derivatives, an important class of organic compounds due to their rigidity allowing a precise disposition of functional groups in space. Numerous bioactive natural products, such as the alkaloid kopsinine (**1**),[8] or synthetic compounds, such as the broadly prescribed opioid analgesic buprenorphine (**2**),[9] contain this scaffold (Scheme 1A). Less saturated bicyclo[2.2.2]octadienes constitute another interesting subclass, as they have found broad applications as (chiral) ligands for late transition metal catalysts (Scheme 1A, dienes **3** and **4**).[10] As unsaturated compounds, they are also ideal starting materials for the synthesis of more functionalized saturated derivatives. Two different strategies can be envisioned to access them by a convergent [4+2] cycloaddition (Scheme 1B): reaction of cyclohexadienes with alkynes (**a**), or reaction of arenes with alkenes (**b**). The first approach is now well established.[11] In contrast, the second strategy is less investigated due to the large aromatic stabilization energy of arenes.[12] From the synthetic point of view however, such an approach is highly attractive, as arenes are easier to access than cyclohexadienes.



Scheme 1. A. Importance of the bicyclo[2.2.2]octane core. B. [4+2] cycloadditions for accessing bicyclo[2.2.2]octadienes. C. Himbert reaction. D. Unexpected Himbert reaction at room temperature. E. One-pot oxyalkynylation/Himbert reaction.

In 1982, Himbert and Henn reported an unusual thermal intramolecular [4+2] cycloaddition of allenecarboxanilides to access complex bridged polycyclic architectures.[13] The Himbert

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and Orahovats groups then studied the scope of allenecarboxylic acid derivatives including esters,[14] amides,[15] thioesters,[16] imides,[17] phosphinamides,[18] and phosphinic esters (Scheme 1C).[19] In 2013, Vanderwal and co-workers extended the Himbert cycloaddition to benzyl allenyl ketones.[20] In 2015, Li and co-workers reported a Ugi/Himbert reaction sequence to synthesize strained polycyclic skeletons.[21] Despite its great potential to assembly complex molecules in a single step, it is therefore apparent that the [4+2] cycloaddition of allenes and arenes has found only a few applications in synthetic chemistry.[22] Two reasons can tentatively be proposed for this lack of impact: 1) The Himbert reaction often requires high reaction temperatures. Rare examples of Himbert reactions at ambient temperature required conformationally constrained amides[17,23] or were performed under high-energy light irradiation.[24] 2) Multiple steps are needed to access the allenecarboxylic acid derivatives, which does not allow one to profit from the broad availability of arenes as partners.

Our group has been interested in electrophilic alkynylation reactions using hypervalent iodine reagents for more efficient and flexible alkyne synthesis.[25] Recently, we developed a copper-catalyzed oxyalkynylation of diazo compounds using ethynylbenziodoxol-(on)e (EBX) reagents.[26] When attempting the deprotection of silyl alkyne **5a** with Et_3N•3HF at room temperature, we did not obtain the expected terminal alkyne **7a**. Instead, polycyclic product **6a** was isolated in excellent yield, probably resulting from a [4+2] cycloaddition of the arene on the *in situ* formed allene (Scheme 1D). The exceptionally mild conditions combined with synthetic accessibility motivated us to investigate this transformation.

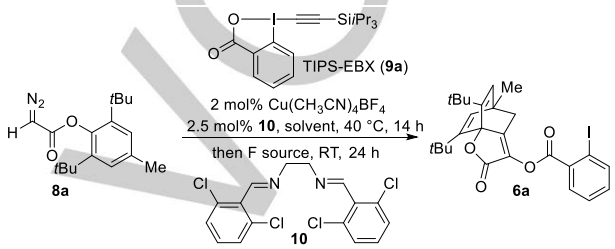
Herein, we report our studies on this fascinating reaction. The cycloaddition proceeded under mild conditions (RT to 90 °C) and exhibited a broad scope of substituents on both arene and allene. By developing a one-pot oxy-alkynylation/cycloaddition process, complex tricyclic compounds are now accessible in a single manipulation from broadly available EBX reagents and diazo esters (Scheme 1E). Preliminary computational studies shed first light on the exceptionally low activation energy of the cycloaddition step, resulting from a combination of attractive interactions from the benzene substituents with the allene and an electronic effect of the oxygen substituent on the allene. This interesting class of heteroatom-substituted allenes has been only rarely investigated so far[27] and the high reactivity observed is promising for other transformations. Furthermore, the iodobenzoyl ester could be easily removed for further modification. Finally, the diene products were effective ligands for rhodium, resulting in quantitative complexation. Preliminary investigations showed that good enantioselectivity can be achieved in rhodium-catalyzed conjugate addition of boronic acids to cyclohexenone using these chiral diene ligands.

Results and Discussion

Optimization and Scope

We started our investigations on developing a one-pot oxy-alkynylation/Himbert reaction by screening various fluoride sources, using 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) with 1-[(tri*iso*-propylsilyl)-ethynyl]-1,2-benziodoxol-3(*1H*)-one (TIPS-EBX (**9a**)), diimine ligand **10** and $Cu(CH_3CN)_4BF_4$ as the copper source in DCE (Table 1).[26a] Compound **6a** was obtained in 88% yield when Et_3N•3HF was used, whereas TASF gave the desired product in 26% yield only (Table 1, entries 1 and 2). The use of TBAF and Py•HF resulted in decomposition of the oxyalkynylated product (Table 1, entries 3 and 4). One equivalent of Et_3N•3HF was sufficient, whereas a sub-stoichiometric amount led to a lower yield (Table 1, entries 5 and 6). Addition of Et_3N•3HF at the start of the reaction did not lead to the formation of the desired product **6a** (Table 1, entry 7). Among the solvents tested, DCE was the best (Table 1, entries, 5 and 8-10). We were able to reduce the amount of diazo **8a** to 1.2 equivalents without a change in yield (Table 1, entry 11). Finally, the yield could be improved to 94% by lowering the concentration of the reaction (Table 1, entry 12). Furthermore, the reaction proved to be easily scalable, as the yield did not change on gram scale.

Table 1. Optimization of the Reaction Conditions[a]

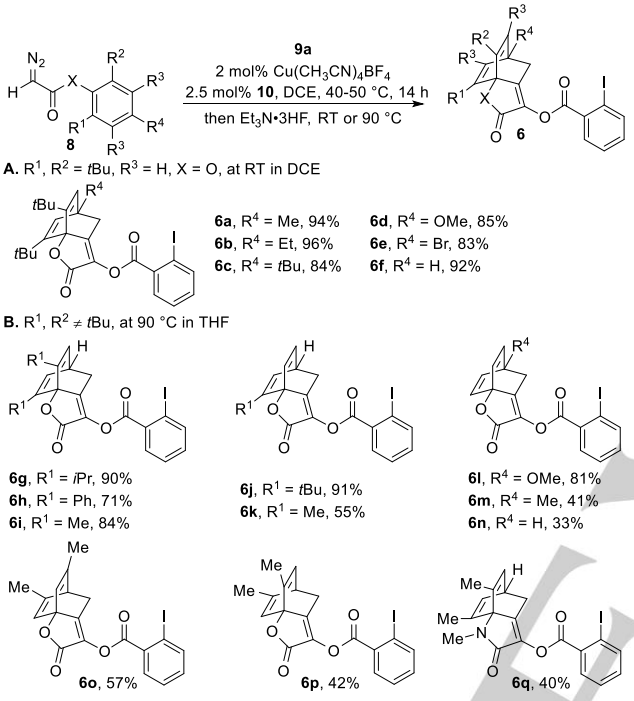


Entry	Fluoride source (x equiv)	Solvent	Yield[b] (%)
1	Et_3N•3HF (2.0)	DCE	88
2	TASF (2.0)	DCE	26
3	TBAF (2.0)	DCE	<5
4	Py•HF (2.0)	DCE	<5
5	Et_3N•3HF (1.0)	DCE	88
6	Et_3N•3HF (0.5)	DCE	65
7[c]	Et_3N•3HF (1.0)	DCE	<5
8	Et_3N•3HF (1.0)	DCM	46
9	Et_3N•3HF (1.0)	THF	<5
10	Et_3N•3HF (1.0)	PhCl	45
11[d]	Et_3N•3HF (1.0)	DCE	87
12[e]	Et_3N•3HF (1.0)	DCE	94

[a]Reaction conditions: 0.30 mmol diazo ester (**8a**), 0.15 mmol TIPS-EBX (**9a**), copper catalyst (2.0 mol%), **10** (2.5 mol%), solvent (0.05 M). [b]Yield after purification by column chromatography. [c]Et_3N•3HF was added at the start of the sequence. [d]1.2 equiv of diazo ester instead of 2.0 equiv. [e]0.025 M instead of 0.05 M.

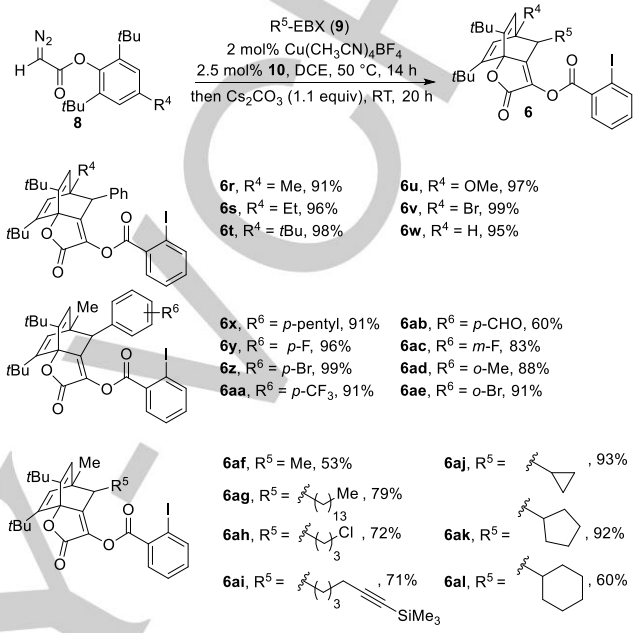
With the optimized conditions in hand, the scope of the reaction was first examined using TIPS-EBX (**9a**) and various diazo esters bearing *tert*-butyl substituents in *ortho* positions of the benzene ring (Scheme 2A). *Para*-substituted products **6a-f** with alkyl, ether, bromine or hydrogen substituents were obtained in 83-96% yield, showing that there was no strong steric or electronic effects at this position.[28] In contrast, the *ortho* substituent size had a strong effect on the reaction outcome. When 2,6-di-*iso*-propyl-phenyl 2-diazoacetate (**8g**) was subjected to the standard reaction conditions, we could not observe the desired product **6g**. Heating to higher temperature led to decomposition. This was due to the presence of the copper catalyst. Removal of the catalyst and heating the reaction at 90 °C, gave the product **6g** in excellent yield. This temperature is significantly lower than reported for similar substrates lacking the oxygen substituent on the allene (140 °C).[14a] Diphenyl- and dimethyl-benzene substituted diazo esters could also be used in the reaction (products **6h** and **6i**).

The formation of the product **6i** is particularly interesting as a similar *o*-dimethylbenzene substituted allene without *α*-oxygen substitution failed to give the corresponding Himbert product even at 140 °C.[14a] Mono-substituted benzene diazo esters also underwent the desired transformation successfully to give products **6j** and **6k** as single diastereoisomers in 91% and 55% yield, respectively.[29] Substitutions at different positions than *ortho* were envisaged: *p*-Substituted and unsubstituted benzene diazo esters gave the corresponding products **6l-n** in moderate to good yield. Dimethyl-substituted benzene diazo esters also gave the desired products **6o** and **6l** in moderate yields. Amide tethered Himbert product **6p** was obtained in 40% yield.



Scheme 2. Scope of diazo esters with TIPS-EBX (**9a**).

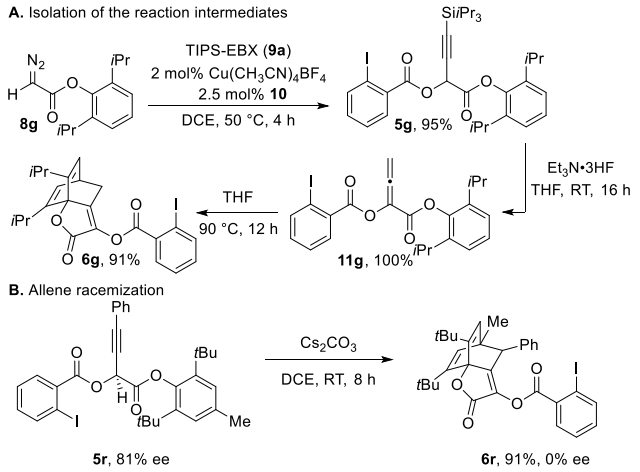
To further increase the molecular complexity of the products, we investigated the reaction of the more reactive *ortho* di-*tert*-butylbenzene substituted diazo esters with functionalized EBX reagents (Scheme 3).[30] Optimization of the reaction conditions showed that it was best to perform the oxyalkynylation at 50 °C and the cycloaddition at room temperature using caesium carbonate as base.[31] The carbonate base is not compatible with the oxyalkynylation and needs to be added afterwards. Under these conditions, the desired product **6q** could be isolated in 91% yield as a single diastereomer using 1.1 equiv of Cs_2CO_3 as a base at room temperature.[32] When the reaction was performed on gram-scale, compound **6r** was obtained in 91% yield. Various benzene diazo esters bearing an alkyl chain, an ether, a halogen or a hydrogen substituent in *para* position gave excellent yields (Scheme 3, products **6s-w**). We then turned our attention to the scope of aryl-EBX reagents using **8a**. The desired products **6x-6ae** bearing alkyl, fluorine, bromine, trifluoromethyl or aldehyde in *para*, *meta* or *ortho* position were obtained in 60-99% yield, demonstrating the tolerance of the reaction towards functional groups and substitution patterns. Next, the scope of alkyl-EBX reagents was examined.[33] Methyl- and long alkyl chain- derived EBX reagents worked well in the reaction, giving products **6af** and **6ag** in 53% and 79% yield, respectively. The reaction was also successful in the case of chlorine and alkynyl group bearing alkyl EBX reagents (products **6ah** and **6ai**). The reaction was not limited to linear alkyl-EBX reagents: Cyclo-propyl, -pentyl, and –hexyl substituted products **6aj-l** were obtained in 60-93% yield. The formation of product **6aj** exclusively indicated that radical intermediates were probably not involved in the reaction.



Scheme 3. Scope of diazo esters with different EBX reagents.

Mechanism Investigations

To confirm our hypothesis for a successive oxyalkynylation/allene formation/ [4+2] cycloaddition sequence, we isolated each intermediate before engaging it in the next step using less reactive alkyne **5g** (Scheme 4A).

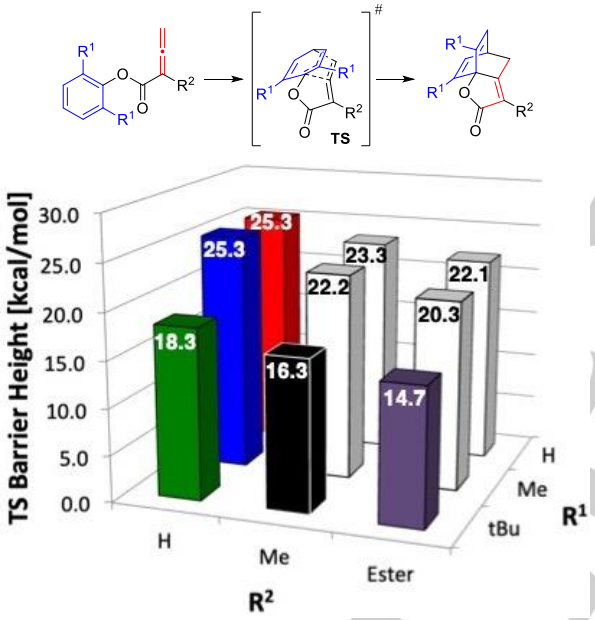


Scheme 4. Control experiments.

In presence of Et_3N•3HF after removal of the copper catalyst, **5g** was cleanly converted to allene **11g**, which was stable at room temperature. Upon heating to 90 °C, [4+2] cycloaddition then occurred in 91% yield. As allene **11g** is non-chiral, no transfer of

chirality is possible when starting from enantioenriched alkynes. However, when using aryl- or alkyl- substituted alkynes, a chiral allene would be formed. We wondered if in this case transfer of chirality would be possible. However, racemic **6r** was isolated starting from enantioenriched alkyne **5r** (Scheme 4B).[34]

Having established that the reaction most probably proceeds via a [4+2] cycloaddition of the allene with the arene ring, we turned to density functional theory computations (at the PBE0-dDsC/TZ2P//M06-2X/def2-SVP level, see SI for full computational details) to better understand the observed amazing reactivity. When comparing the transition state energies of nine different cycloadditions in dependence of the substituents on the benzene ring and allene, computations clearly show the favorable nature that bulky *tert*-butyl groups have on the transition state barrier heights (Scheme 5). The free energies with *tert*-butyl groups (14.7-18.3 kcal/mol) were significantly lower than with methyl (20.3-25.3 kcal/mol) or hydrogen (22.1-25.3 kcal/mol), independently from the substituent on the allene. In addition, the reactivity was further enhanced by the carboxy substituent on the allene, although the effect was weaker. These results are in good accordance with the reaction rates observed experimentally.



Scheme 5. Free energies of transition states in dependence of substituents on benzene and allene. Free energies computed at the PBE0-dDsC/TZ2P//M06-2X/def2-SVP level). Ester = 2-iodobenzoate. Note that column colors correspond to those of the activation strain model computations shown in Figures 1 and 2.

To gain additional insight, we analyzed the energetic profiles of these nine reactions using the activation strain model.[35] Initially, we speculated that the bulky *tert*-butyl groups in R^1 could diminish the planarity of the benzene ring, lowering the distortion energy and making it easier to break aromaticity. However, the calculation results showed that the presence of the bulky substituents in R^1 causes energetically favorable dispersive interactions at longer C-C distances, whereas no major difference in strain energy was observed (Figure 1). This results in an earlier, lower energy transition state for the *tert*-butyl containing variant relative to methyl or hydrogen. Substitution on the allene is characterized by a more complicated picture in which both the unfavorable strain energy and stabilizing interaction energy are influenced by the substituent (Figure 2). Replacing the hydrogen atom with either a methyl or a carboxy group slightly reduces the strain energy. However, this substitution also results in a less favorable interaction energy for the methyl variant while the ester variant provides a more favorable interaction. Overall, this results in the ester having a lower energy transition state barrier relative to either a hydrogen or methyl group.

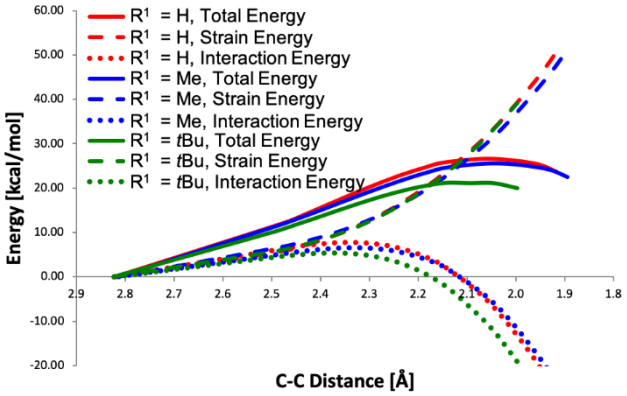


Figure 1. Activation strain model results (computed at the M06-2X/def2-SVP level) in dependence on the R^1 group on the benzene for R^2 = H on the allene. Note that the plots depict electronic energies, as opposed to free energies.

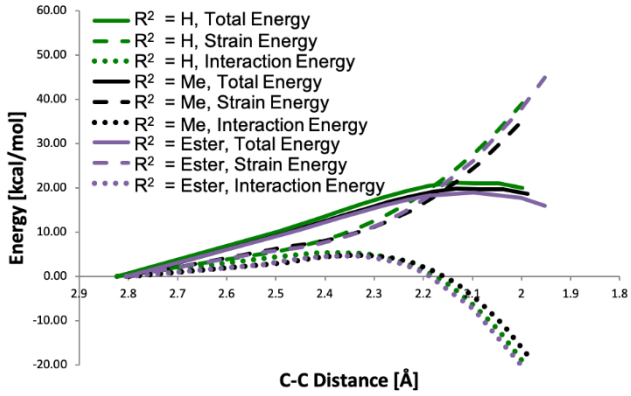
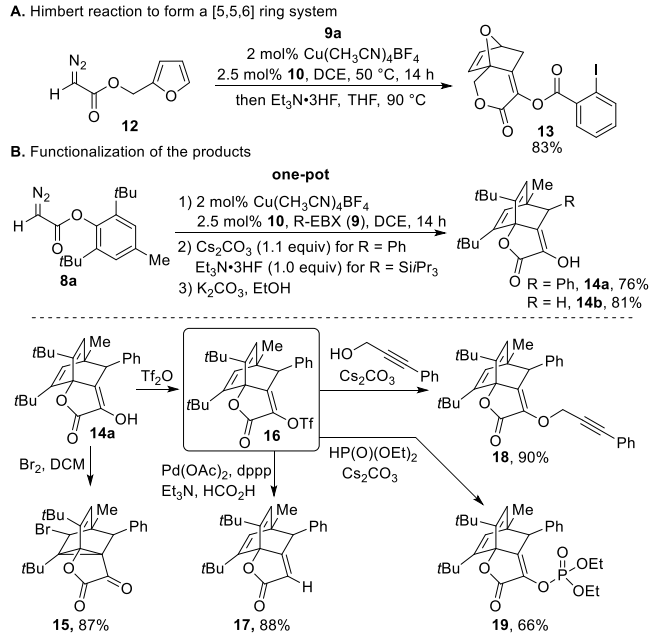


Figure 2. Activation strain model results (computed at the M06-2X/def2-SVP level) in dependence on the R^2 group on the allene for R^1 = *t*Bu on the benzene. Ester = 2-iodobenzoate. Note that the plots depict electronic energies, as opposed to free energies.

Synthetic Applications

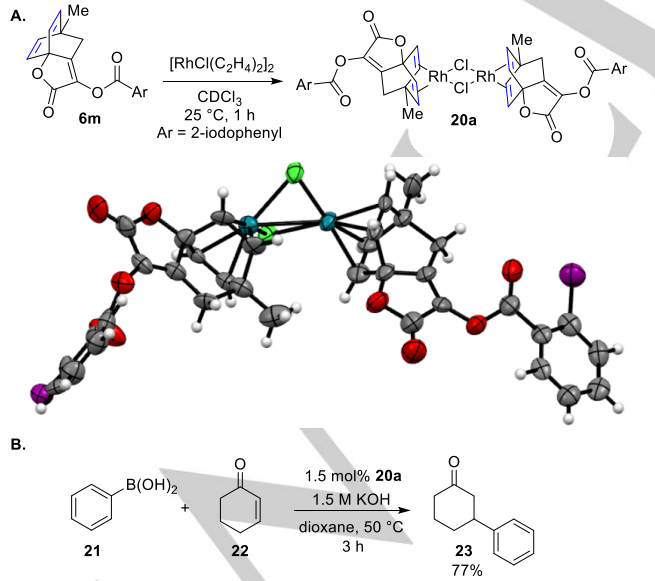
The cycloaddition of allene and benzene rings gave access to [6,6,5] ring systems. It is also important to access other polycyclic systems. In this respect, an interesting preliminary result was obtained with furan-derived diazoester **12**: The oxyalkynylation-Himbert sequence gave a new [5,5,6] ring system **13** in 83% yield (Scheme 6A). Furthermore, the iodobenzoyl ester on the product can be cleaved directly after cycloaddition, giving access to ketoesters **14a** and **14b** (in their enol form) on gram-scale in one-pot (Scheme 6B). Bromination of **14a** yielded highly strained cyclopropane **15** in 86% yield.[36] Alcohol **14a** was quantitatively transformed into the corresponding triflate **16** by reaction with triflic anhydride. Palladium catalyzed reduction of **16** gave

unsaturated ester **17** in 88% yield. Reaction of triflate **16** with 3-phenylprop-2-yn-1-ol or diethyl phosphonate gave access to products **18** and **19** respectively.



Scheme 6. [4+2] Cycloaddition with furan and product derivatization.

When considering that bicyclo[2.2.2]octadienes are an important class of ligands for late transition metals,[10] we then attempted the formation of a rhodium complex. The complexation was not successful when using *tert*-butyl substituted dienes, probably due to excessive steric hindrance. In contrast, dimer **20a** was cleanly formed, by just mixing diene **6m** with $[RhCl(C_2H_4)_2]_2$ in chloroform (Scheme 7A). X-ray quality crystals of **20a** could be obtained, allowing us to confirm its structure.[37]

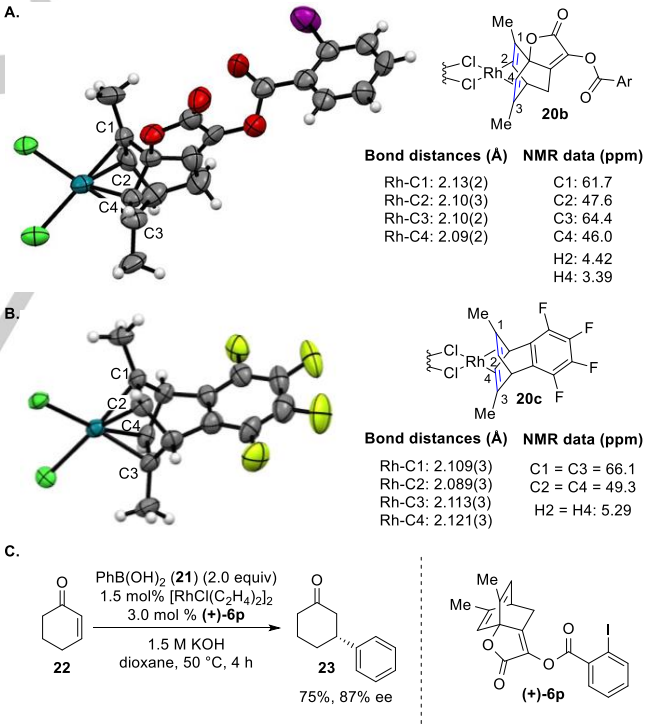


Scheme 7. A. Synthesis and X-ray structure of Rhodium complex **20a**. **B.** Conjugate addition of phenylboronic acid (**21**) on cyclohexenone (**22**) with **20a** as catalyst.

Complex **20a** was a good catalyst for the conjugate addition of phenyl boronic acid (**21**) to cyclohexenone (**22**) under standard conditions (Scheme 7B).[10d]

Next, we envisioned an enantioselective transformation. We decided to take advantage of the pseudo-C2 symmetry of compound **6p**, making it similar to the successful Hayashi-type ligand **4**. Enantiopure (+)-**6p** was isolated by preparative chiral HPLC. We were able to obtain a X-ray crystal structure of the corresponding dimeric complex **20b** (Scheme 8A)[38] and we could compare it with the diene complex **20c** reported by Hayashi and co-workers (Scheme 8B).[39] The immediate coordination sphere around the rhodium was not distorted by the lower symmetry of ligand **20b**: all bonds between the metal and the olefins were of same length, and within error margin also identical to those in complex **20c**.[40] In contrast, the ^{13}C and even more the ^{1}H NMR signals on the olefins were clearly separated for complex **20b**, indicating that this ligand will induce a non-symmetrical electronic environment. From this point of view, it is clearly different from the classical Hayashi dienes.

As a proof of concept for its use in asymmetric catalysis, we then used (+)-**6p** as chiral ligand for the rhodium-catalyzed conjugate addition of phenyl boronic acid (**21**) to cyclohexenone (**22**) under standard reported conditions (Scheme 8C).[10d] The resulting β-functionalized ketone **23** was obtained in 75% yield with 87% *ee*. This is promising when considering that the methyl substituent is smaller than the phenyl or benzyl groups used in previous works[10d] and no attempt was made to optimize the reaction conditions.



Scheme 8. A. X-ray structure of Rhodium complex **20b** with bond lengths and ^{1}H and ^{13}C NMR data. **B.** X-ray structure of Hayashi's Rhodium complex **20c** with bond lengths and ^{1}H and ^{13}C NMR data. **C.** Enantioselective conjugate addition with ligand **(+)-6p**. For simplification, only half of the dimeric complexes **20b** and **20c** is shown.

Conclusion

In summary, we have developed a highly efficient strategy for the rapid assembly of bicyclo[2.2.2]octadienes starting from simple diazo esters and EBX reagents via a one-pot sequential oxyalkynylation/[4+2] cycloaddition reaction proceeding between

25 and 90 °C. The reaction tolerated a broad range of functional groups on both diazo esters and EBX-reagents. Isolation of the reaction intermediates support a cycloaddition of an *in situ* formed allene with the arene ring. The exceptionally low activation energy for the cycloaddition could be rationalized by counter-intuitive favourable dispersive interactions in the transition state, combined with a weaker effect of the carboxy substituent. The obtained products were transformed into useful building blocks and preliminary results indicated that other polycyclic ring systems could also be accessed using this strategy. Importantly, this methodology allows straightforward access to versatile diene ligands for rhodium catalysis with easy variation of the substituents. Pseudo C2-symmetric ligand **6p** could be used in the enantioselective addition of phenyl boronic acid (**21**) to cyclohexenone (**22**) with 87% enantioselectivity. Our future work will focus on catalysis of the cycloaddition step with the goal of developing an enantioselective reaction for a more straightforward access to enantioenriched chiral ligands, and further study the reactivity of this new type of easily accessible "push-pull" allenes.

Acknowledgements

We thank the European Research Council (ERC; Starting Grant iTools4MC, number 334840) the Swiss National Science Foundation (Grant No. 200020_182798) and the EPFL for financial support. MDW acknowledges Prof. C. Corminboeuf for financial support and the Laboratory for Computational Molecular Design for providing computational resources.

Keywords: [4+2] cycloaddition • alkynes • diene ligands • hypervalent iodine reagents • diazo compounds

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[27] There are no reports of carboxy-substituted allene esters and only rare reports of alkoxy substituted allene esters: a) M. J. Sleeman, G. V. Meehan, *Tetrahedron Lett.* **1989**, *30*, 3345; b) Y. Nagao, K. Kim, S. Sano, H. Kakegawa, W. S. Lee, H. Shimizu, M. Shiro, N. Katunuma, *Tetrahedron Lett.* **1996**, *37*, 861. Simple alkoxy-substituted allenes have been more often used: c) R. Zimmer, H.-U. Reissig, *Angew. Chem., Int. Ed.* **1988**, *27*, 1518; d) V. M. Schmiedel, H. U. Reissig, *Curr. Org. Chem.* **2019**, *23*, 2976.

[28] The structure of **6r** was confirmed by X-ray analysis (available at the Cambridge Crystallographic Centre, CCDC number 1848760).

[29] The structure of the diastereoisomers was assigned in analogy to the work in ref 20 and 22.

[30] In the case of less reactive substituted alkynes, the presence of the *tert*-butyl groups was necessary for the success of the cycloaddition.

[31] See Supporting Information for details on the optimization of the reaction conditions.

[32] The structure of **6r** was confirmed by X-ray analysis (available at the Cambridge Crystallographic Centre, CCDC number 1848773).

[33] The reaction with alkyl-EBXs required 50 °C to form allenes, which undergo spontaneous cyclization to give the corresponding Himbert products.

[34] Enantionenriched **5r** was obtained following our previously published methodology, ref. 25b.

[35] F. M. Bickelhaupt, K. N. Houk, *Angew. Chem., Int. Ed.* **2017,** *56*, 10070. And references cited therein.

[36] The structure of **15** was confirmed by X-ray analysis (available at the Cambridge Crystallographic Centre, CCDC number 1850113).
[37] Available at the Cambridge Crystallographic Centre, CCDC number 1945514.
[38] The X-ray structure of **20b** is available at the Cambridge Crystallographic Centre, CCDC number 2027174 See Supporting Information for details.
[39] T. Nishimura, Y. Ichikawa, T. Hayashi, N. Onishi, M. Shiotsuki, T. Masuda, *Organometallics* **2009**, *28*, 4890.
[40] See Figure S1 in Supporting Information for an overlay of the structures of **20b** and **20c**.

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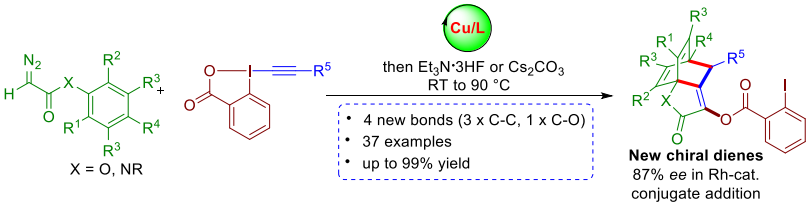
Entry for the Table of Contents



Breaking aromaticity: A highly efficient strategy for the rapid assembly of bicyclooctadienes starting from simple diazo esters and EBX reagents via a one-pot sequential oxyalkynylation/ [4+2] allene-arene cycloaddition reaction at low temperature (23-90 °C) is reported. The obtained products are good chiral ligands for rhodium-catalyzed conjugate addition.

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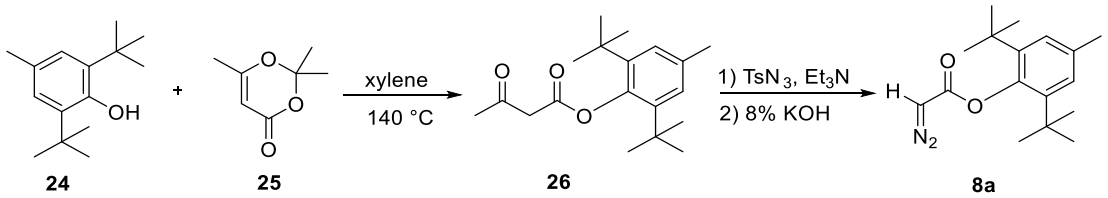
1. General methods

All reactions were carried out in oven dried glassware under an atmosphere of nitrogen, unless stated otherwise. For quantitative flash chromatography, technical grade solvents were used. For flash chromatography for analysis, HPLC grade solvents from Sigma-Aldrich were used. THF, Et_2O, CH_3CN, toluene, hexane and CH_2Cl_2 were dried by passage over activated alumina under nitrogen atmosphere (H_2O content < 10 ppm, *Karl-Fischer* titration). The solvents were degassed by Freeze-Pump-Thaw method when mentioned. All chemicals were purchased from Acros, Aldrich, Fluka, VWR, Aplichem or Merck and used as such unless stated otherwise. Chromatographic purification was performed as flash chromatography using Macherey-Nagel silica 40-63, 60 Å, using the solvents indicated as eluent with 0.1-0.5 bar pressure. TLC was performed on Merck silica gel 60 F_{254} TLC glass plates and visualized with UV light, permanganate stain, CAN stain or Anisaldehyde stain. Melting points were measured on a Büchi B-540 melting point apparatus using open glass capillaries, the data is uncorrected. ^{1}H-NMR spectra were recorded on a Brucker DPX-400 400 MHz spectrometer in chloroform-d, DMSO-d_6 or methanol-d_4, all signals are reported in ppm with the internal chloroform signal at 7.26 ppm, the internal DMSO signal at 2.50 ppm or the internal methanol signal at 3.30 ppm as standard. The data is being reported as (s = singlet, d = doublet, t = triplet, q = quadruplet, qi = quintet, m = multiplet or unresolved, brs = broad signal, app = apparent, coupling constant(s) in Hz, integration, interpretation).^{13}C-NMR spectra were recorded with ^{1}H-decoupling on a Brucker DPX-400 100 MHz spectrometer in chloroform-d, DMSO-d_6 or methanol-d_4, all signals are reported in ppm with the internal chloroform signal at 77.0 ppm, the internal DMSO signal at 39.5 ppm or the internal methanol signal at 49.0 ppm as standard. Infrared spectra were recorded on a JASCO FT-IR B4100 spectrophotometer with an ATR PRO410-S and a ZnSe prisma and are reported as cm^{-1} (w = weak, m = medium, s = strong, br = broad). High resolution mass spectrometric measurements were performed by the mass spectrometry service of ISIC at the EPFL on a MICROMASS (ESI) Q-TOF Ultima API (Waters) or (APPI) LTQ Orbitrap ELITE ETD (Thermo Fisher). The raw data obtained from the Q-TOF Waters instrument does not take into account the mass of the electron for the ion, the obtained raw data has been therefore corrected by removing the mass of the electron (5 mDa). HPLC measurements were done on a Agilent 1260 Infinity autosampler using a CHIRALPAK IA, IB, IC or ID column from DAICEL Chemical.

2. Preparation of diazo compounds

2,6-Di-*tert*-butyl-4-methylphenyl 2-diazoacetate (8a)



24 **25** **26** **8a**

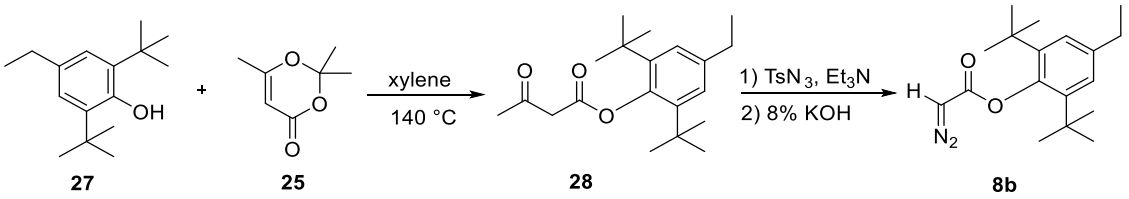
Following a slightly modified procedure,[1] a mixture of 2,6-di-*tert*-butyl-4-methylphenol (**24**) (5.91 g, 25.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (4.43 g, 30.0 mmol, 1.20 equiv), and xylene (5 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-methylphenyl 3-oxobutanoate (**26)** as a white solid (6.40 g, 21.0 mmol, 84%). Mp: 97–100 °C; TLC (EtOAc:pentane, 1:50 v/v): R_f = 0.34, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.16 (s, 0.55H, O*H* of enol form), 7.13 (s, 2H, Ar*H* of enol and keto form), 5.39 – 5.24 (m, 0.55H, vinyl *H* of enol form), 3.73 (s, 0.9H, CH_3COCH_2 of keto form), 2.40 (s, 1.35H, CH_3COCH_2 of keto form), 2.33 (s, 3H, $ArCH_3$ of enol and keto form), 2.07 (s, 1.65H, CH_3 of enol form), 1.33 (s, 8.1H, *t*Bu of keto form), 1.32 (s, 9.9H, *t*Bu of enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.4, 173.3, 144.9, 142.2, 134.6, 126.9, 90.4, 35.2, 31.4, 21.5, 21.5; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 200.2, 167.7, 145.3, 141.8, 135.0, 127.2, 50.7, 35.2, 31.4, 30.8, 21.5; IR ν 2964 (m), 2919 (m), 2880 (w), 2110 (w), 1757 (m), 1726 (m), 1633 (s), 1408 (m), 1369 (m), 1318 (m), 1219 (s), 1199 (s), 1143 (s), 1113 (m), 1030 (w), 978 (w), 924 (w); HRMS (ESI) calcd. for $C_{19}H_{28}NaO_3^+$ $[M+Na]^+$ 327.1931; found 327.1933.

Following a slightly modified procedure,[1] to a solution of 2,6-di-*tert*-butyl-4-methylphenyl 3-oxobutanoate (**26**) (1.52 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 X 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a)** as a yellow solid (1.20 g, 4.16 mmol, 83%). TLC (Et_2O:pentane, 1:30 v/v): R_f = 0.36, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.12 (s, 2H, Ar*H*), 5.00 (s,

[1] D. P. Hari, J. Waser, *J. Am. Chem. Soc.* **2017**, *139*, 8420.

1H, C*H*N_2), 2.32 (s, 3H, ArC*H*$_3$), 1.36 (s, 18H, 2 X *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 145.1, 142.4, 134.8, 127.0, 47.3, 35.3, 31.5, 21.5. The ^{1}H NMR data corresponded to the reported values.[2]

2,6-Di-*tert*-butyl-4-ethylphenyl 2-diazoacetate (8b)



27 **25** **28** **8b**

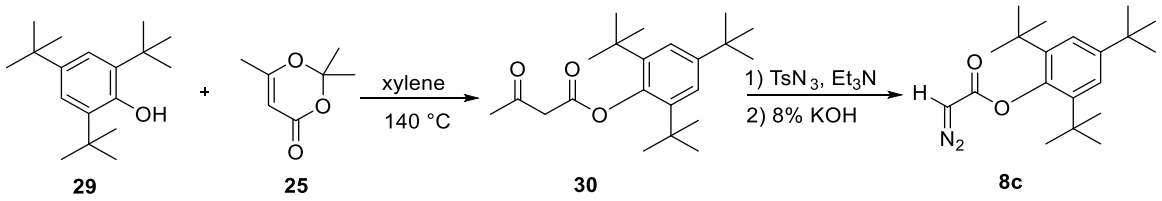
Following a slightly modified procedure,[1] a mixture of 2,6-di-*tert*-butyl-4-ethylphenol (**27**) (2.34 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-ethylphenyl 3-oxobutanoate (**28)** as a white solid (2.75 g, 8.64 mmol, 86%). Mp: 84.5–86.6 °C; TLC (EtOAc:pentane, 1:50 v/v): R_f = 0.34, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.15 (s, 0.54H, O*H* of enol form), 7.15 (s, 2H, Ar*H* of enol and keto form), 5.33 – 5.32 (m, 0.54H, vinyl *H* of enol form), 3.73 (s, 0.9H, CH_3COCH_2 of keto form), 2.66 – 2.60 (m, 2H, $ArCH_2CH_3$ of enol and keto form), 2.40 (s, 1.3H, CH_3COCH_2 of keto form), 2.07 (s, 1.7H, CH_3 of enol form), 1.34 (s, 8.3H, *t*Bu of keto form), 1.33 (s, 9.7H, *t*Bu of enol form), 1.27 – 1.23 (m, 3H, $ArCH_2CH_3$ of enol and keto form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.4, 173.3, 145.1, 142.2, 140.7, 125.7, 90.5, 35.3, 31.4, 28.8, 21.5, 15.4; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 200.1, 167.7, 145.4, 141.8, 141.1, 125.9, 50.7, 35.3, 31.5, 30.8, 28.8, 15.4; IR ν 3000 (w), 2965 (m), 2875 (w), 1758 (w), 1724 (w), 1668 (m), 1633 (m), 1425 (m), 1403 (m), 1366 (w), 1318 (w), 1266 (w), 1230 (s), 1227 (s), 1206 (s), 1187 (s), 1146 (s), 982 (w), 933 (w); HRMS (ESI) calcd. for $C_{20}H_{30}NaO_3^+$ $[M+Na]^+$ 341.2087; found 341.2087.

Following a slightly modified procedure,[1] to a solution of 2,6-di-*tert*-butyl-4-ethylphenyl 3-oxobutanoate (**28**) (1.59 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture was stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 X 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:35 Et_2O:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-ethylphenyl 2-diazoacetate (**8b)** as a yellow solid (1.10 g, 3.64 mmol, 73%). Mp: 126.5–128.0 °C; TLC (Et_2O:pentane, 1:35 v/v): R_f = 0.35, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.15 (s, 2H,

[2] M. P. Doyle, V. Bagheri, T. J. Wandless, N. K. Ham, D. A. Brinker, C. T. Eagle, K. L. Loh, *J. Am. Chem. Soc.* **1990**, *112*, 1906.

Ar*H*), 5.01 (s, 1H, C*H*N_2), 2.63 (q, *J* = 7.6 Hz, 2H, C$H_2$$CH_3$), 1.37 (s, 18H, 2 x *t*Bu), 1.26 (t, *J* = 7.6 Hz, 3H, CH_2CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.8, 145.3, 142.4, 140.8, 125.8, 47.4, 35.4, 31.5, 28.8, 15.4; IR ν 3105 (m), 2964 (m), 2872 (w), 2475 (w), 2114 (s), 1718 (s), 1697 (s), 1597 (w), 1426 (m), 1364 (m), 1332 (s), 1263 (w), 1224 (m), 1191 (m), 1181 (s), 1108 (s), 928 (m); HRMS (ESI) calcd. for $C_{18}H_{26}N_2NaO_2^+$ $[M+Na]^+$ 325.1886; found 325.1887.

2,4,6-Tri-*tert*-butylphenyl 2-diazoacetate (8c)



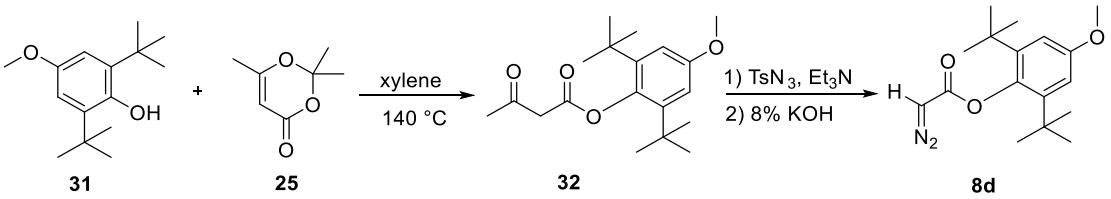
29 **25** **30** **8c**

Following a slightly modified procedure,[1] a mixture of 2,4,6-tri-*tert*-butylphenol (**29**) (2.62 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 2,4,6-tri-*tert*-butylphenyl 3-oxobutanoate (**30)** as a white solid (2.65 g, 7.65 mmol, 76%). Mp: 88.9–89.6 °C; TLC (EtOAc:pentane, 1:50 v/v): R_f = 0.4, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.14 (s, 0.54H, O*H* of enol form), 7.35 – 7.32 (m, 2H, Ar*H* of enol and keto form), 5.33 (s, 0.54H, vinyl *H* of enol form), 3.73 (s, 0.92H, CH_3COCH_2 of keto form), 2.40 (s, 1.4H, CH_3 of keto form), 2.07 (s, 1.6H, CH_3 of enol form), 1.37 – 1.28 (m, 27H, 3 x *t*Bu of keto and enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.4, 173.2, 147.2, 144.7, 141.4, 123.3, 90.5, 35.6, 34.8, 31.6, 31.5, 21.5; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 200.2, 167.7, 147.6, 145.1, 141.1, 123.5, 50.8, 35.5, 31.5, 30.7; IR ν 3001 (w), 2963 (s), 2912 (w), 2869 (w), 2113 (w), 1761 (m), 1725 (m), 1668 (m), 1633 (m), 1479 (w), 1431 (m), 1405 (m), 1365 (m), 1226 (s), 1210 (s), 1136 (m), 1108 (s), 978 (w); HRMS (ESI) calcd. for $C_{22}H_{34}NaO_3^+$ $[M+Na]^+$ 369.2400; found 369.2407. Two carbons of keto form were not resolved at 100 MHz.

Following a slightly modified procedure,[1] to a solution of 2,4,6-tri-*tert*-butylphenyl 3-oxobutanoate (**30**) (1.52 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture was stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford 2,4,6-tri-*tert*-butylphenyl 2-diazoacetate (**8c)** as a yellow solid (1.40 g, 4.24 mmol, 85%). Mp: 130.5–131.5 °C; TLC (Et_2O:pentane, 1:40 v/v): R_f = 0.4, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33 (s, 2H,

Ar*H*), 5.01 (brs, 1H, C*H*N_2), 1.38 (s, 18H, 2 x *t*Bu), 1.32 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 147.3, 145.0, 141.7, 123.4, 47.4, 35.6, 34.8, 31.6, 31.5; IR ν 3101 (w), 2962 (m), 2910 (m), 2872 (w), 2252 (w), 2113 (s), 1702 (s), 1596 (w), 1478 (w), 1432 (w), 1365 (s), 1338 (m), 1278 (w), 1192 (s), 1161 (s), 1135 (s), 1107 (s), 975 (w); HRMS (ESI) calcd. for $C_{20}H_{30}N_2NaO_2^+$ $[M+Na]^+$ 353.2199; found 353.2198.

2,6-Di-*tert*-butyl-4-methoxyphenyl 2-diazoacetate (8d)



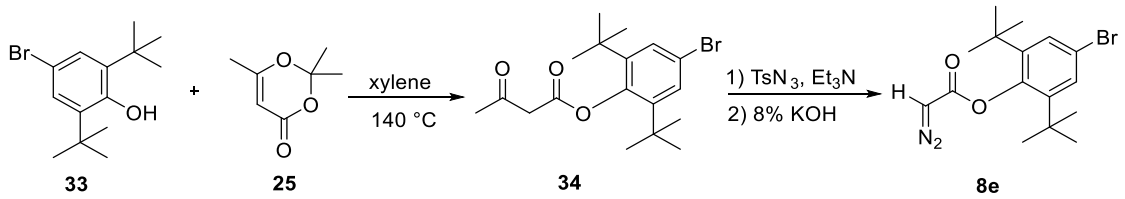
31 **25** **32** **8d**

Following a slightly modified procedure,[1] a mixture of 2,6-di-*tert*-butyl-4-methoxyphenol (**31**) (5.91 g, 25.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (4.43 g, 30.0 mmol, 1.20 equiv), and xylene (5 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:30 EtOAc:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-methoxyphenyl 3-oxobutanoate (**32)** as a white solid (6.64 g, 20.0 mmol, 80%). Mp: 67.0–70.5 °C; TLC (EtOAc:pentane, 1:15 v/v): R_f = 0.46, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.15 (s, 0.55H, O*H* of enol form), 6.87 (s, 2H, Ar*H* of enol and keto form), 5.32 (s, 0.55H, vinyl *H* of enol form), 3.80 (s, 3H, ArOC*H*$_3$ of enol and keto form), 3.73 (s, 0.9H, CH_3COCH_2 of keto form), 2.40 (s, 1.35H, C*H*$_3$COCH_2 of keto form), 2.07 (s, 1.65H, C*H*$_3$ of enol form), 1.33 (s, 8.1H, *t*Bu of keto form), 1.32 (s, 9.9H, *t*Bu of enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.4, 173.5, 156.2, 143.6, 140.7, 111.5, 90.4, 55.2, 35.6, 31.2, 21.5; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 200.1, 167.9, 156.5, 143.3, 141.1, 111.7, 55.2, 50.6, 35.5, 31.3, 30.8; IR ν 2966 (s), 2913 (s), 2118 (w), 1758 (m), 1724 (m), 1634 (s), 1596 (m), 1408 (s), 1310 (m), 1223 (s), 1181 (s), 1143 (s), 1064 (s), 979 (w), 922 (w), 861 (w); HRMS (ESI) calcd. for $C_{19}H_{28}NaO_4^+$ $[M+Na]^+$ 343.1880; found 343.1884.

Following a slightly modified procedure,[1] to a solution of 2,6-di-*tert*-butyl-4-methoxyphenyl 3-oxobutanoate (**32**) (1.6 g, 5.0 mmol, 1.0 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:20 EtOAc:pentane as mobile phase to afford 2,6-di-*tert*-butyl-4-methoxyphenyl 2-diazoacetate (**8d)** as a yellow solid (600 mg, 1.97 mmol, 40%). Mp (Dec.): 125.3–130.0 °C; TLC (EtOAc:pentane, 1:15 v/v): R_f = 0.31, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.86 (s, 2H, Ar*H*), 5.01 (s, 1H, C*H*N_2), 3.80 (s, 3H, ArOC*H*$_3$), 1.36 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz,

$CDCl_3$): δ 166.8, 156.4, 143.9, 141.0, 111.6, 55.2, 47.4, 35.6, 31.4; IR ν 3105 (w), 2961 (m), 2114 (s), 1712 (s), 1593 (m), 1427 (w), 1365 (s), 1180 (s), 1149 (s), 1103 (w), 1064 (m), 919 (w), 862 (w); HRMS (ESI) calcd. for $C_{17}H_{24}N_2NaO_3^+$ $[M+Na]^+$ 327.1679; found 327.1679.

4-Bromo-2,6-di-*tert*-butylphenyl 2-diazoacetate (8e)

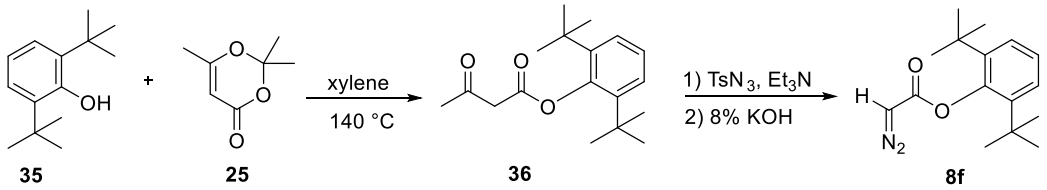


Following a slightly modified procedure,[1] a mixture of 4-bromo-2,6-di-*tert*-butylphenol (**33**) (2.85 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 4-bromo-2,6-di-tert-butylphenyl 3-oxobutanoate (**34)** as a pale yellow solid (3.00 g, 8.12 mmol, 81%). Mp: 86.3–91.6 °C; TLC (EtOAc:pentane, 1:40 v/v): R_f = 0.4, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 11.98 (s, 0.8H, O*H* of enol form), 7.44 – 7.41 (m, 2H, Ar*H* of enol and keto form), 5.32 (s, 0.8H, vinyl *H* of enol form), 3.73 (s, 0.4H, CH_3COCH_2 of keto form), 2.39 (s, 0.6H, CH_3COCH_2 of keto form), 2.08 (s, 2.4H, CH_3 of enol form), 1.32 (s, 3.6H, *t*Bu of keto form), 1.31 (s, 14.4H, *t*Bu of enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form; δ 178.0, 172.7, 146.5, 145.1, 129.3, 119.5, 90.2, 35.7, 31.2, 21.6; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 199.6, 167.2, 146.8, 144.7, 129.6, 119.9, 50.5, 35.6, 31.3, 30.8; IR ν 3001 (w), 2965 (m), 2875 (w), 1762 (w), 1725 (w), 1672 (m), 1629 (m), 1565 (w), 1480 (w), 1407 (m), 1367 (m), 1313 (w), 1261 (m), 1218 (s), 1187 (s), 1148 (s), 1110 (s), 1026 (w), 976 (w), 933 (w); HRMS (ESI) calcd. for $C_{18}H_{25}BrNaO_3^+$ $[M+Na]^+$ 391.0879; found 391.0884.

Following a slightly modified procedure,[1] to a solution of 4-bromo-2,6-di-*tert*-butylphenyl 3-oxobutanoate (**34**) (1.85 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture was stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford 4-bromo-2,6-di-*tert*-butylphenyl 2-diazoacetate (**8e)** as a yellow solid (0.85 g, 2.4 mmol, 48%). Mp: 152.5–154.2 °C; TLC (Et_2O:pentane, 1:30 v/v): R_f = 0.36, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42 (s, 2H, Ar*H*), 5.03 (brs, 1H, C*H*N_2), 1.35 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.6, 146.7, 145.3, 129.4, 119.7, 47.5, 35.7, 31.3; IR ν 3119 (m), 2999 (w), 2967 (m), 2875 (w), 2479 (w), 2291

(w), 2121 (s), 1723 (s), 1700 (s), 1563 (m), 1366 (m), 1338 (s), 1261 (m), 1218 (m), 1184 (s), 1110 (s), 1031 (w), 920 (m); HRMS (ESI) calcd. for $C_{16}H_{22}BrN_2O_2^+$ $[M+H]^+$ 353.0859; found 353.0860.

2,6-Di-*tert*-butylphenyl 2-diazoacetate (8f)



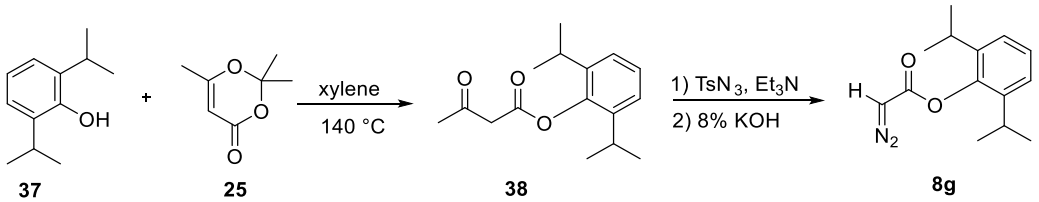
35 25 36 8f

Following a slightly modified procedure,[1] a mixture of 2,6-di-*tert*-butylphenol (**35**) (2.06 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 2,6-di-*tert*-butylphenyl 3-oxobutanoate (**36**) as a pale yellow solid (2.40 g, 8.26 mmol, 83%). Mp: 61.4–62.0 °C; TLC (EtOAc:pentane, 1:50 v/v): R_f = 0.3, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.11 (s, 0.95H, O*H* of enol form), 7.33 (d, *J* = 7.9 Hz, 2H, Ar*H* of enol and keto form), 7.15 (dd, *J* = 8.3, 7.5 Hz, 1H, Ar*H* of enol and keto form), 5.34 (d, *J* = 0.8 Hz, 0.95H, vinyl *H* of enol form), 3.73 (s, 0.1H, CH_3COCH_2 of keto form), 2.40 (s, 0.15H, CH_3 of keto form), 2.08 (s, 2.85H, CH_3 of enol form), 1.35 (s, 0.9H, *t*Bu of keto form), 1.34 (s, 17.1H, *t*Bu of enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.5, 173.1, 147.3, 142.7, 126.2, 125.7, 90.4, 35.4, 31.4, 21.53; IR ν 3079 (w), 2962 (w), 2871 (w), 1758 (w), 1724 (w), 1630 (m), 1481 (w), 1403 (m), 1364 (m), 1317 (m), 1270 (m), 1221 (s), 1183 (s), 1147 (s), 1110 (s), 1024 (w), 977 (m), 933 (m); HRMS (ESI) calcd. for $C_{18}H_{26}NaO_3^+$ $[M+Na]^+$ 313.1774; found 313.1776. Keto form carbons were not resolved at 100 MHz.

Following a slightly modified procedure,[1] to a solution of 2,6-di-*tert*-butylphenyl 3-oxobutanoate (**36**) (1.45 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture was stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford 2,6-di-*tert*-butylphenyl 2-diazoacetate (**8f)** as a yellow solid (0.96 g, 3.5 mmol, 70%). Mp: 88.6–90.7 °C; TLC (Et_2O:pentane, 1:30 v/v): R_f = 0.32, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33 (d, *J* = 7.9 Hz, 2H, Ar*H*), 7.15 (dd, *J* = 8.3, 7.5 Hz, 1H, Ar*H*), 5.02 (brs, 1H, C*H*N_2), 1.38 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 147.5, 143.0, 126.3, 125.8, 47.5, 35.4, 31.5; IR ν 3108 (w), 3002 (w), 2962 (w), 2915 (w), 2873 (w), 2111 (s), 1714 (s), 1579 (w), 1483 (w), 1417 (w), 1369 (s), 1358 (s), 1338 (m), 1272 (w),

1224 (m), 1185 (s), 1152 (s), 1112 (s); HRMS (ESI) calcd. for $C_{16}H_{22}N_2NaO_2^+$ [M+Na]$^+$ 297.1573; found 297.1578.

2,6-Di*iso*propylphenyl 2-diazoacetate (8g)



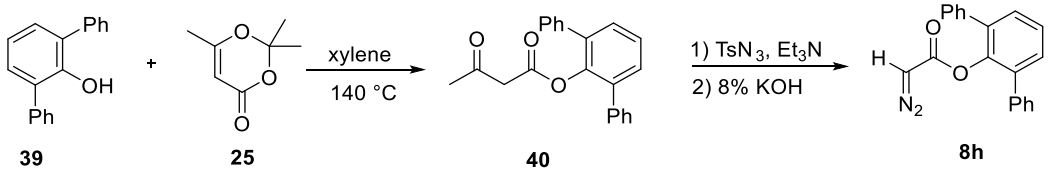
37 25 38 8g

Following a slightly modified procedure,[1] a mixture of 2,6-di*iso*propylphenol (**37**) (4.46 g, 25.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (4.43 g, 30.0 mmol, 1.20 equiv), and xylene (5 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:50 EtOAc:pentane as mobile phase to afford 2,6-di*iso*propylphenyl 3-oxobutanoate (**38)** as a colorless thick oil (5.00 g, 19.1 mmol, 76%). TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.35, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.08 (s, 0.22H, O*H* of enol form), 7.31 – 7.24 (m, 1H, Ar*H* of enol and keto form), 7.24 – 7.18 (m, 2H, Ar*H* of enol and keto form), 5.38 (s, 0.2H, vinyl *H* of enol form), 3.81 (s, 1.56H, CH_3COCH_2 of keto form), 3.03 (m, 2H, 2 x C*H*$(CH_3)_2$ of enol and keto form), 2.41 (s, 2.32H, CH_3COCH_2 of keto form), 2.08 (s, 0.6H, CH_3 of enol form), 1.28 – 1.21 (m, 12H, 2 x CH(CH_3)$_2$); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.7, 171.5, 144.5, 140.5, 126.5, 123.9, 88.7, 23.7, 22.7, 21.4; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 199.9, 165.7, 145.1, 140.2, 126.8, 124.0, 49.6, 30.4, 27.4, 27.3; IR ν 2966 (m), 2876 (w), 1760 (m), 1723 (m), 1634 (w), 1447 (m), 1410 (w), 1360 (m), 1315 (m), 1222 (s), 1140 (s), 1102 (m), 1053 (w), 976 (w); HRMS (ESI) calcd. for $C_{16}H_{22}NaO_3^+$ [M+Na]$^+$ 285.1461; found 285.1467.

Following a slightly modified procedure,[1] to a solution of 2,6-di*iso*propylphenyl 3-oxobutanoate (**38**) (1.31 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford 2,6-di*iso*propylphenyl 2-diazoacetate (**8g)** as a yellow thick oil (620 mg, 2.52 mmol, 50%). TLC (Et_2O:pentane, 1:30 v/v): R_f = 0.36, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32 – 7.25 (m, 1H, Ar*H*), 7.23 – 7.20 (m, 2H, Ar*H*), 5.09 (br s, 1H, C*H*N_2), 3.05 (sept, *J* = 6.9 Hz, 2H, 2 x C*H*$(CH_3)_2$), 1.27 (d, *J* = 6.9 Hz, 12H, 2 x CH(CH_3)$_2$); ^{13}C NMR (100

MHz, $CDCl_3$): δ 165.6, 145.1, 140.8, 126.7, 123.9, 46.3, 27.5, 23.4. The characterization data slightly differ from the reported values.[3]

[1,1':3',1''-Terphenyl]-2'-yl 2-diazoacetate (8h)



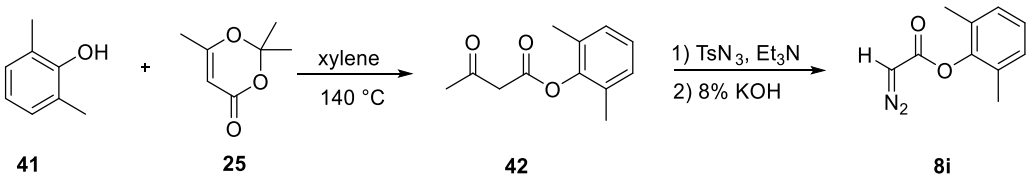
Following a slightly modified procedure,[1] a mixture of [1,1':3',1''-terphenyl]-2'-ol (**39**) (2.46 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:10 EtOAc:pentane as mobile phase to afford [1,1':3',1''-terphenyl]-2'-yl 3-oxobutanoate (**40)** as a white solid (2.91 g, 8.81 mmol, 88%). Mp: 80.2–81.3 °C; TLC (EtOAc:pentane, 1:10 v/v): R_f = 0.38, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 11.47 (s, 0.08H, O*H* of enol form), 7.51 – 7.31 (m, 13H, Ar*H* of enol and keto form), 4.89 (s, 0.08H, vinyl *H* of enol form), 3.12 (s, 1.8H, CH_3COCH_2 of keto form), 1.83 (s, 0.25H, CH_3 of enol form), 1.69 (s, 2.75H, CH_3 of keto form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 176.9, 170.5, 144.4, 137.7, 136.0, 128.9, 128.2, 127.4, 126.5, 88.9, 21.2; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 199.3, 165.1, 144.7, 137.5, 135.8, 130.1, 129.0, 128.4, 127.7, 126.8, 49.6, 29.0; IR ν 3058 (w), 3032 (w), 1957 (w), 1888 (w), 1760 (s), 1721 (s), 1632 (w), 1601 (w), 1500 (w), 1463 (m), 1422 (m), 1361 (m), 1319 (m), 1223 (m), 1175 (s), 1128 (s), 1077 (w), 1022 (w), 975 (w), 921 (m); HRMS (ESI) calcd. for $C_{22}H_{18}NaO_3^+$ $[M+Na]^+$ 353.1148; found 353.1149. One carbon of enol form was not resolved at 100 MHz.

Following a slightly modified procedure,[1] to a solution of [1,1':3',1''-terphenyl]-2'-yl 3-oxobutanoate (**40**) (1.65 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:10 Et_2O:pentane as mobile phase to afford [1,1':3',1''-terphenyl]-2'-yl 2-diazoacetate (**8h**) as a yellow solid (0.71 g, 2.3 mmol, 45%). Mp: 130.3–135.6 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.22, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 – 7.32 (m, 13H, Ar*H*), 4.54 (s, 1H, C*H*N_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.3, 144.6, 137.7, 136.2, 130.1, 129.0, 128.3, 127.5, 126.6,

[3] D. A. Nicewicz, J. S. Johnson, *J. Am. Chem. Soc.* **2005**, *127*, 6170.

46.4; IR ν 3115 (w), 3059 (w), 3032 (w), 2253 (w), 2115 (s), 1707 (s), 1599 (w), 1500 (w), 1462 (w), 1421 (w), 1367 (s), 1341 (m), 1229 (m), 1181 (s), 1143 (s), 1077 (w), 973 (w), 913 (m); HRMS (ESI) calcd. for $C_{20}H_{14}N_2NaO_2^+$ $[M+Na]^+$ 337.0947; found 337.0947.

2,6-Dimethylphenyl 2-diazoacetate (8i)



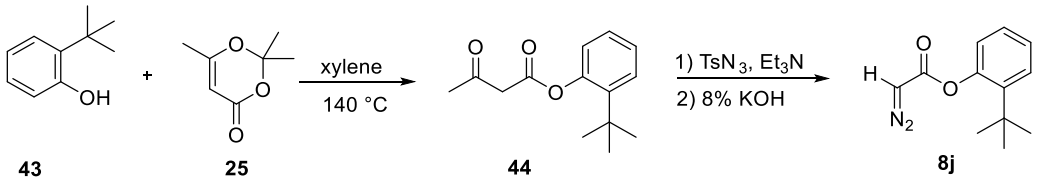
41 **25** **42** **8i**

Following a slightly modified procedure,[1] a mixture of 2,6-dimethylphenol (**41**) (1.22 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:30 EtOAc:pentane as mobile phase to afford 2,6-dimethylphenyl 3-oxobutanoate (**42)** as a white solid (1.60 g, 7.76 mmol, 78%). Mp: 46.8–47.9 °C; TLC (EtOAc:pentane, 1:25 v/v): R_f = 0.28, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 11.98 (s, 0.12H, O*H* of enol form), 7.07 (s, 3H, Ar*H* of enol and keto form), 5.31 (m, 0.12H, vinyl *H* of enol form), 3.75 (s, 1.76H, CH_3COCH_2 of keto form), 2.38 (s, 2.64H, CH_3 of keto form), 2.19 (s, 5.28H, 2 x ArCH_3 of keto form), 2.16 (s, 0.72H, 2 x ArCH_3 of enol form), 2.06 (s, 0.36H, CH_3 of enol form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.7, 170.7, 147.6, 130.4, 128.5, 125.9, 88.7, 21.4, 16.2; ^{13}C NMR (100 MHz, $CDCl_3$), Keto form: δ 199.8, 164.8, 147.8, 130.1, 128.6, 126.2, 49.5, 30.4, 16.4; IR ν 2983 (w), 2926 (w), 1761 (s), 1722 (s), 1663 (w), 1631 (w), 1477 (m), 1444 (w), 1410 (w), 1363 (w), 1320 (m), 1262 (m), 1226 (m), 1167 (s), 1142 (s), 1093 (w), 1028 (w), 983 (w), 926 (w); HRMS (ESI) calcd. for $C_{12}H_{14}NaO_3^+$ $[M+Na]^+$ 229.0835; found 229.0843.

Following a slightly modified procedure,[1] to a solution of 2,6-dimethylphenyl 3-oxobutanoate (**42**) (1.03 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:20 Et_2O:pentane as mobile phase to afford 2,6-dimethylphenyl 2-diazoacetate (**8i)** as a yellow solid (0.50 g, 2.6 mmol, 53%). Mp: 80.5–81.6 °C; TLC (Et_2O:pentane, 1:20 v/v): R_f = 0.25, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (s, 3H, Ar*H*), 5.02

(brs, 1H, C*H*N_2), 2.21 (s, 6H, 2 x C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.5, 147.8, 130.6, 128.5, 126.0, 46.2, 16.3. One carbon was not resolved in the literature reported values.[4]

2-(*Tert*-butyl)phenyl 2-diazoacetate (8j)



43 **25** **44** **8j**

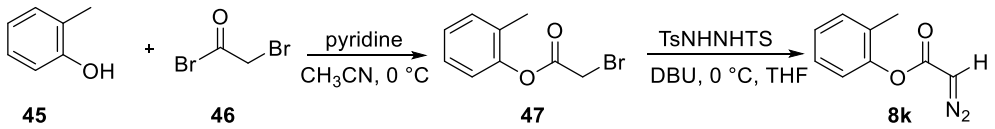
Following a slightly modified procedure,[1] a mixture of 2-(*tert*-butyl)phenol (**43**) (1.50 g, 10.0 mmol, 1.00 equiv), 2,2,6-trimethyl-4*H*-1,3-dioxin-4-one (**25**) (1.90 g, 12.0 mmol, 1.20 equiv), and xylene (2 mL) was stirred at 140 °C for 2 h. After cooling to room temperature, the xylene was evaporated and the residue was purified by flash column chromatography using 1:30 EtOAc:pentane as mobile phase to afford 2-(*tert*-butyl)phenyl 3-oxobutanoate (**44**) as a colorless oil (1.70 g, 7.26 mmol, 73%). TLC (EtOAc:pentane, 1:25 v/v): R_f = 0.29, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 11.99 (s, 0.25H, O*H* of enol form), 7.42 – 7.39 (m, 1H, Ar*H* of enol and keto form), 7.32 – 7.14 (m, 2H¸ Ar*H* of enol and keto form), 7.09 – 7.01 (m, 1H, Ar*H* of enol and keto form), 5.29 (d, *J* = 0.8 Hz, 0.25H, vinyl *H* of enol form), 3.73 (s, 1.5H, CH_3COCH_2 of keto form), 2.38 (s, 2.25H, C*H*$_3$ of keto form), 2.06 (s, 0.75H, C*H*$_3$ of enol form), 1.35 (s, 9H, *t*Bu of enol and keto form); ^{13}C NMR (100 MHz, $CDCl_3$), Enol form: δ 177.7, 171.3, 148.5, 141.3, 127.2, 126.9, 125.8, 123.9, 89.6, 34.5, 30.1, 21.4; Keto form: δ 199.8, 165.9, 149.0, 140.9, 127.3, 127.0, 126.1, 123.7, 50.3, 34.4, 30.4, 30.2; IR ν 3066 (w), 2998 (w), 2962 (w), 2916 (w), 2873 (w), 1763 (s), 1723 (s), 1665 (w), 1629 (w), 1578 (w), 1487 (m), 1443 (m), 1408 (m), 1364 (m), 1316 (m), 1251 (m), 1221 (s), 1188 (s), 1143 (s), 1088 (m), 1051 (w), 1024 (w), 979 (w), 929 (w); HRMS (ESI) calcd. for $C_{14}H_{18}NaO_3^+$ $[M+Na]^+$ 257.1148; found 257.1161.

Following a slightly modified procedure,[1] to a solution of 2-(*tert*-butyl)phenyl 3-oxobutanoate (**44**) (1.17 g, 5.00 mmol, 1.00 equiv) in acetonitrile (6 mL) was added triethylamine (660 mg, 6.50 mmol, 1.30 equiv). The reaction mixture was cooled in an ice bath and a solution of tosyl azide (1.1 g, 5.5 mmol, 1.1 equiv) in acetonitrile (6 mL) was added slowly. The reaction mixture was allowed to warm to room temperature and stirred for 20 h. 8% aqueous KOH solution (25 mL) was added and the reaction mixture was stirred vigorously for 4 h. The reaction mixture was extracted with diethyl ether (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:20 Et_2O:pentane as mobile phase to afford 2-(*tert*-butyl)phenyl 2-diazoacetate (**8j**) as a yellow oil (0.21 g, 0.96 mmol, 20%). TLC (Et_2O:pentane, 1:20 v/v): R_f = 0.22, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (dd, *J* = 7.8, 1.7 Hz, 1H,

[4] B. Xu, J. A. Gartman, U. K. Tambar, *Tetrahedron* **2017**, *73*, 4150.

Ar*H*), 7.31 – 7.14 (m, 2H, Ar*H*), 7.09 (dd, *J* = 7.8, 1.5 Hz, 1H, Ar*H*), 5.03 (brs, 1H, C*H*N_2), 1.39 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.0, 148.8, 141.2, 127.2, 126.8, 125.8, 124.1, 47.0, 34.5, 30.2; IR ν 3111 (w), 2995 (w), 2962 (w), 2913 (w), 2869 (w), 2483 (w), 2291 (w), 2112 (s), 1707 (s), 1486 (m), 1444 (w), 1365 (s), 1340 (m), 1286 (w), 1188 (s), 1147 (s), 1084 (s), 1051 (w), 975 (w), 929 (m); HRMS (ESI) calcd. for $C_{12}H_{14}N_2NaO_2^+$ $[M+Na]^+$ 241.0947; found 241.0951.

2-Methylphenyl 2-diazoacetate (8k)



45 **46** **47** **8k**

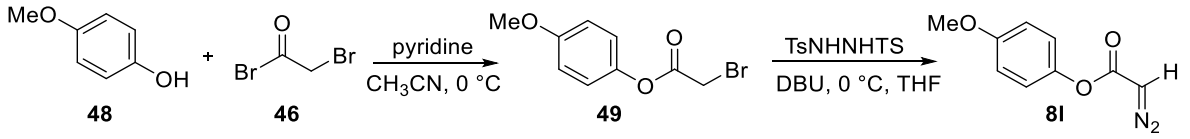
Following a reported procedure,[5] bromoacetyl bromide (**46**) (1.31 mL, 15.0 mmol, 1.50 equiv) was added to a stirred solution of *o*-cresol (**45**) (1.08 g, 10.0 mmol, 1.00 equiv) and pyridine (1.61 mL, 20.0 mmol, 2.00 equiv) in acetonitrile (50 mL) at 0 °C over 10 min. The mixture was stirred for further 5 min at 0 °C and then quenched with water (30 mL). The reaction mixture was extracted with CH_2Cl_2 (3 x 30 mL). The combined organic layers were washed with brine (50 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:40 EtOAc:pentane as mobile phase to afford *o*-tolyl 2-bromoacetate (**47**) as a colorless oil (1.9 g, 8.3 mmol, 83%). TLC (EtOAc:pentane, 1:25 v/v): R_f = 0.42, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 – 7.16 (m, 3H, Ar*H*), 7.07 (dd, *J* = 7.7, 1.5 Hz, 1H, Ar*H*), 4.09 (s, 2H, CH_2), 2.26 (s, 3H, ArCH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.6, 148.9, 131.3, 130.0, 127.0, 126.5, 121.4, 25.2, 16.0; IR ν 3064 (w), 3032 (w), 2961 (w), 2116 (w), 1758 (s), 1586 (w), 1492 (m), 1461 (w), 1423 (w), 1261 (s), 1221 (m), 1174 (s), 1129 (s), 1112 (s), 1039 (w), 952 (w); HRMS (ESI) calcd. for $C_9H_{10}BrO_2^+$ $[M+H]^+$ 228.9859; found 228.9861.

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (2.72 g, 8.00 mmol, 2.00 equiv) was added to a solution of *o*-tolyl 2-bromoacetate (**47**) (0.92 g, 4.0 mmol, 1.0 equiv) in tetrahydrofuran (20 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (3.0 mL 20 mmol, 5.0 equiv) was added dropwise over 20 min at 0 °C. Upon completion of addition of 1,8-diazabicycloundec-7-ene the reaction was quenched by a saturated aqueous Na_2CO_3 solution (30 mL). The reaction mixture was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine (40 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:20 Et_2O:pentane as mobile phase to afford *o*-tolyl 2-diazoacetate (**8k**) as a yellow oil (0.400 g, 2.27 mmol, 57%). TLC (Et_2O:pentane, 1:20 v/v): R_f = 0.22, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.26 – 7.13 (m, 3H, Ar*H*), 7.08 (dd, *J* = 7.9, 1.5 Hz, 1H, Ar*H*), 4.99 (brs, 1H, C*H*N_2), 2.23 (s, 3H, ArCH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.2, 149.0, 131.1, 130.4, 126.9, 126.1, 122.0, 46.5, 16.1; IR ν

[5] L. Candish, D. W. Lupton, *J. Am. Chem. Soc.* **2013**, *135*, 58–61.

3115 (w), 2113 (s), 1702 (s), 1590 (w), 1492 (w), 1462 (w), 1366 (s), 1341 (m), 1219 (s), 1172 (s), 1144 (s), 1108 (s), 1041 (w), 975 (w), 928 (w); HRMS (ESI) calcd. for $C_9H_8N_2NaO_2^+$ $[M+Na]^+$ 199.0478; found 199.0479.

4-Methoxyphenyl 2-diazoacetate (8l)

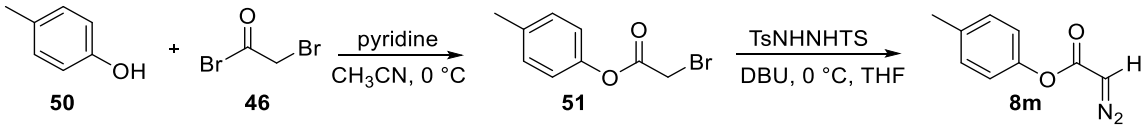


Following a reported procedure,[5] bromoacetyl bromide (**46**) (1.31 ml, 15.0 mmol, 1.50 equiv) was added to a stirred solution of 4-methoxyphenol (**48**) (1.24 g, 10.0 mmol, 1.00 equiv) and pyridine (1.61 mL, 20.0 mmol, 2.00 equiv) in acetonitrile (50 mL) at 0 °C over 10 min. The mixture was stirred for further 5 min at 0 °C and then quenched with water (30 mL). The reaction mixture was extracted with CH_2Cl_2 (3 x 30 mL). The combined organic layers were washed with brine (30 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:20 EtOAc:pentane as mobile phase to afford 4-methoxyphenyl 2-bromoacetate (**49**) as a colorless oil (2.2 g, 9.0 mmol, 90%). TLC (EtOAc:pentane, 1:10 v/v): R_f = 0.42, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.05 (d, *J* = 9.1 Hz, 2H, Ar*H*), 6.90 (d, *J* = 9.0 Hz, 2H, Ar*H*), 4.03 (s, 2H, CH_2), 3.80 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.1, 157.6, 143.9, 121.8, 114.5, 55.6, 25.5. The ^{1}H NMR data corresponded to the reported values.[6]

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (2.72 g, 8.00 mmol, 2.00 equiv) was added to a solution of 4-methoxyphenyl 2-bromoacetate (**49**) (0.98 g, 4.0 mmol, 1.0 equiv) in tetrahydrofuran (20 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (3.0 mL, 20 mmol, 5.0 equiv) was added dropwise over 20 min at 0 °C. Upon completion of the addition of 1,8-diazabicycloundec-7-ene, the reaction was quenched by a saturated aqueous Na_2CO_3 solution (30 mL). The reaction mixture was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine (40 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash chromatography using 1:10 EtOAc:pentane as mobile phase to afford 4-methoxyphenyl 2-diazoacetate (**8l**) as a yellow solid (0.600 g, 3.12 mmol, 78%). TLC (EtOAc:pentane, 1:10 v/v): R_f = 0.23, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.05 (d, *J* = 9.1 Hz, 2H, Ar*H*), 6.89 (d, *J* = 9.0 Hz, 2H, Ar*H*), 4.95 (brs, 1H, C*H*N_2), 3.80 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.8, 157.2, 143.9, 122.4, 114.4, 55.5, 46.6. The ^{1}H NMR data corresponded to the reported values.[5]

[6] T. Mohamad-Ali, S. Stéphane, C. Anne-Caroline, Y. Cédric, C. Jean-Louis, G. Didier, M. Fabrice, F. Jean-Pierre, N. Markus, T. Théophile, et al., *Chem. Eur. J.* **2014**, *20*, 5054.

***p*-Tolyl 2-diazoacetate (8m)**

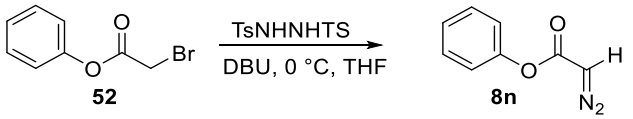


Following a reported procedure,[5] bromoacetyl bromide (**46**) (1.31 mL, 15.0 mmol, 1.50 equiv) was added to a stirred solution of *p*-cresol (**50**) (1.08 g, 10.0 mmol, 1.00 equiv) and pyridine (1.61 mL, 20.0 mmol, 2.00 equiv) in acetonitrile (50 mL) at 0 °C over 10 minutes. The mixture was stirred for further 5 minutes at 0 °C and then quenched with water (30 mL). The reaction mixture was extracted with dichloromethane (3 x 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:20 EtOAc:pentane as mobile phase to afford *p*-tolyl 2-bromoacetate (**51**) as a colorless oil (2.1 g, 9.2 mmol, 92%). TLC (EtOAc:pentane, 1:30 v/v): R_f = 0.52; $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23 – 7.15 (m, 2H, Ar*H*), 7.05 – 6.95 (m, 2H, Ar*H*), 4.04 (s, 2H, CH_2), 2.35 (s, 3H, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 148.4, 136.2, 130.2, 120.9, 25.7, 21.0. The ^{1}H NMR data corresponded to the reported values.[7]

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (3.40 g, 10.0 mmol, 2.00 equiv) was added to a solution of *p*-tolyl 2-bromoacetate (**51**) (1.15 g, 5.00 mmol, 1.00 equiv) in tetrahydrofuran (20 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (3.8 mL, 25 mmol, 5.0 equiv) was added dropwise over 20 minutes at 0 °C. The reaction was stirred 2 h at 0 °C before being quenched by a saturated aqueous Na_2CO_3 solution (30 mL). The reaction mixture was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:20 EtOAc:pentane as mobile phase to afford *p*-tolyl 2-diazoacetate (**8m**) as a yellow oil (0.450 g, 2.55 mmol, 51%). TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.33, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20 – 7.14 (m, 2H, Ar*H*), 7.03 – 6.98 (m, 2H, Ar*H*), 4.95 (br s, 1H, C*H*N_2), 2.34 (s, 3H, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.4, 135.7, 130.1, 121.5, 46.9, 21.0; IR ν 3115 (w), 2112 (s), 1699 (s), 1508 (m), 1364 (s), 1342 (s), 1193 (s), 1167 (s), 1143 (s), 923 (m), 831 (m), 728 (m); HRMS (ESI) calcd. for $C_9H_9N_2O_2^+$ $[M+H]^+$ 177.0659; found 177.0656. One carbon was not resolved at 100 MHz.

[7] G. Himbert, D. Fink, K. Diehl, *Chem. Ber.* **1988**, *121*, 431.

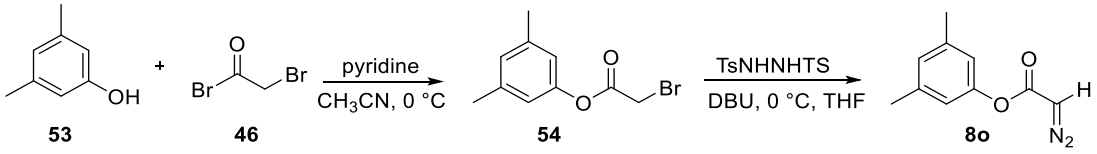
Phenyl 2-diazoacetate (8n)



52 8n

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (3.40 g, 10.0 mmol, 2.00 equiv) was added to a solution of phenyl 2-bromoacetate (**52**) (1.07 g, 5.00 mmol, 1.00 equiv) in tetrahydrofuran (20 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (3.8 mL, 25 mmol, 5.0 equiv) was added dropwise over 20 minutes at 0 °C. The reaction was stirred 2 h at 0 °C before being quenched by a saturated aqueous Na_2CO_3 solution (30 mL). The reaction mixture was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:15 EtOAc:pentane as mobile phase to afford phenyl 2-diazoacetate (**8n**) as a yellow oil (0.460 g, 2.84 mmol, 57%). TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.30, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.40 – 7.31 (m, 2H, Ar*H*), 7.24 – 7.18 (m, 1H, Ar*H*), 7.08 (m, 2H, Ar*H*), 4.87 (br s, 1H, C*H*N_2). The ^{1}H NMR data corresponded to the reported values.[8]

3,5-Dimethylphenyl 2-diazoacetate (8o)



53 46 54 8o

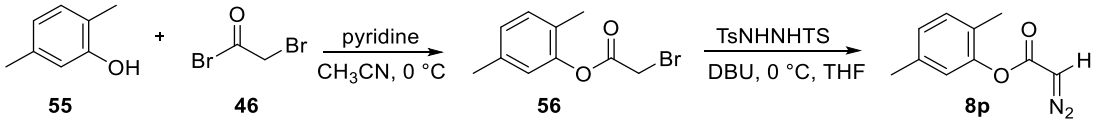
Following a reported procedure,[5] bromoacetyl bromide (**46**) (1.31 mL, 15.0 mmol, 1.50 equiv) was added to a stirred solution of 3,5-dimethylphenol (**53**) (1.22 g, 10.0 mmol, 1.00 equiv) and pyridine (1.61 mL, 20.0 mmol, 2.00 equiv) in acetonitrile (50 mL) at 0 °C over 10 minutes. The mixture was stirred for further 5 minutes at 0 °C and then quenched with water (30 mL). The reaction mixture was extracted with dichloromethane (3 x 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:20 EtOAc:pentane as mobile phase to afford 3,5-dimethylphenyl 2-bromoacetate (**54**) as a colorless oil (2.0 g, 8.3 mmol, 83%). TLC (EtOAc:pentane, 1:30 v/v): R_f = 0.57, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.90 (tt, *J* = 1.6, 0.8 Hz, 1H, Ar*H*), 6.74 (dt, *J* = 1.5, 0.7 Hz, 2H, Ar*H*), 4.03 (s, 2H, CH_2), 2.32 (m, 6H, 2 x CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 150.4, 139.6, 128.2, 118.7, 25.7, 21.4. The ^{1}H NMR data corresponded to the reported values.[7]

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (3.40 g, 10.0 mmol, 2.00 equiv) was added to a solution of 3,5-dimethylphenyl 2-bromoacetate (**54**) (1.21 g, 5.00 mmol, 1.00 equiv) in tetrahydrofuran

[8] T. Torna, J. Shimokawa, T. Fukuyama, *Org. Lett.* **2007**, *9*, 3195.

(20 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (3.8 mL, 25 mmol, 5.0 equiv) was added dropwise over 20 minutes at 0 °C. The reaction was stirred 2 h at 0 °C before being quenched by a saturated aqueous Na_2CO_3 solution (30 mL). The reaction mixture was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:20 EtOAc:pentane as mobile phase to afford 3,5-dimethylphenyl 2-diazoacetate (**8o**) as a yellow oil (0.480 g, 2.52 mmol, 51%). TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.38, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.87 (tt, *J* = 1.6, 0.8 Hz, 1H, Ar*H*), 6.75 (dt, *J* = 1.5, 0.8 Hz, 2H, Ar*H*), 4.94 (br s, 1H, C*H*N_2), 2.32 (d, *J* = 0.8 Hz, 6H, 2 x C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.9, 150.5, 139.4, 127.8, 119.4, 46.9, 21.4; IR ν 3109 (w), 2922 (w), 2112 (s), 1701 (s), 1618 (m), 1364 (s), 1342 (m), 1292 (m), 1219 (s), 1161 (s), 1143 (s), 849 (m), 726 (m); HRMS (ESI) calcd. for $C_{10}H_{11}N_2O_2^+$ $[M+H]^+$ 191.0815; found 191.0812.

2,5-dimethylphenyl 2-diazoacetate (8p)



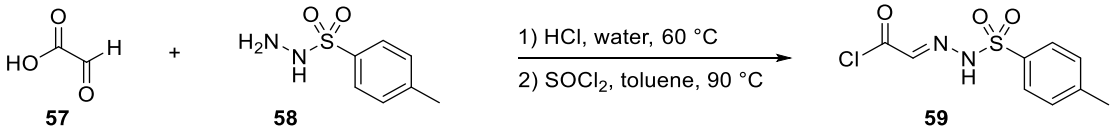
55 **46** **56** **8p**

Following a reported procedure,[5] bromoacetyl bromide (**46**) (1.31 mL, 15.0 mmol, 1.50 equiv) was added to a stirred solution of 2,5-dimethylphenol (**55**) (1.22 g, 10.0 mmol, 1.00 equiv) and pyridine (1.61 mL, 20.0 mmol, 2.00 equiv) in acetonitrile (50 mL) at 0 °C over 10 minutes. The mixture was stirred for further 5 minutes at 0 °C and then quenched with water (30 mL). The reaction mixture was extracted with dichloromethane (3 x 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using 1:20 EtOAc:pentane as mobile phase to afford 2,5-dimethylphenyl 2-bromoacetate (**56**) as a colorless oil (1.9 g, 8.3 mmol, 79%). TLC (EtOAc:pentane, 1:30 v/v): R_f = 0.62, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.12 (d, *J* = 7.7 Hz, 1H, Ar*H*), 7.01 – 6.95 (m, 1H, Ar*H*), 6.88 – 6.81 (m, 1H, Ar*H*), 4.05 (s, 2H, C*H*$_2$), 2.32 (s, 3H, C*H*$_3$), 2.17 (s, 3H, C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.9, 148.9, 137.2, 131.2, 127.5, 126.8, 122.0, 25.4, 21.0, 15.8. The ^{1}H NMR data corresponded to the reported values.[7]

Following a reported procedure,[5] *N,N'*-Ditosylhydrazine (4.77 g, 14.0 mmol, 2.00 equiv) was added to a solution of 2,5-dimethylphenyl 2-bromoacetate (**56**) (1.70 g, 7.00 mmol, 1.00 equiv) in tetrahydrofuran (28 mL) and the mixture was cooled to 0 °C. 1,8-Diazabicycloundec-7-ene (5.3 mL, 35 mmol, 5.0 equiv) was added dropwise over 20 minutes at 0 °C. The reaction was stirred 2 h at 0 °C before being quenched by a saturated aqueous Na_2CO_3 solution (40 mL). The reaction mixture was extracted with diethyl ether (3 x 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using

1:20 EtOAc:pentane as mobile phase to afford 2,5-dimethylphenyl 2-diazoacetate (**8p**) as a yellow oil (0.802 g, 4.22 mmol, 60%). TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.43, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.11 (d, *J* = 7.7 Hz, 1H, Ar*H*), 6.96 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 6.88 (d, *J* = 1.7 Hz, 1H, Ar*H*), 4.98 (br s, 1H, C*H*N_2), 2.32 (s, 3H, C*H*$_3$), 2.17 (s, 3H, C*H*$_3$).; ^{13}C NMR (100 MHz, $CDCl_3$): 149.0, 137.1, 131.0, 127.3, 127.1, 122.7, 46.7, 21.0, 15.9; IR ν 3110 (w), 2112 (s), 1701 (s), 1498 (m), 1365 (s), 1340 (s), 1183 (s), 1167 (s), 1143 (s), 920 (w), 831 (m), 730 (w); HRMS (ESI) calcd. for $C_{10}H_{10}N_2NaO_2^+$ $[M+Na]^+$ 213.0634; found 213.0632. One carbon was not resolved at 100 MHz.

***p*-Toluenesulfonylhydrazone of glyoxylic acid chloride (59)**



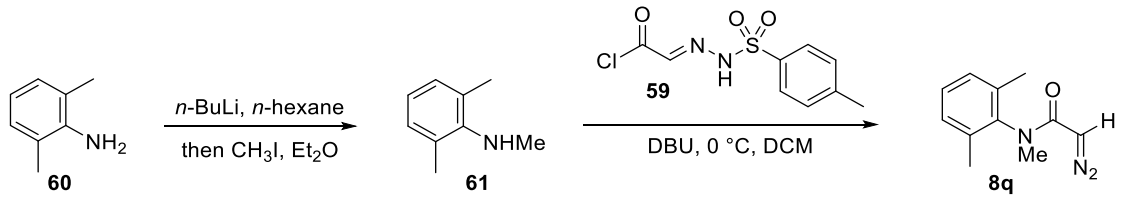
Following a modified procedure,[9] a solution of glyoxylic acid (**57**) (37.0 g, 50% in water, 0.25 mole, 1.00 equiv) in water (250 mL) was placed in a 500 mL Erlenmeyer flask and warmed to 60 °C. This solution was then treated with a warm (60 °C) solution of *p*-toluenesulfonylhydrazide (**58**) (47.0 g, 0.250 mole, 1.00 equiv) in aqueous hydrochloric acid (125 mL, 2.5 M, 0.310 mole, 1.25 equiv). The resulting mixture was stirred at 60 °C until all the hydrazine was solidified (about 5 minutes is required). The reaction mixture was cooled to room temperature and then allowed to stand in a refrigerator overnight, the solid was collected by filtration, washed with cold water (2 times), and allowed to dry for 2 days. Glyoxylic acid *p*-toluenesulfonylhydrazone was collected as a white solid (55.5 g, 0.23 mole, 92%). ^{1}H NMR (400 MHz, DMSO-d6) δ 13.10 (br s, 1H, CO_2*H*), 12.27 (br s, 1H, N*H*Ts), 7.73 – 7.67 (m, 2H, Ar*H*), 7.47 – 7.41 (m, 2H, Ar*H*), 7.18 (s, 1H, COC*H*N), 2.39 (s, 3H, C*H*$_3$). ^{13}C NMR (100 MHz, δ DMSO-d6) δ 163.6, 144.0, 137.5, 135.7, 129.9, 127.1, 21.1. The NMR data corresponded to the reported values.[10]

Following a modified procedure,[9] thionyl chloride (6.03 mL, 83.0 mmol, 2.00 equiv) was added to a suspension of glyoxylic acid *p*-poluenesulfonylhydrazone (10.0 g, 41.3 mmol, 1.00 equiv) in dry toluene (50 mL). The reaction mixture was stirred at 85 °C for 30 min, until the gaz evolution has ceased. The resulting orange reaction mixture was then cooled to room temperature and filtered through Celite. The filtrate was recovered, concentrated under reduced pressure and the residual solid was treated with hot toluene (10 mL, 65 °C). The reaction mixture was cooled to room temperature and the solid was filtered, washed with cold toluene (2 x 10 mL) and then washed with pentane to afford *p*-toluenesulfonylhydrazone of glyoxylic acid chloride (**59**) as pale yellow prisms (7.46 g, 28.6 mmol, 69 % yield). ^{1}H NMR (400 MHz, CD_3CN) δ 10.36 (br s, 1H, N*H*Ts), 7.86 – 7.75 (m, 2H, Ar*H*), 7.43 (d, *J* = 8.1 Hz,

[9] C. J. Blankley, F. J. Sauter, H. O. House, J. H. Ham, R. E. Ireland, *Org. Synth.* **1969**, *49*, 22.
[10] H. Lei, J. Atkinson, *J. Org. Chem.* **2000**, *65*, 2560.

2H, Ar*H*), 7.29 (d, *J* = 0.8 Hz, 1H, COC*H*N), 2.43 (s, 3H, C*H*$_3$). ^{13}C NMR (100 MHz, CD_3CN) δ 165.8, 146.5, 137.7, 135.8, 131.0, 128.7, 21.6. The ^{1}H NMR data corresponded to the reported values.[11]

2-Diazo-*N*-(2,6-dimethylphenyl)-*N*-methylacetamide (8q)



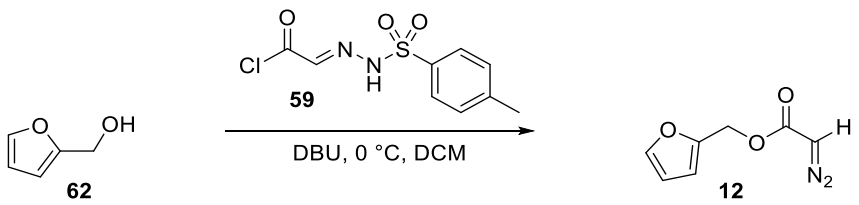
Following a slightly modified procedure,[12] a solution of *n*-BuLi (4.35 mL, 2.50 M in *n*-hexane, 11.0 mmol, 1.10 equiv) was added to a solution of 2,6-dimethylaniline (**60**) (1.23 mL, 10.0 mmol, 1.00 equiv) in *n*-hexane (15 mL) at –20 °C. The reaction mixture was warmed to room temperature and stirred for 3 h. The solvent of the reaction mixture was evaporated and the light-yellow solid was dissolved in diethyl ether (30 mL). The obtained solution was slowly added to a solution of iodomethane (0.65 mL, 10.50 mmol, 1.05 equiv.) in diethyl ether (10.0 mL) at -20 °C. The reaction mixture was warmed to room temperature and stirred overnight. The reaction was then quenched with H_2O (20 mL). The layers were separated and the aqueous layer was extracted with diethyl ether (3 x 15 mL). The combined organic layers were washed with brine (30 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product *N*,2,6-trimethylaniline (**61**) was obtained as a yellow oil (1.28 g, 9.44 mmol, 94%) and used in the next step without further purification. TLC (EtOAc:pentane, 1:9 v/v): R_f = 0.56, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.00 (d, *J* = 7.5 Hz, 2H, Ar*H*), 6.82 (t, *J* = 7.4 Hz, 1H, Ar*H*), 2.79 (s, 3H, NHC*H*$_3$), 2.30 (s, 6H, 2 x C*H*$_3$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.6, 129.3, 129.1, 121.9, 35.5, 18.5. The NMR data corresponded to the reported values.[13]

Following a slightly modified procedure,[14] to a solution of *p*-toluenesulfonylhydrazone of glyoxylic acid chloride (**62**) (1.30 g, 5.00 mmol, 1.00 equiv) in CH_2Cl_2 (10 mL) were added *N*,2,6-trimethylaniline (**61**) (744 mg, 5.50 mmol, 1.10 equiv) and then DBU (1.89 mL, 12.5 mmol, 2.50 equiv) dropwise at 0 °C. After stirring for 2 h at the same temperature, the reaction was stirred 30 min at room temperature and then poured into saturated NH_4Cl solution (10 mL). The organic layer was then extracted with CH_2Cl_2 (3 x 10 mL), washed with saturated brine (20 mL), dried over $MgSO_4$, filtered and concentrated under reduced. The crude product was purified by column chromatography using 1:4 EtOAc:pentane as mobile phase to afford 2-diazo-*N*-(2,6-dimethylphenyl)-*N*-methylacetamide (**8q)** as a yellow solid (609 mg, 3.00 mmol, 60%). TLC (EtOAc:pentane, 1:4 v/v): R_f = 0.48, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19 – 7.07 (m, 3H,

[11] H. O. House, C. J. Blankley, *J. Org. Chem.* **1968**, *33*, 53.
[12] K. Liu, Q. Wu, W. Gao, Y. Mu, L. Ye, *Eur. J. Inorg. Chem.* **2011**, *2011*, 1901.
[13] S. L. Cockroft, J. Perkins, C. Zonta, H. Adams, S. E. Spey, C. M. R. Low, J. G. Vinter, K. R. Lawson, C. J. Urch, C. A. Hunter, *Org. Biomol. Chem.* **2007**, *5*, 1062.

Ar*H*), 4.30 (s, 1H, CN_2H), 3.18 (s, 3H, NHCH_3), 2.21 (s, 6H, 2 x CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.8, 140.0, 136.6, 129.1, 128.6, 46.2, 34.3, 17.7; IR ν 2989 (m), 2116 (s), 1706 (s), 1509 (m), 1369 (s), 1343 (m), 1216 (s), 1204 (s); HRMS (ESI) calcd. for $C_{11}H_{14}N_3O^+$ $[M+H]^+$ 204.1131; found 204.1128.

Furan-2-ylmethyl 2-diazoacetate (12)



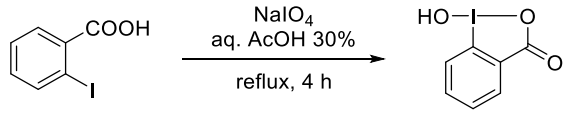
Following a slightly modified procedure,[14] to a solution of *p*-toluenesulfonylhydrazone of glyoxylic acid chloride (**59**) (1.30 g, 5.00 mmol, 1.00 equiv) in CH_2Cl_2 (10 mL) were added furfuryl alcohol (**62**) (475 µL, 5.50 mmol, 1.10 equiv) and then DBU (1.89 mL, 12.5 mmol, 2.50 equiv) dropwise at 0 °C. After stirring for 2 h at the same temperature, the reaction was stirred 30 min at room temperature and then poured into saturated NH_4Cl solution (10 mL). The organic layer was then extracted with CH_2Cl_2 (3 x 10 mL), washed with saturated brine (20 mL), dried over $MgSO_4$, filtered and concentrated under reduced. The crude product was purified by column chromatography using 1:30 EtOAc:pentane as mobile phase to afford furan-2-ylmethyl 2-diazoacetate (**12**) as a yellow oil (534 mg, 3.21 mmol, 64%). Mp: 76–78 °C; TLC (EtOAc:pentane, 1:20 v/v): R_f = 0.33, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42 (dd, *J* = 1.9, 0.9 Hz, 1H, Ar*H*), 6.42 (dd, *J* = 3.3, 0.8 Hz, 1H, Ar*H*), 6.36 (dd, *J* = 3.3, 1.8 Hz, 1H, Ar*H*), 5.14 (s, 2H, CH_2O), 4.78 (br s, 1H, CN_2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 149.5, 143.5, 111.0, 110.7, 58.3, 46.5. IR ν 3117 (m), 2112 (s), 1691 (s), 1383 (s), 1348 (s), 1238 (s), 1173 (s), 1153 (s), 1004 (s), 921 (m), 740 (s); HRMS (ESI) calcd. for $C_7H_6N_2NaO_3^+$ $[M+Na]^+$ 189.0271; found 189.0269.

[14] T. Hashimoto, N. Uchiyama, K. Maruoka, *J. Am. Chem. Soc.* **2008**, *130*, 14380.

3. Preparation of EBX reagents

The preparation of R-EBX reagents 1**5a**-**q** except **15p** had been already described before. The procedures are taken here from the indicated publications to facilitate reproduction of the results by having all the data in the same file.

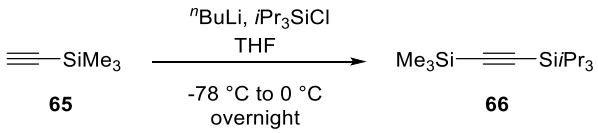
1-Hydroxy-1,2-benziodoxol-3-(1*H*)-one (64)



63 **64**

Following a reported procedure,[15] $NaIO_4$ (7.24 g, 33.8 mmol, 1.05 equiv) and 2-iodobenzoic acid (**63**) (8.00 g, 32.2 mmol, 1.00 equiv) were suspended in 30% (v/v) aq. AcOH (48 mL). The mixture was vigorously stirred and refluxed for 4 h. The reaction mixture was then diluted with cold water (180 mL) and allowed to cool to room temperature, protecting it from light. After 1 h, the crude product was collected by filtration, washed on the filter with ice water (3 x 20 mL) and acetone (3 x 20 mL), and air-dried in the dark to give the pure product **64** as a white solid (8.3 g, 31 mmol, 98%). ^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ 8.02 (dd, *J* = 7.7, 1.4 Hz, 1H, Ar*H*), 7.97 (m, 1H, Ar*H*), 7.85 (dd, *J* = 8.2, 0.7 Hz, 1H, Ar*H*), 7.71 (td, *J* = 7.6, 1.2 Hz, 1H, ArH); ^{13}C NMR (100 MHz, $(CD_3)_2SO$): δ 167.7, 134.5, 131.5, 131.1, 130.4, 126.3, 120.4; IR ν 3083 (w), 3060 (w), 2867 (w), 2402 (w), 1601 (m), 1585 (m), 1564 (m), 1440 (m), 1338 (s), 1302 (m), 1148 (m), 1018 (w), 834 (m), 798 (w), 740 (s), 694 (s), 674 (m), 649 (m). The values of the NMR spectra are in accordance with reported literature data.[15]

Tri*iso*propylsilyl trimethylsilylacetylene (66)



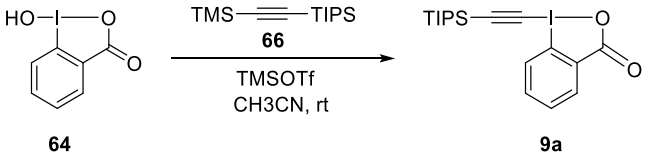
65 **66**

Following a reported procedure,[16] ^{n}BuLi (2.50 M in hexanes, 12.0 mL, 29.9 mmol, 0.98 equiv) was added dropwise to a stirred solution of ethynyltrimethylsilane (**65**) (3.0 g, 30 mmol, 1.0 equiv) in THF (48 mL) at -78 °C. The mixture was then warmed to 0 °C and stirred for 5 min. The mixture was then cooled back to -78 °C and chlorotri*iso*propylsilane (6.4 mL, 30 mmol, 1.0 equiv) was added dropwise. The mixture was then allowed to warm to room temperature and stirred overnight. A saturated solution of ammonium chloride (40 mL) was added, and the reaction mixture was extracted with diethyl ether (2 x

[15] L. Kraszkiewicz, L. Skulski, *Arkivoc* **2003**, *2003*, 120.
[16] C. J. Helal, P. A. Magriotis, E. J. Corey, *J. Am. Chem. Soc.* **1996**, *118*, 10938.

60 mL). The organic layer was washed with water and brine, then dried over $MgSO_4$, filtered and concentrated under reduced pressure to obtain a colorless liquid which was further purified by Kugelrohr distillation (56-57 °C/0.25 mm of Hg) to yield **66** as a colorless liquid (7.16 g, 28.0 mmol, 92% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.08 (m, 21H, TIPS), 0.18 (s, 9H, TMS); IR ν 2959 (m), 2944 (m), 2896 (w), 2867 (m), 1464 (w), 1385 (w), 1250 (m), 996 (w), 842 (s), 764 (s), 675 (m), 660 (m). The values of the NMR spectra are in accordance with reported literature data.[16]

1-[(Tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (9a)

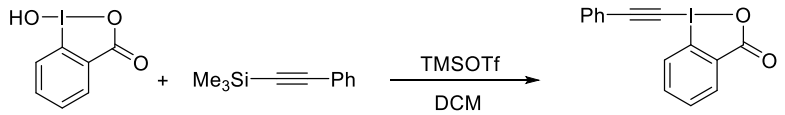


64 **9a**

Following a reported procedure,[17] 2-iodosylbenzoic acid (**64**) (21.7 g, 82.0 mmol, 1.00 equiv) was charged in oven-dried three-neck 1L flask equipped with a magnetic stirrer. After 3 vacuum/nitrogen cycles, anhydrous acetonitrile (500 mL) was added *via* canula and cooled to 0 °C. Trimethylsilyltriflate (16.4 mL, 90.0 mmol, 1.10 equiv) was added dropwise *via* a dropping funnel over 30 min (no temperature increase was observed). After 15 min, (trimethylsilyl)(tri*iso*propylsilyl)acetylene (**66**) (23.0 g, 90.0 mmol, 1.10 equiv) was added *via* canula over 15 min (no temperature increase was observed). After 30 min, the suspension became an orange solution. After 10 min, pyridine (7.0 mL, 90 mmol, 1.1 equiv) was added *via* syringe. After 15 min, the reaction mixture was transferred in a one-neck 1L flask and reduced under vacuum until a solid was obtained. The solid was dissolved in CH_2Cl_2 (200 mL) and transferred in a 1L separatory funnel. The organic layer was added and washed with 1 M HCl (200 mL) and the aqueous layer was extracted with CH_2Cl_2 (200 mL). The organic layers were combined, washed with a saturated solution of $NaHCO_3$ (2 x 200 mL), dried over $MgSO_4$, filtered and the solvent was evaporated under reduced pressure. Recrystallization from acetonitrile (*ca* 120 mL) afforded **9a** as colorless crystals (30.1 g, 70.2 mmol, 86%). Mp (Dec.): 170.0-176.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.44 (m, 1H, Ar*H*), 8.29 (m, 1H, Ar*H*), 7.77 (m, 2H, Ar*H*), 1.16 (m, 21H, TIPS); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 134.6, 132.3, 131.4, 131.4, 126.1, 115.6, 114.1, 64.6, 18.4, 11.1; IR ν 2943 (m), 2865 (m), 1716 (m), 1618 (m), 1604 (s), 1584 (m), 1557 (m), 1465 (m), 1439 (w), 1349 (m), 1291 (m), 1270 (w), 1244 (m), 1140 (m), 1016 (m), 999 (m), 883 (m), 833 (m), 742 (m), 702 (s), 636 (m). The characterization data corresponded to the reported values.[17]

[17] J. P. Brand, J. Waser, *Angew. Chem., Int. Ed.* **2010**, *49*, 7304.

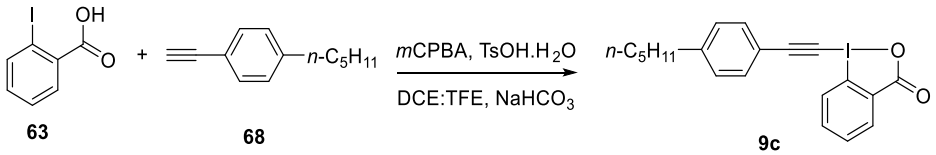
1-[Phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9b)



64 67 9b

Following a reported procedure,[18] trimethylsilyl triflate (7.50 mL, 41.5 mmol, 1.10 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (10.0 g, 37.7 mmol, 1.00 equiv) in CH_2Cl_2 (100 mL) at room temperature. The resulting yellow mixture was stirred for 1 h, followed by the dropwise addition of trimethyl(phenylethynyl)silane (**67**) (8.10 mL, 41.5 mmol, 1.10 equiv) (slightly exothermic). The resulting suspension was stirred for 6 h at room temperature, during this time a white solid was formed. A saturated solution of $NaHCO_3$ (100 mL) was then added and the mixture was stirred vigorously. The resulting suspension was filtered on a glass filter of porosity 4. The two layers of the mother liquors were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (100 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting mixture was combined with the solid obtained by filtration and boiled in CH_3CN (*ca* 300 mL). The mixture was cooled down, filtered and dried under high vacuum to afford **9b** as a white solid (6.08 g, 17.4 mmol, 46 %). Mp (Dec.); 155.0–160.0 °C (lit 153-155°C); ^{1}H NMR (400 MHz, $CDCl_3$); δ 8.46 (m, 1H, Ar*H*), 8.28 (m, 1H, Ar*H*), 7.80 (m, 2H, Ar*H*), 7.63 (m, 2H, Ar*H*), 7.48 (m, 3H, Ar*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.9, 134.9, 132.9, 132.5, 131.6, 131.3. 130.8, 128.8, 126.2, 120.5, 116.2, 106.6, 50.2. The characterization data corresponded to the reported values.[18]

1-((4-Pentylphenyl)ethynyl)-1,2-benziodoxol-3(1*H*)-one (9c)



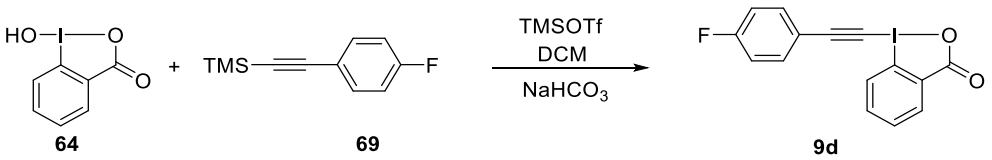
63 68 9c

In a sealed tube, 2-iodobenzoic acid (**63**) (1.00 g, 4.03 mmol, 1.00 equiv), 4-methylbenzenesulfonic acid (775 mg, 4.03 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (*m*CPBA-70%, 994 mg, 4.44 mmol, 1.10 equiv) were suspended in DCE:TFE 1:1 (12 mL) and stirred for 1 h at 55 °C. After 1 h, 1-ethynyl-4-pentylbenzene (**68**) (1.1 mL, 5.6 mmol, 1.4 equiv) was added and the reaction was stirred at 55 °C for 24 h. After 24 h, the solvent was evaporated and the residue was redissolved in CH_2Cl_2 (20 mL) and stirred vigorously with saturated $NaHCO_3$ solution (30 mL). After 1 h, the reaction mixture was transferred into a separating funnel and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 50

[18] J. P. Brand, C. Chevalley, R. Scopelliti, J. Waser, *Chem. Eur. J.* **2012**, *18*, 5655.

mL). The combined organic layers were washed with saturated $NaHCO_3$ solution, dried over $MgSO_4$, filtered and concentrated under vacuum. The resulting solid was boiled in MeCN (20 mL), then filtered and the collected solid was further purified by flash column chromatography using EtOAc. Trituration in pentane afforded **9c** as a pale yellow solid (191 mg, 0.457 mmol, 11%). M.p. (Dec.) 104-107 °C; TLC (EtOAc): R_f = 0.21, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 8.45 – 8.40 (m, 1H, Ar*H*), 8.28 – 8.21 (m, 1H, Ar*H*), 7.79 – 7.74 (m, 2H, Ar*H*), 7.56 – 7.48 (m, 2H, Ar*H*), 7.26 – 7.23 (m, 2H, Ar*H*), 2.71 – 2.60 (m, 2H, ArCH_2), 1.69 – 1.54 (m, 2H, $ArCH_2CH_2$), 1.40 – 1.27 (m, 4H, $CH_2CH_2CH_3$), 0.90 (t, *J* = 6.8 Hz, 3H, CH_2CH_3); ^{13}C NMR (101 MHz, $CDCl_3$): δ 166.6, 146.7, 135.0, 133.0, 132.6, 131.7, 131.5, 129.0, 126.3, 117.7, 116.4, 107.4, 49.4, 36.2, 31.5, 31.0, 22.6, 14.1; IR ν 3446 (m), 3359 (w), 2349 (w), 1644 (s), 1482 (m), 1327 (m), 1214 (m), 1121 (m), 1034 (m), 840 (s), 753 (m); HRMS (ESI) calcd. for $C_{20}H_{20}IO_2^+$ $[M+H]^+$ 419.0503; found 419.0496. The characterization data corresponded to the reported values.[19]

1-[4-Fluorophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9d)

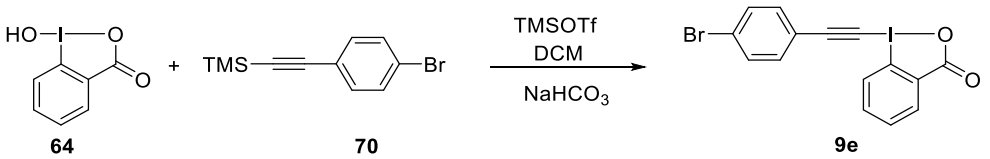


64 **69** **9d**

Following a reported procedure,[20] trimethylsilyl triflate (1.0 mL, 5.5 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.32 g, 5.00 mmol, 1.00 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting suspension was stirred for 1 h, followed by the drop wise addition of ((4-fluorophenyl)ethynyl)trimethylsilane (**69**) (1.1 mL, 5.5 mmol, 1.1 equiv), which was dissolved in CH_2Cl_2 (1 mL). The resulting suspension was stirred for 6 h. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was boiled in CH_3CN (20 mL). The mixture was cooled down, filtered and dried under high vacuum to afford **9d** as a white solid (750 mg, 2.05 mmol, 41%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.48 – 8.34 (m, 1H, Ar*H*), 8.29 – 8.16 (m, 1H, Ar*H*), 7.85 – 7.69 (m, 2H, Ar*H*), 7.68 – 7.53 (m, 2H, Ar*H*), 7.17 – 7.05 (m, 2H, Ar*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.8, 164.0 (d, *J* = 253.9 Hz), 135.2 (d, *J* = 8.8 Hz), 135.0, 132.6, 131.7, 131.50, 126.4, 116.9 (d, *J* = 3.6 Hz), 116.4 (d, *J* = 22.4 Hz), 116.3, 105.5, 50.5. The characterization data corresponded to the reported values.[20]

[19] F. Le Vaillant, M. Garreau, S. Nicolai, G. Gryn'ova, C. Corminboeuf, J. Waser, *Chem. Sci.* **2018**, *9*, 5883.
[20] K. Jia, F. Zhang, H. Huang, Y. Chen, *J. Am. Chem. Soc.* **2016**, *138*, 1514.

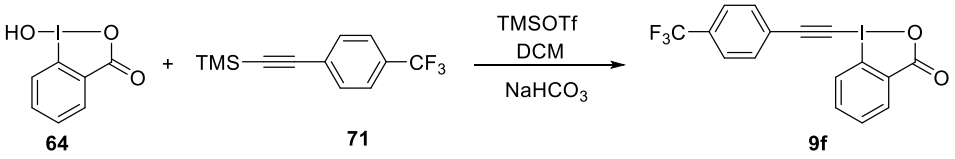
1-[4-Bromophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9e)



64 **70** **9e**

Following a reported procedure,[21] trimethylsilyl triflate (1.0 mL, 5.5 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.32 g, 5.00 mmol, 1.00 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting suspension was stirred for 1 h, followed by the drop wise addition of ((4-bromophenyl)ethynyl)trimethylsilane (**70**) (1.17 g, 5.50 mmol, 1.10 equiv), which was dissolved in CH_2Cl_2 (1 mL). The resulting suspension was stirred for 6 h. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was boiled in CH_3CN (20 mL). The mixture was cooled down, filtered and dried under high vacuum to afford **9e** as a pale yellow solid (1.00 g, 2.34 mmol, 47%). Mp (Dec.):158.0-163.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51–8.30 (m, 1H, Ar*H*), 8.30–8.13 (m, 1H, Ar*H*), 7.84–7.72 (m, 2H, Ar*H*), 7.58 (d, 2H, *J* = 8.5 Hz, Ar*H*), 7.46 (d, 2H, *J* = 8.5 Hz, Ar*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 135.1, 134.3, 132.7, 132.3, 131.9, 131.4, 126.3, 125.7, 119.6, 116.3, 105.4, 52.1; IR ν 2155 (w), 1612 (s), 1559 (w), 1479 (w), 1445 (w), 1328 (m), 1297 (w), 1007 (w), 906 (w). The characterization data corresponded to the reported values.[21]

1-[4-Trifluoromethylphenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9f)



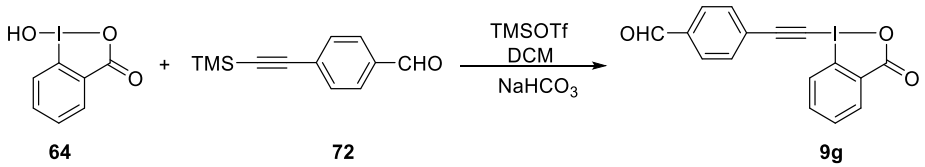
64 **71** **9f**

Following a reported procedure,[22] trimethylsilyl triflate (0.80 mL, 4.4 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.06 g, 4.00 mmol, 1.00 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting yellow mixture was stirred for 1 h, followed by the dropwise addition of trimethyl((4-(trifluoromethyl)phenyl)ethynyl)silane (**71**) (1.07 g, 4.40 mmol, 1.10 equiv). The resulting suspension was stirred for 6 h. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was recrystallized in CH_3CN (ca 20 mL) to afford **9f** as a pale yellow solid

[21] F. Le Vaillant, T. Courant, J. Waser, *Angew. Chem., Int. Ed.* **2015**, *54*, 11200.
[22] B. Lu, J. Wu, N. Yoshikai, *J. Am. Chem. Soc.* **2014**, *136*, 11598.

(850 mg, 2.04 mmol, 51%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.46 – 8.38 (m, 1H, Ar*H*), 8.28 – 8.19 (m, 1H, Ar*H*), 7.84 – 7.74 (m, 2H, Ar*H*), 7.74 – 7.65 (m, 4H, Ar*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 135.0, 133.0, 132.6, 132.2 (q, $J_{C\text{-}F}$ = 33.0 Hz), 131.7, 131.2, 126.3, 125.7 (q, $J_{C\text{-}F}$ = 3.6 Hz), 124.4, 123.4 (q, $J_{C\text{-}F}$ = 272.6 Hz), 116.1, 104.2, 53.7. The characterization data corresponded to the reported values.[22]

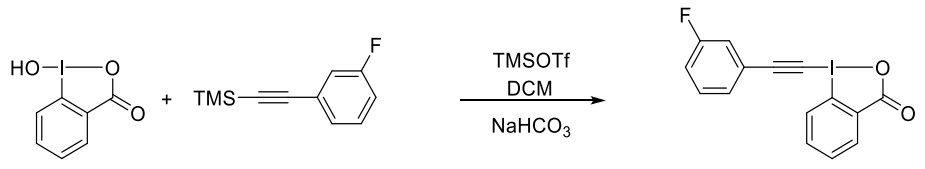
1-((4-Formylphenyl)ethynyl)-1,2-benziodoxol-3(1*H*)-one (9g)



64 **72** **9g**

Following a reported procedure,[23] trimethylsilyl triflate (0.89 mL, 4.9 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.19 g, 4.49 mmol, 1.00 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting suspension was stirred for 1 h, followed by the drop wise addition of ((4-formylphenyl)ethynyl)trimethylsilane (**72**) (1.00 g, 4.94 mmol, 1.10 equiv), which was dissolved in CH_2Cl_2 (1 mL). The resulting suspension was stirred for 6 h. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was boiled in CH_3CN (20 mL). The mixture was cooled down, filtered and dried under high vacuum to afford **9g** as a yellow solid (0.80 g, 2.1 mmol, 41%). ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.08 (s, 1H, C*H*O), 8.35 (d, *J* = 9.1 Hz, 1H, Ar*H*), 8.14 (dd, *J* = 7.4, 1.7 Hz, 1H, Ar*H*), 8.02 (d, *J* = 8.5 Hz, 2H, Ar*H*), 7.96 – 7.88 (m, 3H, Ar*H*), 7.82 (t, *J* = 7.3 Hz, 1H, Ar*H*); ^{13}C NMR (101 MHz, DMSO-d_6): δ 192.6, 166.3, 136.7, 135.3, 133.2, 131.9, 131.4, 129.8, 127.7, 126.1, 116.4, 102.9, 56.6. The characterization data corresponded to the reported values.[23]

1-[3-Fluorophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9h)



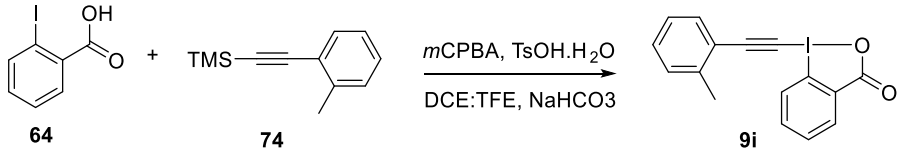
64 **73** **9h**

Following a reported procedure,[20] trimethylsilyl triflate (1.0 mL, 5.5 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.32 g, 5.00 mmol, 1.0 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting suspension was stirred for 1 h, followed by the drop wise addition of ((3-fluorophenyl)ethynyl)trimethylsilane (**73**) (1.1 mL, 5.5 mmol, 1.1 equiv). The resulting suspension was

[23] H. Huang, G. Zhang, L. Gong, S. Zhang, Y. Chen, *J. Am. Chem. Soc.* **2014**, *136*, 2280.

stirred for 6 h. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was boiled in CH_3CN (20 mL). The mixture was cooled down, filtered and the collected solid was dried under high vacuum to afford **9h** as a colorless solid (787 mg, 2.15 mmol, 43%). M.p. (Dec.) 160-164 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.33 (dd, *J* = 8.2, 0.8 Hz, 1H, Ar*H*), 8.13 (dd, *J* = 7.4, 1.7 Hz, 1H, Ar*H*), 7.91 (ddd, *J* = 8.2, 7.2, 1.7 Hz, 1H, Ar*H*), 7.81 (td, *J* = 7.3, 0.9 Hz, 1H, Ar*H*), 7.64 – 7.59 (m, 1H, Ar*H*), 7.58 – 7.53 (m, 2H, Ar*H*), 7.47 – 7.37 (m, 1H, Ar*H*); ^{13}C NMR (101 MHz, DMSO-d_6): δ 166.3, 161.8 (d, *J* = 245.6 Hz), 135.3, 131.9, 131.3, 131.2 (d, *J* = 8.7 Hz), 129.0 (d, *J* = 2.9 Hz), 127.7, 122.4 (d, *J* = 9.6 Hz), 119.2 (d, *J* = 23.4 Hz), 118.1 (d, *J* = 21.1 Hz), 116.4, 102.5 (d, *J* = 3.3 Hz), 53.8; ^{19}F NMR (376 MHz, DMSO-d_6): δ -111.7; IR ν 3477 (w), 3334 (w), 2380 (w), 1644 (s), 1457 (m), 1339 (w), 1252 (w), 1146 (m), 946 (w), 840 (w), 753 (m), 2143 (w); HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_9FIO_2^+$ 366.9626; Found 366.9625. One carbon was not resolved at 100 MHz. The characterization data corresponded to the reported values.[19]

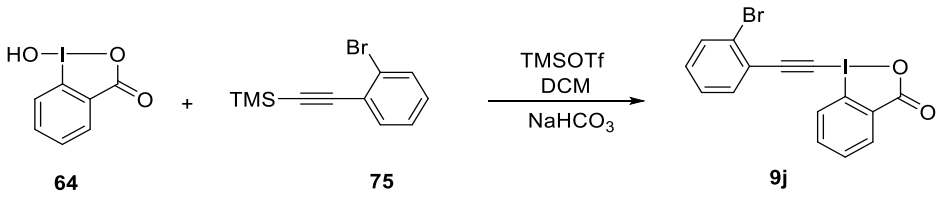
1-[2-Methylphenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9i)



64 **74** **9i**

In a sealed tube, 2-iodobenzoic acid (**64**) (1.00 g, 4.03 mmol, 1.00 equiv), 4-methylbenzenesulfonic acid (775 mg, 4.03 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (*m*CPBA-70%, 994 mg, 4.44 mmol, 1.10 equiv) were suspended in DCE:TFE 1:1 (12 mL) and stirred for 1 h at 55 °C. After 1 h, trimethyl(*o*-tolylethynyl)silane (**74**) (1.2 mL, 5.6 mmol, 1.4 equiv) was added and the reaction was stirred at 55 °C for 24 h. After 24 h, the solvent was evaporated and the residue was redissolved in CH_2Cl_2 (20 mL) and stirred vigorously with saturated $NaHCO_3$ solution (30 mL). After 1 h, the reaction mixture was transferred into a separating funnel and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL). The combined organic layers were washed with saturated $NaHCO_3$ solution, dried over $MgSO_4$, filtered and concentrated under vacuum. The residue was purified by flash column chromatography using EtOAc to afford **9i** as a pale yellow solid (0.4 g, 1.1 mmol, 28%). TLC (EtOAc): R_f = 0.21, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.47 – 8.36 (m, 1H, Ar*H*), 8.32 – 8.22 (m, 1H, Ar*H*), 7.82 – 7.68 (m, 2H, Ar*H*), 7.56 (dd, *J* = 7.7, 1.4 Hz, 1H, Ar*H*), 7.37 (td, *J* = 7.6, 1.4 Hz, 1H, Ar*H*), 7.30 (d, *J* = 7.7 Hz, 1H, Ar*H*), 7.27 – 7.21 (m, 1H, Ar*H*), 2.53 (s, 3H, ArC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 141.9, 134.8, 133.4, 132.5, 131.5, 131.4, 130.7, 129.9, 126.2, 126.0, 120.4, 116.3, 105.7, 53.2, 20.8. The characterization data corresponded to the reported values.[20]

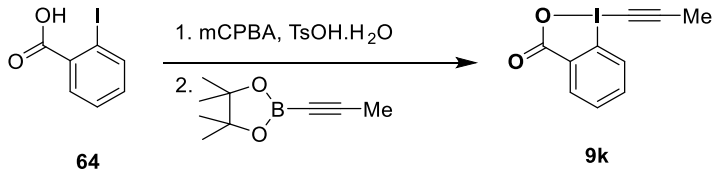
1-[2-Bromophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (9j)



64 **75** **9j**

Following a reported procedure,[21] trimethylsilyl triflate (1.0 mL, 5.5 mmol, 1.1 equiv) was added to a suspension of 2-iodosylbenzoic acid (**64**) (1.32 g, 5.00 mmol, 1.00 equiv) in CH_2Cl_2 (15 mL) at room temperature. The resulting suspension was stirred for 1 h, followed by the drop wise addition of ((2-bromophenyl)ethynyl)trimethylsilane (**75**) (1.17 g, 5.50 mmol, 1.10 equiv). The resulting suspension was stirred for 6 h at room temperature. A saturated solution of $NaHCO_3$ (20 mL) was then added and the mixture was stirred vigorously for 30 min, the two layers were separated and the organic layer was washed with saturated solution of $NaHCO_3$ (20 mL), dried over $MgSO_4$, filtered and evaporated under reduced pressure. The resulting solid was boiled in CH_3CN (*ca* 20 mL). The mixture was cooled down, filtered and dried under high vacuum to afford **9j** as a white solid (1.50 g, 3.51 mmol, 70%). Mp (Dec.): 174.0-177.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.44 (td, *J* = 7.3, 2.1 Hz, 2H, Ar*H*), 7.84–7.74 (m, 2H, Ar*H*), 7.68 (d, *J* = 1.1 Hz, 1H, Ar*H*), 7.61 (dd, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 7.36 (dtd, *J* = 22.4, 7.5, 1.5 Hz, 2H, Ar*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 135.2, 134.7, 133.0, 132.7 , 131.8, 131.3, 127.6, 126.8, 126.4, 123.2, 116.5, 104.3, 55.4; IR ν 2358 (w), 2155 (w), 1638 (s), 1616 (m), 1585 (w), 1466 (w), 1316 (m), 1147 (w). The characterization data corresponded to the reported values.[21]

Propynyl-1,2-benziodoxol-3(1*H*)-one (9k)



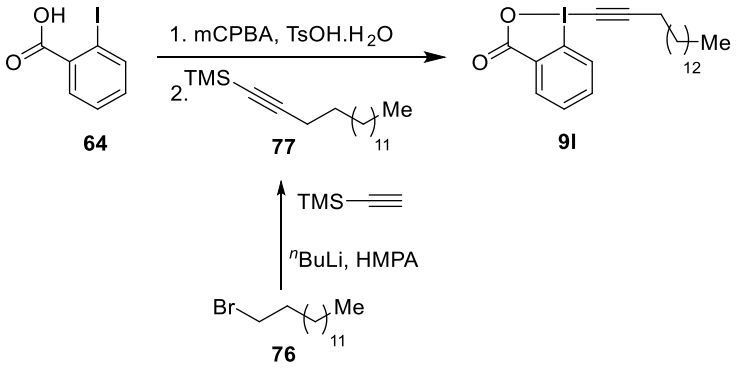
64 **9k**

Following a reported procedure,[24] 2-iodobenzoic acid (**64**) (1.07 g, 4.30 mmol, 1.00 equiv), *para*-toluenesulfonic acid monohydrate ($TsOH{\cdot}H_2O$, 818 mg, 4.30 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (*m*CPBA-70%, 1.17 g, 4.73 mmol, 1.10 equiv) were dissolved in CH_2Cl_2 (7 mL) and 2,2,2-trifluoroethanol (7 mL). The mixture was stirred at room temperature under nitrogen for 1 h, after which propynyl-1-boronic acid pinacol ester (4.85 g, 21.2 mmol, 1.40 equiv) was added in one portion. The reaction mixture was stirred for 2.5 h at room temperature, filtered and concentrated *in vacuo*. The resulting oil was dissolved in CH_2Cl_2 (30 mL) and under vigorous stirring, saturated aq.

[24] R. Frei, M. D. Wodrich, D. P. Hari, P. A. Borin, C. Chauvier, J. Waser, *J. Am. Chem. Soc.* **2014**, *136*, 16563.

$NaHCO_3$ (30 mL) was added. The mixture was stirred for 15 min, the two layers were separated and the aqueous phase was extracted with additional portions of CH_2Cl_2 (3 x 25 mL). The combined organic layers were washed with brine (25 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography using ethyl acetate to afford **9k** as a white solid (1.03 g, 3.60 mmol, 84%). TLC (EtOAc): R_f = 0.10, $KMnO_4$; Mp (Dec) 124-150 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.41-8.35 (m, 1 H, Ar*H*), 8.22-8.14 (m, 1 H, Ar*H*), 7.79-7.68 (m, 2 H, Ar*H*), 2.27 (s, 3 H, CCC*H*$_3$); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.7, 134.8, 132.5, 131.6, 126.4, 115.6, 105.1, 39.0, 5.7. IR ν 2183 (w), 1607 (s), 1559 (m), 1350 (m), 746 (m), 730 (m). HRMS (ESI) $C_{10}H_8IO_2^+$ $[M+H]^+$ calc. = 286.9564; $[M+H]^+$ obs. = 286.9561. The characterization data corresponded to the reported values.[24]

Hexadecynyl-1,2-benziodoxol-3(1*H*)-one (9l)

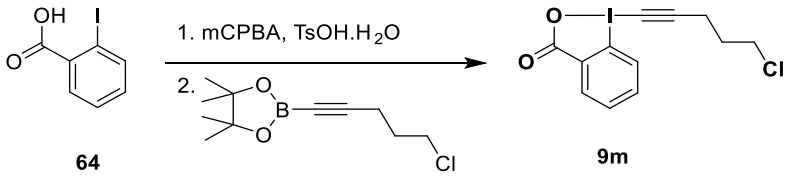


Following a reported procedure,[24] to a mixture of trimethylsilylacetylene (8.33 g, 85.0 mmol, 1.20 equiv) and dry THF (46 mL) was added at -78 °C under nitrogen 2.5 M ^{n}BuLi in hexanes (33.9 mL, 85.0 mmol, 1.20 equiv) over 10 min. The resulting light yellow solution was stirred at -78 °C for 1 h, after which a mixture consisting of 1-bromotetradecane (**76**) (19.6 g, 70.7 mmol, 1.00 equiv), hexamethylphosphoramide (HMPA, 14.2 mL, 78.0 mmol, 1.10 equiv) and dry THF (23 mL) was slowly added *via* cannula over 20 min. The reaction mixture was stirred for 1 h at -78 °C, followed by 24 h of stirring at room temperature. The reaction was quenched at 0 °C with saturated aq. NH_4Cl (50 mL) and diluted with water (10 mL) and EtOAc (50 mL). The two layers were separated and the aq. layer was extracted with additional portions of EtOAc (3 x 50 mL). The combined organic layers were washed with water (2 x 100 mL), brine (100 mL), dried over $MgSO_4$, filtered and concentrated in vacuo. The light brown crude liquid was finally pushed through a small plug of silica gel with pentane as eluent to afford pure hexadec-1-yn-1-yltrimethylsilane (**77**) as a colorless liquid (19.3 g, 65.5 mmol, 92.7% yield). TLC (pentane): R_f = 0.78, $KMnO_4$; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.19 (t, *J* = 7.1 Hz, 2H, CCC*H*$_2$), 1.54-1.44 (m, 2H, C*H*$_2$), 1.42-1.18 (m, 22H, C*H*$_2$), 0.87 (t, *J* = 6.7 Hz, 3H, CH_2CH_3), 0.13 (s, 9H, TMS); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 107.7, 84.3, 32.2, 29.9, 29.8, 29.7, 29.6, 29.3, 29.0, 28.9, 22.9, 20.0, 14.3, 0.3; IR ν 2924 (m),

2854 (m), 2175 (w), 1461 (w), 1249 (w), 910 (w), 841 (s), 761 (w), 736 (m). The characterization data corresponded to the reported values.[24]

Following a reported procedure,[24] 2-iodobenzoic acid (**64**) (8.00 g, 32.2 mmol, 1.00 equiv), *para*-toluenesulfonic acid monohydrate ($TsOH.H_2O$, 6.13 g, 32.2 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (mCPBA-70%, 8.74 g, 35.5 mmol, 1.10 equiv) were dissolved in CH_2Cl_2 (60 mL) and 2,2,2-trifluoroethanol (60 mL). The mixture was stirred at room temperature under nitrogen for 1 h, after which hexadec-1-yn-1-yltrimethylsilane (**77**) (13.3 g, 45.1 mmol, 1.40 equiv) was added in one portion. The reaction mixture was stirred for 14 h at room temperature, filtered and concentrated in vacuo. The resulting oil was dissolved in CH_2Cl_2 (400 mL) and under vigorous stirring, saturated solution of $NaHCO_3$ (400 mL) was added. The mixture was stirred for 1 h, the two layers were separated and the aqueous layer was extracted with additional portions of CH_2Cl_2 (3 x 100 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated in vacuo. The crude product was purified by flash column chromatography using EtOAc to afford **9l** as a white solid (6.02 g, 12.9 mmol, 40%). TLC (EtOAc): R_f = 0.36, $KMnO_4$; Mp: 102.6–105.3 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44-8.37 (m, 1H, Ar*H*), 8.21-8.14 (m, 1H, Ar*H*), 7.80-7.70 (m, 2H, Ar*H*), 2.59 (t, *J* = 7.1 Hz, 2H, CCC*H*$_2$), 1.65 (p, *J* = 7.1 Hz, 2H, CCCH$_2$C*H*$_2$), 1.52-1.40 (m, 2H), 1.39-1.19 (m, 20H, C*H*$_2$), 0.86 (t, *J* = 6.7 Hz, 3H, CH$_2$C*H*$_3$); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.6, 134.7, 132.5, 131.7, 131.6, 126.2, 115.7, 109.9, 39.5, 32.1, 29.8, 29.7, 29.6, 29.5, 29.2, 29.1, 28.3, 22.8, 20.6, 14.3; IR ν 2924 (s), 2853 (m), 2166 (w), 1649 (m), 1623 (m), 1439 (w), 908 (m), 736 (s). The characterization data corresponded to the reported values.[24]

(5-Chloropent-1-ynyl)-1,2-benziodoxol-3(1*H*)-one (9m)

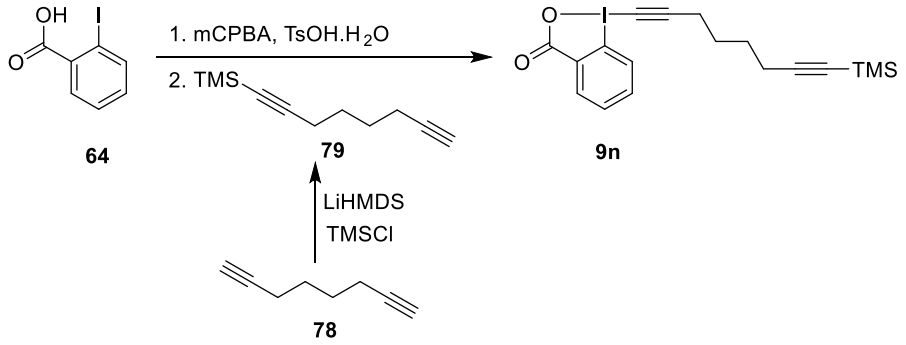


64 **9m**

Following a reported procedure,[24] 2-iodobenzoic acid (**64**) (3.76 g, 15.2 mmol, 1.00 equiv), *para*-toluenesulfonic acid monohydrate ($TsOH.H_2O$, 2.88 g, 15.2 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (*m*CPBA-70%, 4.11 g, 16.7 mmol, 1.10 equiv) were dissolved in CH_2Cl_2 (30 mL) and 2,2,2-trifluoroethanol (30 mL). The mixture was stirred at room temperature under nitrogen for 1 h, after which 5-chloro-1-pentynyl-1-boronic acid pinacol ester (4.85 g, 21.2 mmol, 1.40 equiv) was added in one portion. The reaction mixture was stirred for 90 min at room temperature, filtered and concentrated in vacuo. The resulting oil was dissolved in CH_2Cl_2 (15 mL) and under vigorous stirring, saturated solution of $NaHCO_3$ (15 mL) was added. The mixture was stirred for 10 min, the two layers were separated and the aqueous layer was extracted with additional portions of CH_2Cl_2 (3 x 15 mL). The

combined organic layers were dried over $MgSO_4$, filtered and concentrated in vacuo. The crude product was purified by flash column chromatography using ethyl acetate to afford **9m** as a white solid (3.76 g, 10.8 mmol, 71%). TLC (EtOAc): R_f = 0.15, $KMnO_4$; Mp: 138.5–141.7 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.41-8.34 (m, 1H, Ar*H*), 8.22-8.13 (m, 1H, Ar*H*), 7.82-7.68 (m, 2H, Ar*H*), 3.71 (t, *J* = 6.1 Hz, 2H, $ClCH_2CH_2$), 2.82 (t, *J* = 6.9 Hz, 2H, $CCCH_2CH_2$), 2.18-2.05 (m, 2H, $ClCH_2CH_2$); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.8, 134.9, 132.5, 131.6, 131.6, 126.4, 115.8, 107.1, 43.4, 41.2, 30.7, 18.0; IR ν 2942 (w), 2866 (w), 2171 (w), 2091 (w), 1727 (w), 1617 (s), 1556 (w), 1441 (w), 1339 (m), 1213 (w), 1023 (w), 846 (w), 742 (s). The characterization data corresponded to the reported values.[24]

8-(Trimethylsilyl)octa-1,7-diyn-1-yl-1,2-benziodoxol-3(1*H*)-one (9n)



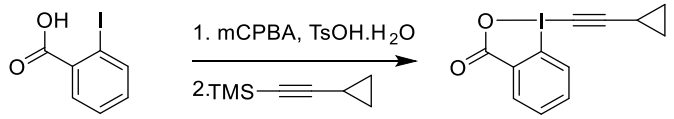
Following a reported procedure,[25] to a solution of 1,7-octadiyne **78** (10.6 g, 100 mmol, 1.00 equiv) in dry THF (150 mL) was added at -78 °C under nitrogen 1 M lithium bis(trimethylsilyl)amide in THF (LiHMDS, 100 mL, 100 mmol, 1.00 equiv). The solution was stirred at -78 °C for 30 min, after which trimethylsilyl chloride (TMSCl, 13.0 mL, 100 mmol, 1.00 equiv) was added dropwise. The reaction was warmed to room temperature and stirred for 2 h. The reaction was cooled to 0 °C and quenched by adding water (10 mL). The mixture was diluted with 1 M HCl (200 mL) and extracted with diethyl ether (100 mL and 2 x 75 mL). The combined organic layers were washed with brine (200 mL), dried over $MgSO_4$, filtered and concentrated in vacuo. The crude product was purified by vacuum distillation using a 20 cm Vigreux column (oil bath set to 98 °C at 0.3 mbar) furnishing pure trimethyl(octa-1,7-diyn-1-yl)silane (**79**) as a colorless liquid (8.37 g, 46.9 mmol, 47%). TLC (pentane): R_f = 0.2, $KMnO_4$; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.28-2.17 (m, 4H), 1.93 (t, *J* = 2.7 Hz, 1H, CC*H*), 1.68-1.57 (m, 4H), 0.13 (s, 9H, TMS); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 107.0, 84.9, 84.2, 68.6, 27.7, 27.6, 19.5, 18.1, 0.3; IR ν 3309 (w), 2951 (w), 2175 (w), 1250 (m), 912 (w), 841 (s), 761 (m), 734 (m). The characterization data corresponded to the reported values.[25]

Following a reported procedure,[25] 2-iodobenzoic acid (**64**) (8.43 g, 33.3 mmol, 1.00 equiv), *para*-toluenesulfonic acid monohydrate ($TsOH.H_2O$, 6.40 g, 33.3 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (mCPBA-70%, 9.04 g, 36.7 mmol, 1.10 equiv) were dissolved in CH_2Cl_2 (60 mL)

[25] D. P. Hari, J. Waser, *J. Am. Chem. Soc.* **2016**, *138*, 2190.

and 2,2,2-trifluoroethanol (60 mL). The mixture was stirred at room temperature under nitrogen for 1 h, after which trimethyl(octa-1,7-diyn-1-yl)silane (**79**) (8.32 g, 46.7 mmol, 1.40 equiv) was added. The reaction mixture was stirred for 15 h at room temperature and then filtered and concentrated in vacuo. The resulting light being solid was dissolved in CH_2Cl_2 (500 mL) and under vigorous stirring, saturated solution of $NaHCO_3$ (500 mL) was added. The mixture was stirred for 1 h, the two layers were separated and the aqueous layer was extracted with additional portions of CH_2Cl_2 (3 x 150 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated in vacuo. The crude product was purified by flash column chromatography using ethyl acetate to afford **9n** as a white solid (4.2 g, 9.9 mmol, 30%). Mp: 152.3–155.6 °C; TLC (EtOAc:MeOH, 9:1 v/v): R_f = 0.59, $KMnO_4$; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.37 (dd, *J* = 6.7, 2.3 Hz, 1H, Ar*H*), 8.17 (dd, *J* = 7.8, 1.5 Hz, 1H, Ar*H*), 7.82-7.66 (m, 2H, Ar*H*), 2.63 (t, *J* = 6.8 Hz, 2H,), 2.29 (t, *J* = 6.7 Hz, 2H), 1.83-1.62 (m, 4H), 0.13 (s, 9H, TMS); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.7, 134.8, 132.4, 131.7, 131.5, 126.3, 115.7, 109.1, 106.4, 85.4, 40.0, 27.7, 27.3, 20.2, 19.4, 0.3; IR ν 2955 (w), 2170 (w), 1647 (m), 1621 (s), 1439 (w), 1329 (m), 1296 (w), 1249 (m), 840 (s), 746 (s). The characterization data corresponded to the reported values.[25]

2-Cyclopropylethynyl-1,2-benziodoxol-3(1*H*)-one (9o)

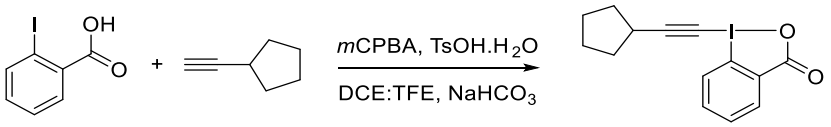


64 **9o**

Following a reported procedure,[25] 2-iodobenzoic acid (**64**) (6.41 g, 25.8 mmol, 1.00 equiv), *para*-toluenesulfonic acid monohydrate ($TsOH{\cdot}H_2O$, 4.91 g, 25.8 mmol, 1.00 equiv) and *meta*-chloroperoxybenzoic acid (*m*CPBA-70%, 7.00 g, 28.4 mmol, 1.10 equiv) were dissolved in CH_2Cl_2 (48 mL) and 2,2,2-trifluoroethanol (48 mL). The mixture was stirred at room temperature under nitrogen for 1 h, after which (cyclopropylethynyl)trimethylsilane (5.00 g, 36.2 mmol, 1.40 equiv) was added in one portion. The reaction mixture was stirred for 12 h at room temperature, filtered and concentrated in vacuo. The resulting oil was dissolved in CH_2Cl_2 (400 mL) and under vigorous stirring, a saturated solution of $NaHCO_3$ (400 mL) was added. The mixture was stirred for 1 h, the two layers were separated and the aqueous layer was extracted with additional portions of CH_2Cl_2 (3 x 100 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated in vacuo. The crude product was purified by flash column chromatography using ethyl acetate to afford **9o** as a white solid (2.11 g, 6.76 mmol, 26 %). Mp (Dec.): 174.2–177.6 °C; TLC (EtOAc:MeOH, 9:1 v/v): R_f = 0.46, $KMnO_4$; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.34 (dd, *J* = 7.0, 2.1 Hz, 1H, Ar*H*), 8.18-8.09 (m, 1H, Ar*H*), 7.81-7.63 (m, 2H, Ar*H*), 1.59 (tt, *J* = 8.2, 5.0 Hz, 1H, C*H*), 1.07-0.85 (m, 4H, CH_2CH_2); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.7, 134.7, 132.3, 131.7, 131.4, 126.2, 115.9, 113.3, 35.0, 9.8, 1.1; IR ν 3464 (w), 3077 (w), 3012 (w), 2238 (w), 2159 (m), 1607 (s), 1559 (m),

1438 (m), 1338 (m), 1298 (m), 833 (m), 744 (s), 691 (m). The characterization data corresponded to the reported values.[25]

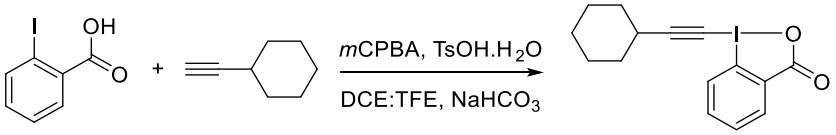
2-Cyclopentylethynyl-1,2-benziodoxol-3(1*H*)-one (9p)



64 **80** **9p**

In a sealed tube, 2-iodobenzoic acid (**64**) (1.00 g, 4.03 mmol, 1.00 equiv), 4-methylbenzenesulfonic acid (775 mg, 4.03 mmol, 1.00 equiv) and *m*CPBA (77%, 994 mg, 4.44 mmol, 1.10 equiv) were suspended in DCE:TFE 1:1 (12 mL) and stirred for 1 h at 55 °C. After 1 h, ethynylcyclopentane (**80**) (0.65 mL, 5.6 mmol, 1.4 equiv) was added and the reaction was stirred at 55 °C for 24 h. After 24 h, the solvent was evaporated and the residue was redissolved in CH_2Cl_2 (20 mL) and stirred vigorously with saturated solution of $NaHCO_3$ (30 mL). After 1 h, the reaction mixture was transferred into a separating funnel and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL). The combined organic layers were washed with saturated solution of $NaHCO_3$ (50 mL), dried over $MgSO_4$, filtered and concentrated under vacuum. The crude product was purified by flash column chromatography using ethyl acetate to afford **9p** as a white solid (0.95 g, 2.8 mmol, 70%). Mp (Dec.): 151.5–156.6 °C; TLC (EtOAc): R_f = 0.21, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.42 – 8.34 (m, 1H, Ar*H*), 8.14 (dd, *J* = 7.4, 1.8 Hz, 1H, Ar*H*), 7.79 – 7.67 (m, 2H, Ar*H*), 3.05 – 2.92 (m, 1H, CCC*H*), 2.10 – 2.00 (m, 2H, 1 x CH_2), 1.85 – 1.70 (m, 4H, 2 x CH_2), 1.69 – 1.62 (m, 2H, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 134.6, 132.3, 131.5, 131.6, 126.0, 115.6, 114.0, 38.6, 33.7, 31.5, 25.1; IR 3070 (w), 2960 (m), 2869 (w), 2239 (w), 2169 (w), 1610 (s), 1560 (m), 1440 (w), 1344 (m), 1301 (w), 1110 (w), 1010 (w), 910 (m); HRMS (ESI) calcd. for $C_{14}H_{14}IO_2^+$ $[M+H]^+$ 341.0033; found 341.0037.

2-Cyclohexylethynyl-1,2-benziodoxol-3(1*H*)-one (9q)



64 **81** **9q**

In a sealed tube, 2-iodobenzoic acid (**64**) (1.00 g, 4.03 mmol, 1.00 equiv), 4-methylbenzenesulfonic acid (775 mg, 4.03 mmol, 1.00 equiv) and *m*CPBA (77%, 994 mg, 4.44 mmol, 1.1 equiv) were suspended in DCE:TFE 1:1 (12 mL) and stirred for 1 h at 55 °C. After 1 h, ethynylcyclohexane (**81**) (0.74 mL, 5.6 mmol, 1.4 equiv) was added and the reaction was stirred at 55 °C for 24 h. After 24 h, the solvent was evaporated and the residue was redissolved in CH_2Cl_2 (20 mL) and stirred vigorously with a saturated

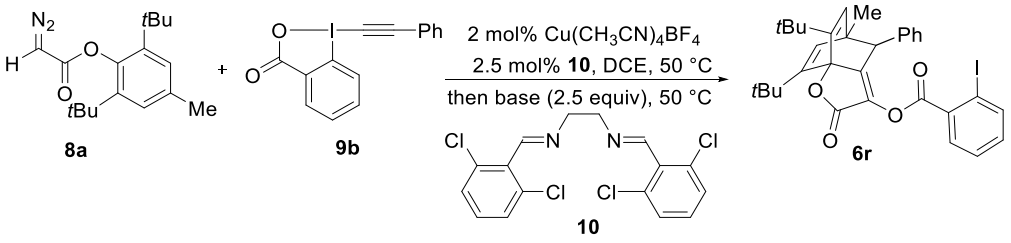
solution of $NaHCO_3$ (30 mL). After 1 h, the reaction mixture was transferred into a separating funnel and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL). The combined organic layers were washed with saturated solution of $NaHCO_3$ (50 mL), dried over $MgSO_4$, filtered and concentrated under vacuum. The crude product was purified by flash column chromatography using ethyl acetate to afford **9q** as a white solid (0.85 g, 2.4 mmol, 60%). TLC (EtOAc): R_f = 0.26, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 8.45 – 8.33 (m, 1H, Ar*H*), 8.21 – 8.10 (m, 1H, Ar*H*), 7.83 – 7.67 (m, 2H, Ar*H*), 2.80 – 2.73 (m, 1H, CCC*H*), 1.95 – 1.89 (m, 2H, 1 x C*H*$_2$), 1.81 – 1.69 (m, 2H, 1 x C*H*$_2$), 1.62 – 1.53 (m, 3H), 1.45 – 1.32 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 134.6, 132.3, 131.5, 131.4, 126.0, 115.5, 113.6, 39.1, 32.2, 30.7, 25.5, 24.7. The characterization data corresponded to the reported values.[26]

[26] M. Ochiai, Y. Masaki, M. Shiro, *J. Org. Chem.* **1991**, *56*, 5511.

4. Optimization of the reaction conditions for Ph-EBX

a) Screening of bases

A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (0.15 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.30 mmol, 2.0 equiv) and dry DCE (2 mL) in a 5 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, base (0.375 mmol, 2.50 equiv) was added and the reaction mixture was stirred at 50 °C. After the reaction was completed (monitored by TLC, Et_2O; pentane, 1:10 v/v), the reaction mixture was filtered, evaporated under reduced pressure and the crude product was purified by flash column chromatography (Et_2O:pentane, 1:20 v/v) directly without any further work-up.

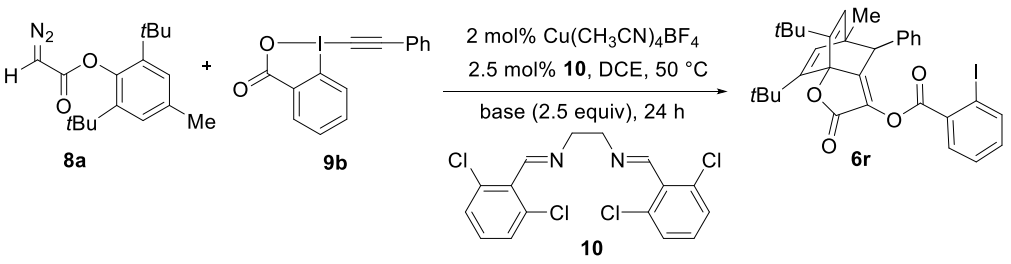


8a 9b 10 6r

Entry	Base	Time	Yield (%)
1	K_3PO_4	20 h	85
2	Cs_2CO_3	1 h	88
3	K_2CO_3	16 h	84
4	DBU	1 h	decomposition

b) Pre-addition of base

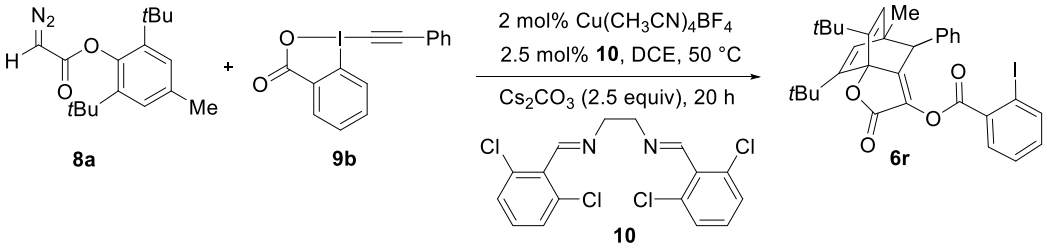
A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (0.15 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.30 mmol, 2.0 equiv), base (0.375 mmol, 2.50 equiv) and dry DCE (2 mL) in a 5 mL microwave vial over 2 min and the resulting reaction mixture was stirred for 14 h at 50 °C. After 24 h, no product formation was observed by TLC (Et_2O;pentane, 1:10 v/v).



Entry	Base	Yield (%)
1	K_3PO_4	0
2	Cs_2CO_3	0
3	K_2CO_3	0
4	DBU	0

c) Screening of temperature

A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (0.15 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.30 mmol, 2.0 equiv) and dry DCE (2 mL) in 5 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, Cs_2CO_3 (0.375 mmol, 2.50 equiv) was added and the reaction mixture was stirred. After 20 h, the reaction mixture was filtered, evaporated under reduced pressure and the crude product was purified by flash chromatography (Et_2O:pentane, 1:20 v/v) directly without any further work-up.

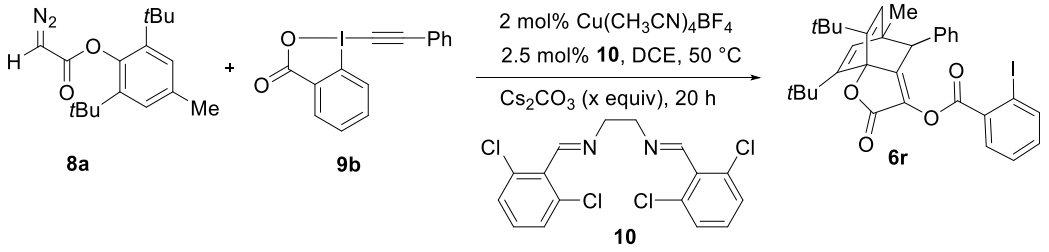


8a 9b 10 6r

Entry	T	Yield (%)
1	RT	88
2	35 °C	87
3	50 °C	88

d) Screening of equivalents of Cs_2CO_3

A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (0.15 mmol, 1.0 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.30 mmol, 2.0 equiv) in dry DCE (2 mL) in 5 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, Cs_2CO_3 (x equiv) was added and the reaction mixture stirred at room temperature. After 20 h, the reaction mixture was filtered, evaporated under reduced pressure and the crude product was purified by flash column chromatography (Et_2O:pentane, 1:20 v/v) directly without any further work-up.

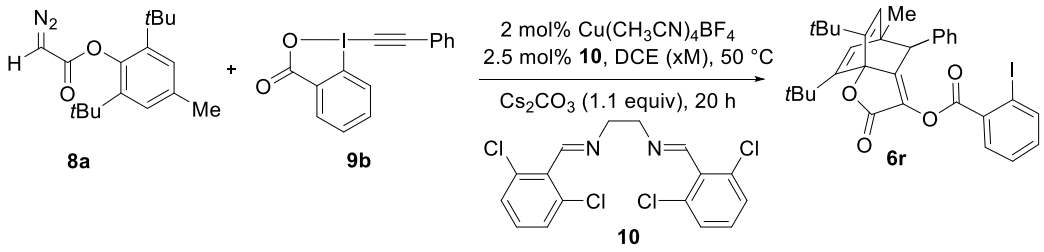


8a 9b 10 6r

Entry	Cs_2CO_3 (x equiv)	Yield (%)
1	2.5	88
2	2	87
3	1.1	87

e) Screening of concentration

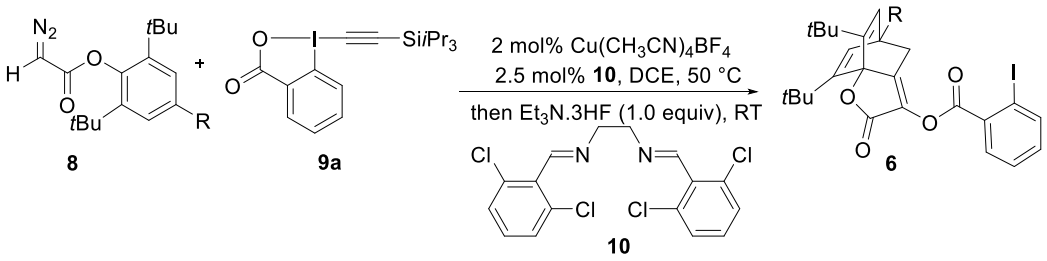
A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (0.15 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.30 mmol, 2.0 equiv) and dry DCE (x M) over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, Cs_2CO_3 (0.165 mmol, 1.10 equiv) was added and the reaction mixture stirred at room temperature. After 20 h, the reaction mixture was filtered, evaporated under reduced pressure and the crude product was purified by flash column chromatography (Et_2O:pentane, 1:20 v/v) directly without any further work-up.



Entry	Concentration (x M)	Yield (%)
1	0.1	82
2	0.05	87
3	0.025	92

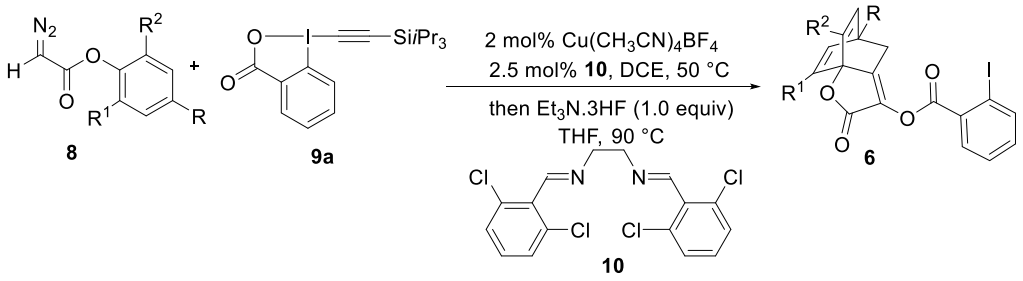
5. One-pot oxy-alkynylation/Himbert reaction

General procedure A



A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (0.15 mmol, 1.0 equiv), diazo compound **8** (0.18 mmol, 1.2 equiv) and dry DCE (5 mL) in 20 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C. Next, the reaction mixture was cooled down to room temperature and triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture was stirred. After the reaction was completed (monitored by TLC, EtOAc:pentane or Et_2O:pentane), the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (EtOAc:pentane or Et_2O:pentane) directly without any further work-up.

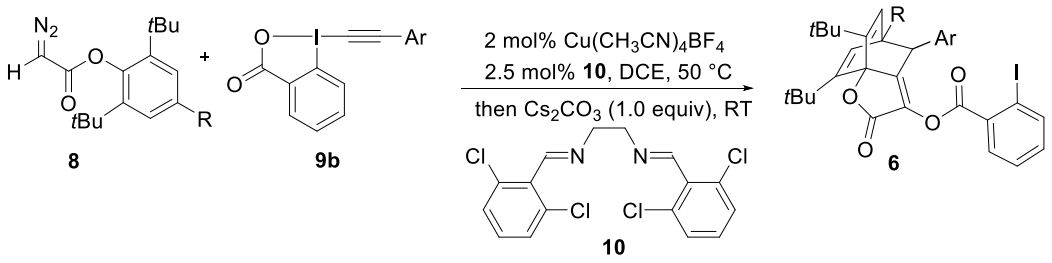
General procedure B



A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (0.15 mmol, 1.0 equiv), diazo compound **8** (0.18 mmol, 1.2 equiv) and dry DCE (5 mL) in 20 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C. The solvent was evaporated and the residue was filtered through a small plug of silica gel using Et_2O (*ca* 15 mL). The Et_2O was evaporated and the crude redissolved in THF (6 mL) in a 20 mL microwave vial. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture stirred at 90 °C. After the reaction was completed (monitored by TLC, EtOAc:pentane or Et_2O:pentane), the

solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (EtOAc:pentane or Et_2O:pentane) directly without any further work-up.

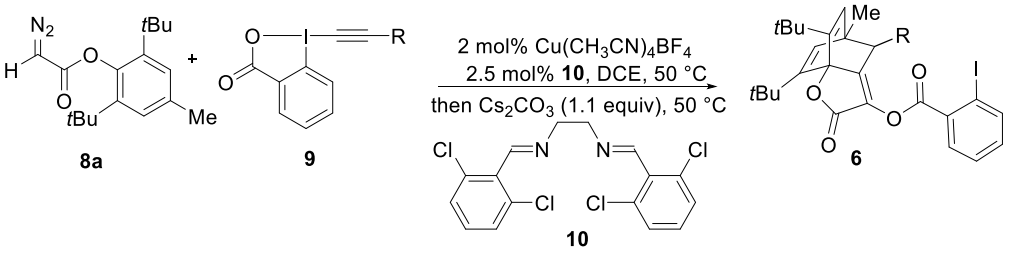
General procedure C



8 9b 10 6

A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of Ph-EBX (**9b)** (0.15 mmol, 1.0 equiv), diazo compound **8** (0.18 mmol, 1.2 equiv) and dry DCE (5 mL) in 20 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C. Next, the reaction mixture was cooled down to room temperature and Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture was stirred. After the reaction was completed (monitored by TLC, EtOAc:pentane or Et_2O:pentane), the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (EtOAc:pentane or Et_2O:pentane) directly without any further work-up.

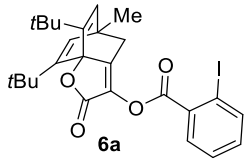
General procedure D



8a 9 10 6

A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.0 mg, 3.0 µmol, 0.02 equiv), ligand **10** (1.4 mg, 3.8 µmol, 0.025 equiv) and dry DCE (1 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of R-EBX **(9)** (0.15 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (0.18 mmol, 1.2 equiv) and dry DCE (5 mL) in 20 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture was stirred at 50 °C. After the reaction was completed (monitored by TLC, EtOAc:pentane or Et_2O:pentane), the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (EtOAc:pentane or Et_2O:pentane) directly without any further work-up.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6a)

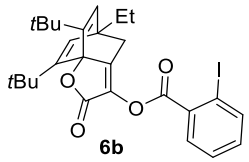


6a

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (52 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6a** as a white solid (75.0 mg, 0.141 mmol, 94%). Mp: 162.3–162.7 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.37, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 – 8.02 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 5.81 (s, 2H, 2 x *t*BuCC*H*), 2.36 (s, 2H, $CH_3CC\mathit{H_2}$), 1.62 (s, 3H, $CHCC\mathit{H_3}$), 1.16 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.1, 162.1, 157.8, 151.3, 141.7, 133.7, 132.5, 132.2, 132.2, 129.4, 128.1, 95.0, 92.9, 41.6, 38.6, 35.2, 29.1, 22.2; IR ν 3058 (w), 2961 (w), 2871 (w), 1783 (s), 1758 (m), 1718 (w), 1692 (w), 1583 (w), 1472 (w), 1365 (w), 1333 (w), 1292 (w), 1233 (s), 1155 (m), 1086 (s), 1057 (m), 1004 (s), 923 (w); HRMS (ESI) calcd. for $C_{26}H_{30}IO_4^+$ $[M+H]^+$ 533.1183; found 533.1191.

Large scale procedure: Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (860 mg, 2.00 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (692 mg, 2.40 mmol, 1.20 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (0.33 mL, 2.0 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6a** as a white solid (1.00 g, 1.88 mmol, 94%).

7,8-Di-*tert*-butyl-5-ethyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6b)

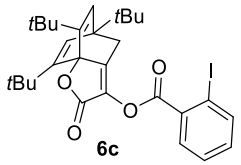


6b

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-ethylphenyl 2-diazoacetate (**8b**) (54.4 mg, 0.180 mmol, 1.20 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture was further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6b** as a white solid (79.0 mg, 0.145 mmol, 96%). Mp: 164.0–166.5 °C; TLC (Et_2O:pentane, 1:10

v/v): R_f = 0.39, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 – 8.02 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.7, 1.2 Hz, 1H, Ar*H*), 7.20 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.88 (s, 2H, 2 x *t*BuCC*H*), 2.34 (s, 2H, EtCCH_2), 1.97 (q, *J* = 7.5 Hz, 2H, CH_2CH$_3$), 1.20 – 1.12(m, 21H, 2 x *t*Bu and CH$_2$CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.1, 157.8, 151.5, 141.7, 133.6, 132.6, 132.2, 130.2, 129.7, 128.1, 94.9, 92.7, 46.1, 36.1, 35.4, 29.2, 28.1, 9.6; IR ν 3063 (w), 2962 (m), 2871 (w), 2255 (w), 1778 (s), 1710 (w), 1583 (w), 1464 (m), 1429 (w), 1363 (w), 1273 (m), 1236 (s), 1191 (m), 1088 (s), 1008 (s), 913 (m); HRMS (ESI) calcd. for $C_{27}H_{31}INaO_4^+$ $[M+Na]^+$ 569.1159; found 569.1173.

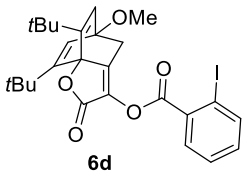
5,7,8-Tri-*tert*-butyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6c)



6c

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,4,6-tri-*tert*-butylphenyl 2-diazoacetate (**8c**) (59.5 mg, 0.180 mmol, 1.20 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 24 h at 50 °C. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6c** as a white solid (72.0 mg, 0.125 mmol, 84%). Mp: 183.0–187.5 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.4, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 7.9, 3.7, 1.4 Hz, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.20 (td, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 6.04 (s, 2H, 2 x *t*BuCC*H*), 2.39 (s, 2H, EtCCH_2), 1.17 (s, 18H, 2 x *t*Bu), 1.14 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.1, 162.2, 158.6, 151.3, 141.7, 133.6, 132.6, 132.2, 129.7, 128.3, 128.1, 94.9, 92.2, 52.6, 35.5, 32.5, 31.9, 29.2, 26.4; IR ν 3081 (w), 2961 (m), 2871 (w), 2255 (w), 1782 (s), 1711 (w), 1584 (w), 1467 (w), 1430 (w), 1359 (w), 1274 (w), 1234 (s), 1190 (m), 1141 (m), 1084 (s), 1035 (w), 1008 (m), 911 (s), 832 (w); HRMS (ESI) calcd. for $C_{29}H_{36}IO_4^+$ $[M+H]^+$ 575.1653; found 575.1660.

7,8-Di-*tert*-butyl-5-methoxy-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6d)

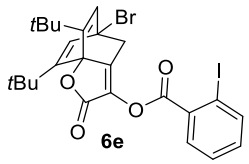


6d

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methoxyphenyl 2-diazoacetate (**8d**) (59 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified

by flash chromatography using Et_2O:pentane 1:10 as mobile phase to afford **6d** as a white solid (70.0 mg, 0.128 mmol, 85%). Mp: 159.5–160.8 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.23, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): 8.06 – 8.01 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.18 (s, 2H, 2 x *t*BuCC*H*), 3.61 (s, 3H, OCH_3), 2.67 (s, 2H, OCH_3CCH_2), 1.18 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.6, 162.1, 154.2, 149.7, 141.7, 133.7, 132.5, 132.8, 129.6, 128.2, 128.1, 94.9, 91.3, 82.6, 53.4, 35.7, 35.4, 29.0; IR ν 3060 (w), 2996 (w), 2960 (m), 2870 (w), 2835 (w), 1767 (s), 1706 (m), 1635 (w), 1584 (w), 1563 (w), 1469 (w), 1427 (w), 1392 (w), 1363 (w), 1310 (m), 1273 (m), 1240 (s), 1191 (m), 1137 (m), 1089 (s), 1029 (m), 1008 (m), 966 (w), 932 (w); HRMS (ESI) calcd. for $C_{26}H_{30}IO_5^+$ $[M+H]^+$ 549.1132; found 549.1139.

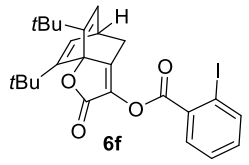
5-Bromo-7,8-di-*tert*-butyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6e)



6e

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 4-bromo-2,6-di-*tert*-butylphenyl 2-diazoacetate (**8e**) (64 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6e** as a white solid (74.0 mg, 0.124 mmol, 83%). Mp: 146.5–147.5 °C; TLC (Et_2O:pentane, 1:20 v/v): R_f = 0.28, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 7.8, 3.0, 1.4 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.21 (s, 2H, 2 x *t*BuCC*H*), 3.04 (s, 2H, $BrCCH_2$), 1.18 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.1, 161.9, 153.7, 151.1, 141.8, 133.9, 132.2, 132.2, 132.1, 128.8, 128.1, 95.1, 90.8, 53.9, 43.1, 35.4, 28.9; IR ν 2997 (w), 2963 (w), 2869 (w), 2259 (w), 1789 (s), 1766 (m), 1705 (w), 1583 (w), 1466 (w), 1365 (w), 1275 (w), 1236 (s), 1189 (w), 1124 (m), 1081 (s), 1035 (w), 1007 (m), 911 (m); HRMS (ESI) calcd. for $C_{25}H_{26}BrINaO_4^+$ $[M+Na]^+$ 618.9951; found 618.9958.

7,8-Di-*tert*-butyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6f)

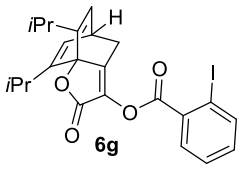


6f

Following general procedure **A**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butylphenyl 2-diazoacetate (**8f**) (50 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and

the reaction mixture further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:15 as mobile phase to afford **6f** as a white solid (72.0 mg, 0.138 mmol, 92%). Mp: 146.5–147.8 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.31, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 8.1, 6.8, 1.4 Hz, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.10 (d, *J* = 6.5 Hz, 2H, 2 x *t*BuCC*H*), 3.88 – 3.83 (m, 1H, CHC*H*CH_2), 2.48 (d, *J* = 2.6 Hz, 2H, CHCH_2), 1.17 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.1, 156.2, 151.4, 141.7, 133.6, 132.7, 132.2, 130.4, 128.1, 126.6, 94.9, 92.7, 36.4, 35.4, 31.6, 29.2; IR ν 3070 (w), 2961 (w), 2870 (w), 1779 (s), 1710 (w), 1584 (w), 1465 (w), 1428 (w), 1363 (w), 1269 (m), 1233 (s), 1174 (m), 1128 (s), 1075 (s), 1030 (m), 1008 (s), 966 (w); HRMS (ESI) calcd. for $C_{25}H_{28}IO_4^+$ $[M+H]^+$ 519.1027; found 519.1044.

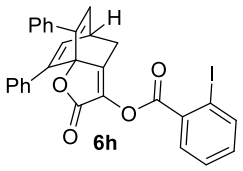
7,8-Di*iso*propyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6g)



6g

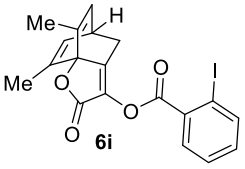
Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di*iso*propylphenyl 2-diazoacetate (**8g**) (44 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 24 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:15 as mobile phase to afford **6g** as a white solid (66.0 mg, 0.135 mmol, 90%). Mp: 99.1–100.3 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.3, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 8.06 – 8.02 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.05 (dd, *J* = 6.3, 1.4 Hz, 2H, 2 x *i*PrCC*H*), 3.92 (tt, *J* = 6.3, 2.6 Hz, 1H, CHC*H*CH_2), 2.62 – 2.55 (m, 2H, CH_3CHCH_3), 2.46 (d, *J* = 2.6 Hz, 2H, CHCH_2), 1.10 (d, *J* = 6.9 Hz, 6H, *i*Pr), 1.03 (d, *J* = 6.7 Hz, 6H, *i*Pr); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.1, 162.0, 154.0, 149.9, 141.7, 133.7, 132.4, 132.2, 129.5, 128.1, 125.7, 95.0, 90.5, 36.8, 32.2, 27.9, 21.9, 21.4; IR ν 3063 (w), 2964 (m), 2931 (w), 2872 (w), 1779 (s), 1709 (w), 1583 (w), 1465 (w), 1430 (w), 1270 (m), 1235 (s), 1174 (m), 1098 (s), 1071 (s), 1009 (m), 957 (w), 916 (w); HRMS (ESI) calcd. for $C_{23}H_{24}IO_4^+$ $[M+H]^+$ 491.0714; found 491.0718. Three carbons were resolved from two *i*Pr groups at 100 MHz.

2-Oxo-7,8-diphenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6h)



Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and [1,1':3',1''-terphenyl]-2'-yl 2-diazoacetate (**8h**) (57 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 30 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:4 as mobile phase to afford **6h** as a white solid (60.0 mg, 0.107 mmol, 71%). Mp: 172.5–175.6 °C; TLC (Et_2O:pentane, 1:2 v/v): R_f = 0.4, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (dd, *J* = 4.2, 1.4 Hz, 1H, Ar*H*), 7.93 (dd, *J* = 4.1, 1.4 Hz, 1H, Ar*H*), 7.38 – 7.19 (m, 11H, Ar*H*), 7.12 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.54 (d, *J* = 6.3 Hz, 2H, 2 x PhCC*H*), 4.12 (tt, *J* = 6.4, 2.6 Hz, 1H, CHC*H*CH_2), 2.72 (d, *J* = 2.6 Hz, 2H, CHC*H*$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.9, 161.8, 152.3, 144.2, 141.8, 133.8, 133.6, 132.2, 132.1, 131.5, 130.3, 128.4, 128.2, 128.1, 95.1, 88.6, 37.9, 31.9; IR ν 3056 (w), 2954 (w), 2919 (m), 2854 (w), 2249 (w), 1946 (w), 1780 (s), 1760 (s), 1713 (w), 1582 (w), 1492 (w), 1465 (w), 1427 (w), 1264 (m), 1234 (s), 1183 (m), 1097 (s), 1031 (w), 1008 (m), 960 (w), 911 (m); HRMS (ESI) calcd. for $C_{29}H_{19}INaO_4^+$ $[M+Na]^+$ 581.0220; found 581.0224.

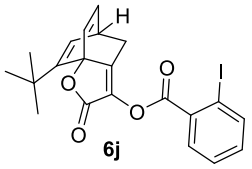
7,8-Dimethyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6i)



Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-dimethylphenyl 2-diazoacetate (**8i**) (34.5 mg, 0.180 mmol, 1.20 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 30 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:10 as mobile phase to afford **6i** as a white solid (55.0 mg, 0.127 mmol, 84%). Mp: 127.6–128.9 °C; TLC (Et_2O:pentane, 1:5 v/v): R_f = 0.37, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 (dd, *J* = 5.2, 1.6 Hz, 1H, Ar*H*), 8.04 (dd, *J* = 5.3, 1.7 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.7, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.09 (dq, *J* = 6.2, 1.7 Hz, 2H, 2 x CH_3CC*H*), 3.85 (tt, *J* = 6.2, 2.6 Hz, 1H, CHC*H*CH_2), 2.47 (d, *J* = 2.6 Hz, 2H, CHC*H*$_2$), 1.85 (d, *J* = 1.7 Hz, 6H, 2 x C*H*$_3$CCH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.0, 152.2, 141.8, 139.5, 133.8, 132.2, 129.4, 128.6, 128.1, 95.1, 89.9, 37.5, 32.5, 14.4; IR ν 3051 (w), 2977 (w), 2944 (w), 2916 (w), 2257 (w), 1779 (s), 1757 (s), 1708 (m), 1582 (w),

1562 (w), 1467 (w), 1437 (w), 1283 (m), 1234 (s), 1205 (m), 1172 (s), 1128 (m), 1086 (s), 1029 (m), 1012 (s), 912 (m); HRMS (ESI) calcd. for $C_{19}H_{16}IO_4^+$ $[M+H]^+$ 435.0088; found 435.0081. One carbon was not resolved at 100 MHz.

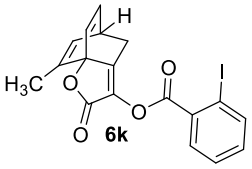
7-(*Tert*-butyl)-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6j)



6j

Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2-(*tert*-butyl)phenyl 2-diazoacetate (**8j**) (39.5 mg, 0.180 mmol, 1.20 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 30 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:10 as mobile phase to afford **6j** as a white solid (63.0 mg, 0.136 mmol, 91%). Mp: 145.3–147.3 °C; TLC (Et_2O:pentane, 1:5 v/v): R_f = 0.38, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 – 8.02 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.51 – 6.44 (m, 2H, *t*BuCC*H* and OCCHC*H*), 6.09 (d, *J* = 6.5 Hz, 1H, OCC*H*CH), 4.02 – 3.97 (m, 1H, CHC*H*CH_2), 2.58 – 2.44 (m, 2H, CHCH_2), 1.15 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 162.0, 153.5, 151.4, 141.7, 135.1, 133.7, 132.4, 132.2, 130.2, 128.1, 125.5, 95.0, 89.8, 38.1, 34.9, 31.6, 28.4; IR ν 3068 (w), 2961 (w), 2870 (w), 1781 (s), 1710 (w), 1583 (w), 1465 (w), 1429 (w), 1363 (w), 1333 (w), 1271 (m), 1236 (s), 1183 (m), 1136 (m), 1099 (s), 1059 (m), 1029 (w), 1008 (m), 951 (w); HRMS (ESI) calcd. for $C_{21}H_{20}IO_4^+$ $[M+H]^+$ 463.0401; found 463.0401. One carbon was not resolved at 100 MHz.

7-Methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6k)

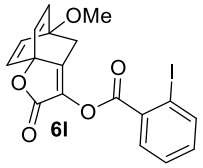


6k

Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and *o*-tolyl 2-diazoacetate (**8k**) (32 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:7 as mobile phase to afford **6k** as a colorless thick gel (35.0 mg, 0.083 mmol, 55%). TLC (Et_2O:pentane, 1:5 v/v): R_f = 0.25, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$); δ 8.10 – 8.01 (m, 2H, Ar*H*), 7.45 (t, *J* = 7.6 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.57 – 6.42 (m, 2H, OCCHC*H* and CH_3CC*H*), 6.09 (d, *J* = 5.7 Hz, 1H, OCC*H*CH), 3.99 (tt, *J* = 5.9, 2.6 Hz, 1H, C*H*CH_2), 2.62 – 2.40

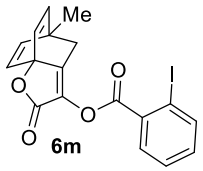
(m, 2H, CHC*H*$_2$), 1.86 (d, *J* = 1.6 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.9, 162.0, 151.7, 141.8, 140.0, 135.2, 133.8, 132.2, 132.2, 131.0, 129.7, 128.1, 127.8, 95.1, 88.5, 38.5, 32.1, 14.3; IR ν 3063 (w), 2917 (w), 1782 (s), 1759 (s), 1710 (w), 1584 (w), 1563 (w), 1466 (w), 1435 (w), 1336 (w), 1286 (m), 1236 (s), 1203 (m), 1175 (m), 1150 (m), 1096 (s), 1064 (m), 1029 (m), 1009 (m); HRMS (ESI) calcd. for $C_{18}H_{14}IO_4^+$ $[M+H]^+$ 420.9931; found 420.9937.

5-Methoxy-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (8l)



Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 4-methoxyphenyl 2-diazoacetate (**8l**) (35 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:5 as mobile phase to afford **6l** as a colorless thick gel (53.0 mg, 0.122 mmol, 81%). TLC (Et_2O:pentane, 1:3 v/v): R_f = 0.25, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 (dd, *J* = 3.3, 1.4 Hz, 1H, Ar*H*), 8.03 (dd, *J* = 3.2, 1.5 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.62 (d, *J* = 7.8 Hz, 2H, 2 x CH_3OCC*H*), 6.46 (d, *J* = 7.8 Hz, 2H, 2 x CH_3OCCHC*H*), 3.64 (s, 3H, O*C*H_3), 2.71 (s, 2H, OCH_3CC*H*$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.4, 161.9, 149.4, 141.9, 136.1, 133.9, 132.2, 132.0, 129.5, 129.4, 128.2, 95.2, 85.7, 85.2, 54.0, 36.2; IR ν 3071 (w), 2942 (w), 2836 (w), 1788 (s), 1760 (m), 1581 (w), 1564 (w), 1504 (w), 1465 (w), 1429 (w), 1352 (m), 1314 (w), 1276 (m), 1237 (s), 1198 (m), 1168 (m), 1095 (s), 1010 (m), 913 (w); HRMS (ESI) calcd. for $C_{18}H_{14}IO_5^+$ $[M+H]^+$ 436.9880; found 436.9881.

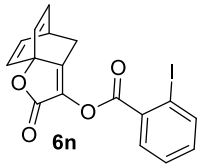
5-Methyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6m)



Following general procedure **B**, 1-[(triiso-propylsilyl)ethynyl]-1,2-benziodoxol-3(1H)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and *p*-tolyl 2-diazoacetate (**8m**) (32 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using EtOAc:pentane 1:9 as mobile phase to afford **6m** as a white solid (26.0 mg, 62.0 µmol, 41%). Mp: 128–130 °C; TLC (EtOAc:pentane, 1:9 v/v): Rf = 0.35, KMnO4; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (dt, *J* =

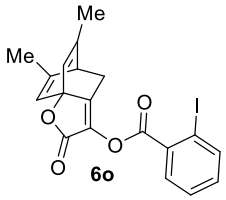
7.8, 1.3 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.48 (d, *J* = 7.4 Hz, 2H, 2 x OCC*H*), 6.24 (d, *J* = 7.4 Hz, 2H, 2 x H_3CCC*H*), 2.41 (s, 2H, CH_3CC*H*$_2$), 1.72 (s, 3H, C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.3, 162.3, 152.9, 144.6, 142.0, 133.9, 132.4, 132.4, 129.1, 128.3, 124.3, 95.2, 87.3, 50.3, 31.1, 19.7; IR ν 2988 (s), 2904 (m), 2114 (s), 1707 (m), 1370 (s), 1216 (m), 1077 (m), 1049 (s); HRMS (ESI) calcd. for $C_{18}H_{14}IO_4^+$ $[M+H]^+$ 420.9931; found 420.9927.

2-Oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6n)



Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and phenyl 2-diazoacetate (**8n**) (30 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 48 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:4 as mobile phase to afford **6n** as a colorless thick gel (20.0 mg, 0.049 mmol, 33%). TLC (Et_2O:pentane, 1:2 v/v): R_f = 0.5, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 – 8.02 (m, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.8 Hz, 1H, Ar*H*), 6.54 – 6.49 (m, 4H, 4 x vinyl C*H*), 4.13 (p, *J* = 3.5 Hz, 1H, CHC*H*CH_2), 2.52 (d, *J* = 2.6 Hz, 2H, CHCHC*H*$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 162.0, 151.2, 141.8, 134.5, 133.8, 132.2, 132.2, 131.5, 130.0, 128.2, 95.1, 87.1, 39.3, 31.8; IR ν 3060 (w), 2953 (w), 2924 (w), 2856 (w), 1783 (s), 1760 (s), 1583 (w), 1492 (w), 1465 (w), 1428 (w), 1344 (w), 1286 (m), 1270 (m), 1238 (s), 1192 (m), 1128 (m), 1109 (s), 1079 (m), 1071 (w), 1054 (w), 1010 (m), 938 (w); HRMS (ESI) calcd. for $C_{17}H_{12}IO_4^+$ $[M+H]^+$ 406.9775; found 406.9779.

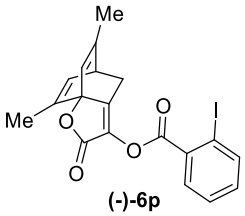
6,9-Dimethyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6o)



Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1H)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 3,5-dimethylphenyl 2-diazoacetate (**8o**) (34 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture was further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using EtOAc:pentane 1:9 as mobile phase to afford **6o** as a white solid (37.0 mg, 85.0 µmol, 57%). Mp: 169–171 °C; TLC (EtOAc:pentane, 1:9 v/v): R_f = 0.33, $KMnO_4$; ^{1}H NMR

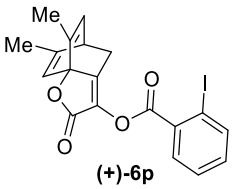
(400 MHz, $CDCl_3$): δ 8.05 (ddd, *J* = 7.9, 2.2, 1.4 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.02 (p, *J* = 1.8 Hz, 2H, 2 x OCC*H*), 3.48 (h, *J* = 2.4 Hz, 1H, C*H*CH_2), 2.51 (d, *J* = 2.6 Hz, 2H, C*H*$_2$), 1.91 (d, *J* = 1.6 Hz, 6H, 2 x C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.3, 162.3, 152.9, 144.6, 142.0, 133.9, 132.4, 132.4, 129.1, 128.3, 124.3, 95.2, 87.3, 50.3, 31.1, 19.7; IR ν 2988 (s), 2924 (s), 2114 (s), 1378 (s), 1215 (m), 1074 (s), 1048 (s); HRMS (ESI) calcd. for $C_{19}H_{16}IO_4^+$ $[M+H]^+$ 435.0088; found 435.0080.

(-)-(5S,7aR)-6,8-Dimethyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (-)-(6p) and (+)-(5R,7aS)-6,8-Dimethyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (+)-(6p).



(-)-6p

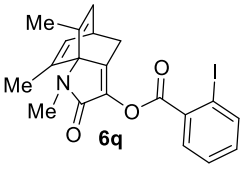
and



(+)-6p

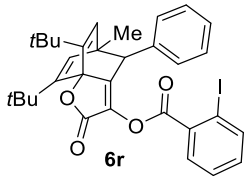
Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1H)-one (**15a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,5-dimethylphenyl 2-diazoacetate (**8p**) (34 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture was further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:9 as mobile phase to afford **6p** as a white solid (28.0 mg, 64.0 µmol, 42%). The obtained racemic mixture was resolved by preparative chiral HPLC, Chiralpak IB, iPOH/hexane 3.5:96.5, 18 mL/min, tr (+) = 14.9 min. and tr (-) = 16.4 min. λ = 254 cm^{-1}. Mp: 125-126 °C; TLC (Et_2O:pentane, 1:9 v/v): R_f = 0.27, $KMnO_4$; $[\alpha]_D^{20}$ = +7.78 (c = 0.3, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 7.9, 3.6, 1.4 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.08 (dt, *J* = 6.1, 1.7 Hz, 1H, CH_3C=C*H*), 5.99 (p, *J* = 1.8 Hz, 1H, OCC*H*), 3.65 (dq, *J* = 6.1, 2.4 Hz, 1H, C*H*CH_2), 2.49 (d, *J* = 2.6 Hz, 2H, C*H*$_2$), 1.89 (d, *J* = 1.7 Hz, 3H, C*H*$_3$), 1.84 (d, *J* = 1.7 Hz, 3H, C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2, 162.2, 152.6, 145.7, 142.0, 140.5, 133.9, 132.4, 132.4, 129.3, 128.3, 127.6, 123.3, 95.2, 88.7, 44.0, 31.8, 19.5, 14.4.; IR ν 2987 (w), 2965 (w), 2359 (w), 2341 (w), 1757 (s), 1705 (m), 1428 (m), 1228 (s), 1128 (s), 1114 (m), 1102 (s), 1052 (s), 1006 (s), 818 (m), 767 (m), 727 (s); HRMS (ESI) calcd. for $C_{19}H_{16}IO_4^+$ $[M+H]^+$ 435.0088; found 435.0083. The crystal structure of **(+)-6p** has been deposited at the Cambridge Crystallographic Data Centre and allocated the deposition number: CCDC 2027173. $[\alpha]_D^{20}$ of **(-)-6p** was not determined.

1,7,8-trimethyl-2-oxo-1,2,4,5-tetrahydro-5,7a-ethenoindol-3-yl 2-iodobenzoate (6q)



Following general procedure **B**, 1-[(triiso-propylsilyl)ethynyl]-1,2-benziodoxol-3(1H)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2-diazo-*N*-(2,6-dimethylphenyl)-*N*-methylacetamide (**6q**) (37 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (48 µL, 0.30 mmol, 2.0 equiv) was added and the reaction mixture further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using EtOAc:pentane 3:7 as mobile phase to afford **6q** as a white solid (27.0 mg, 60.0 µmol, 40%). Mp: 149–151 °C; TLC (EtOAc:pentane, 1:3 v/v): Rf = 0.23, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (m, 2H, Ar*H*), 7.43 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.19 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.13 (dq, *J* = 6.2, 1.6 Hz, 2H, 2 x CH_3C=C*H*), 3.79 (tt, *J* = 6.3, 2.6 Hz, 1H, CHCH_2), 3.36 (s, 3H, NCH_3), 2.31 (d, *J* = 2.6 Hz, 2H, CH_2), 1.84 (d, *J* = 1.6 Hz, 6H, 2 x CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.0, 162.7, 143.2, 141.7, 139.4, 134.3, 133.5, 133.2, 132.4, 130.2, 128.2, 95.1, 75.3, 37.8, 31.8, 31.2, 16.4; IR ν 2990 (s), 2922 (s), 2114 (s), 1702 (m), 1372 (s), 1215 (s), 1075 (s), 1050 (s); HRMS (ESI) calcd. for $C_{20}H_{19}INO_3$+ $[M+H]^+$ 448.0404; found 448.0416.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6r)

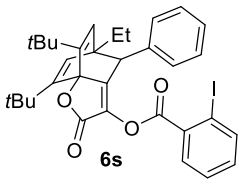


Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6r** as a white solid (83.0 mg, 0.137 mmol, 91%). Mp: 190.0–191.5 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.37, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 7.9, 1.1 Hz, 1H, Ar*H*), 7.25 – 7.13 (m, 5H, Ar*H*), 7.06 (td, *J* = 7.6, 1.9 Hz, 1H, Ar*H*), 7.00 (dd, *J* = 7.2, 2.3 Hz, 2H, Ar*H*), 5.93 (s, 1H, *t*BuCC*H*), 5.63 (s, 1H, *t*BuCC*H*), 3.63 (s, 1H, ArC*H*), 1.31 (s, 3H, CHCCH_3), 1.29 (s, 9H, *t*Bu), 1.22 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 162.0, 159.1, 152.3, 150.1, 141.3, 136.8, 133.5, 133.2, 132.4, 131.7, 130.7, 130.4, 129.4, 128.2, 127.6, 127.4, 94.4, 92.7, 53.6, 46.6, 35.4, 35.3, 29.2, 29.1, 20.2; IR ν 3063 (w), 2962 (m), 2871 (w), 2256 (w), 1777 (s), 1703 (w), 1582

(w), 1463 (w), 1363 (w), 1236 (s), 1091 (s), 1007 (m), 910 (m); HRMS (ESI) calcd. for $C_{32}H_{33}INaO_4^+$ $[M+Na]^+$ 631.1316; found 631.1325.

Large scale procedure: Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (670 mg, 2.00 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (865 mg, 3.00 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (720 mg, 2.20 mmol, 1.10 equiv) was added and further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6r** as a white solid (1.10 g, 1.80 mmol, 90%).

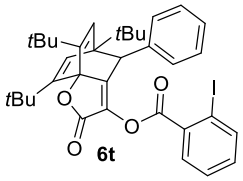
7,8-Di-*tert*-butyl-5-ethyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6s)



6s

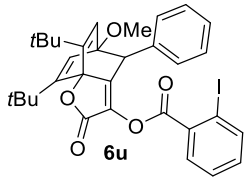
Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-ethylphenyl 2-diazoacetate (**8b**) (68.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6s** as a white solid (90.0 mg, 0.145 mmol, 96%). Mp: 68.0–74.5 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.32, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, *J* = 7.8 Hz, 1H, Ar*H*), 7.22 – 7.13 (m, 5H, Ar*H*), 7.10 – 6.94 (m, 3H, Ar*H*), 6.04 (s, 1H, *t*BuCC*H*), 5.74 (s, 1H, *t*BuCC*H*), 3.66 (s, 1H, ArC*H*), 1.68 – 1.50 (m, 2H, CH_2CH$_3$), 1.29 (s, 9H, *t*Bu), 1.23 (s, 9H, *t*Bu), 1.04 (t, *J* = 7.4 Hz, 3H, CH$_2$CH_3); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 161.9, 160.0, 152.5, 150.2, 141.3, 136.9, 133.2, 132.3, 131.7, 130.7, 130.6, 129.3, 128.8, 128.2, 127.6, 127.4, 94.5, 92.5, 52.5, 51.1, 35.6, 35.5, 29.2, 29.1, 25.8, 9.6; IR ν 3063 (w), 2962 (m), 2871 (w), 2255 (w), 1777 (s), 1700 (w), 1583 (w), 1463 (w), 1364 (w), 1272 (w), 1236 (s), 1184 (m), 1130 (w), 1091 (s), 1036 (m), 1007 (s), 911 (m); HRMS (ESI) calcd. for $C_{33}H_{36}IO_4^+$ $[M+H]^+$ 623.1653; found 623.1655.

5,7,8-Tri-*tert*-butyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6t)



Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,4,6-tri-*tert*-butylphenyl 2-diazoacetate (**8c**) (74.5 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6t** as a white solid (96.0 mg, 0.148 mmol, 98%). Mp: 84.5–89.5 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.35, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (dd, *J* = 7.9, 1.3 Hz, 1H, Ar*H*), 7.21 – 7.04 (m, 5H, Ar*H*), 7.03 – 6.95 (m, 3H, Ar*H*), 6.18 (s, 2H, 2 x *t*BuCC*H*), 3.82 (s, 1H, ArC*H*), 1.32 (s, 9H, *t*Bu), 1.23 (s, 9H, *t*Bu), 0.88 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 161.7, 161.5, 151.6, 150.0, 141.5, 139.0, 133.3, 132.0, 131.7, 131.6, 130.7, 131.0, 129.0, 128.4, 127.5, 127.3, 127.2, 126.9, 95.0, 91.7, 57.5, 50.8, 35.7, 35.6, 33.9, 29.2, 29.1, 27.0; IR ν 3085 (w), 2961 (m), 2872 (w), 2255 (w), 1778 (s), 1694 (w), 1583 (w), 1467 (m), 1431 (w), 1397 (w), 1367 (w), 1271 (w), 1236 (s), 1184 (m), 1136 (m), 1082 (s), 1040 (m), 1009 (m), 912 (m); HRMS (ESI) calcd. for $C_{35}H_{39}INaO_4^+$ $[M+Na]^+$ 673.1785; found 673.1788. All six carbons of phenyl group are different due to adjacent *t*Bu group.

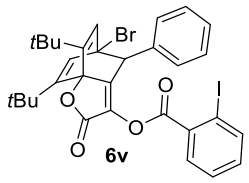
7,8-Di-*tert*-butyl-5-methoxy-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6u)



Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methoxyphenyl 2-diazoacetate (**8d**) (68.5 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:15 as mobile phase to afford **6u** as a white solid (91.0 mg, 0.146 mmol, 97%). Mp: 153.9–157.8 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.13, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.31 – 7.26 (m, 1H, Ar*H*), 7.24 – 7.14 (m, 4H, Ar*H*), 7.10 – 7.04 (m, 3H, Ar*H*), 6.33 (d, *J* = 1.3 Hz, 1H, *t*BuCC*H*), 5.98 (d, *J* = 1.2 Hz, 1H, *t*BuCC*H*), 4.05 (s, 1H, ArC*H*), 3.51 (s, 3H, OCH_3), 1.29 (s, 9H, *t*Bu), 1.24 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.4, 161.9, 156.4, 150.9, 148.1, 141.6, 135.8, 133.3, 132.4, 131.7, 130.7, 129.7, 128.5, 128.1, 127.7, 127.6,

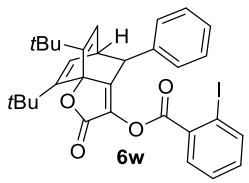
126.9, 94.4, 91.3, 85.6, 53.8, 52.1, 35.7, 35.5, 29.1, 29.0; IR ν 3063 (w), 2961 (m), 2253 (w), 1783 (s), 1706 (w), 1583 (w), 1465 (w), 1430 (w), 1364 (w), 1307 (m), 1270 (m), 1236 (m), 1187 (m), 1130 (m), 1090 (s), 1036 (w), 1007 (m); HRMS (ESI) calcd. for $C_{32}H_{33}INaO_5^+$ $[M+Na]^+$ 647.1265; found 647.1265.

5-Bromo-7,8-di-*tert*-butyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6v)



Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 4-bromo-2,6-di-*tert*-butylphenyl 2-diazoacetate (**8e**) (79.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6v** as a white solid (100 mg, 0.149 mmol, 99%). Mp: 178.6–180.1 °C; TLC (Et_2O:pentane, 1:20 v/v): R_f = 0.28, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.27 – 7.17 (m, 5H, Ar*H*), 7.13 – 7.05 (m, 3H, Ar*H*), 6.37 (s, 1H, *t*BuCC*H*), 6.01 (s, 1H, *t*BuCC*H*), 4.10 (s, 1H, ArC*H*), 1.30 (s, 9H, *t*Bu), 1.24 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.9, 162.0, 155.1, 152.1, 149.9, 141.5, 135.5, 133.8, 133.5, 131.9, 131.7, 130.3, 130.2, 130.1, 128.2, 128.1, 127.7, 94.6, 90.9, 61.3, 56.0, 35.6, 35.5, 29.0, 28.9; IR ν 3064 (w), 2962 (m), 2871 (w), 2255 (w), 1785 (s), 1702 (w), 1650 (w), 1606 (w), 1584 (w), 1464 (w), 1430 (w), 1365 (w), 1235 (s), 1184 (m), 1123 (m), 1080 (s), 1033 (m), 1005 (s), 911 (s); HRMS (ESI) calcd. for $C_{31}H_{31}BrIO_4^+$ $[M+H]^+$ 673.0445; found 673.0451.

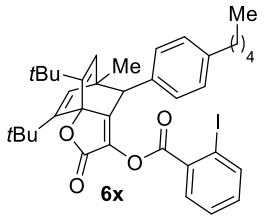
7,8-Di-*tert*-butyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl-2-iodobenzoate (6w)



Following general procedure **C**, 1-[phenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9b**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butylphenyl 2-diazoacetate (**8f**) (62.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:15 as mobile phase to afford **6w** as a white solid (85.0 mg, 0.143 mmol, 95%). Mp: 159.5–162.3 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.25, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 8.0, 1.2 Hz, 1H, Ar*H*), 7.47 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 7.25 – 7.14 (m, 4H,

Ar*H*), 7.11 – 7.03 (m, 3H, Ar*H*), 6.24 (d, *J* = 6.5 Hz, 1H, *t*BuCC*H*), 5.86 (d, *J* = 6.3 Hz, 1H, *t*BuCC*H*), 4.00 (d, *J* = 2.4 Hz, 1H, ArC*H*), 3.80 (td, *J* = 6.4, 2.5 Hz, 1H, ArCHC*H*), 1.26 (s, 9H, *t*Bu), 1.23 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.7, 162.1, 156.4, 152.3, 150.4, 141.3, 139.0, 133.3, 132.6, 131.8, 131.7, 128.5, 128.1, 127.7, 127.3, 127.2, 125.0, 94.4, 92.9, 48.8, 45.4, 35.5, 35.4, 29.2, 29.1; IR ν 3068 (w), 2960 (m), 2870 (w), 2255 (w), 1777 (s), 1706 (w), 1583 (w), 1466 (w), 1430 (w), 1363 (w), 1272 (m), 1241 (m), 1170 (m), 1127 (s), 1083 (s), 1032 (m), 1008 (s), 912 (m); HRMS (ESI) calcd. for $C_{31}H_{31}INaO_4^+$ $[M+Na]^+$ 617.1159; found 617.1172.

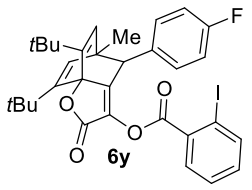
7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-(4-pentylphenyl)-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6x)



6x

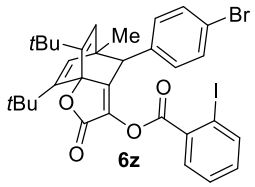
Following general procedure **C**, 1-[4-pentylphenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9c**) (63.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:25 as mobile phase to afford **6x** as a white solid (93.0 mg, 0.137 mmol, 91%). Mp: 189.6–192.5 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.38, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.23 – 7.12 (m, 2H, Ar*H*), 7.05 (td, *J* = 7.6, 2.0 Hz, 1H, Ar*H*), 6.98 (d, *J* = 8.0 Hz, 2H, Ar*H*), 6.89 (d, *J* = 8.1 Hz, 2H, Ar*H*), 5.91 (s, 1H, *t*BuCC*H*), 5.64 (s, 1H, *t*BuCC*H*), 3.58 (s, 1H, ArC*H*), 2.51 – 2.44 (m, 2H, ArCH_2), 1.47 (p, *J* = 7.6 Hz, 2H, ArCH_2CH_2), 1.40 – 1.08 (m, 25H, CHCCH_3, 2 x *t*Bu, and $CH_2CH_2CH_3$), 0.85 (t, *J* = 7.1 Hz, 3H, $CH_2CH_2CH_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 161.9, 159.4, 152.2, 150.0, 142.2, 141.3, 133.8, 133.5, 133.1, 132.5, 131.6, 130.6, 130.5, 129.2, 128.2, 127.5, 94.4, 92.7, 53.3, 46.7, 35.4, 35.3, 31.5, 31.1, 29.2, 29.1, 22.5, 20.2, 14.0; IR ν 2959 (w), 2930 (w), 2867 (w), 1782 (s), 1703 (w), 1584 (w), 1464 (w), 1363 (w), 1237 (m), 1188 (w), 1146 (w), 1092 (s), 1007 (m), 911 (w), 848 (w); HRMS (ESI) calcd. for $C_{37}H_{44}IO_4^+$ $[M+H]^+$ 679.2279; found 679.2282. One carbon was not resolved at 100 MHz.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6y)



Following general procedure **C**, 1-[4-fluorophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9d**) (55.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:25 as mobile phase to afford **6y** as a white solid (90.0 mg, 0.144 mmol, 96%). Mp: 197.3–198.7 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.36, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 7.91 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.39 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 7.26 – 7.21 (m, 1H, Ar*H*), 7.10 (td, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 7.01 – 6.95 (m, 2H, Ar*H*), 6.88 (t, *J* = 8.7 Hz, 2H, Ar*H*), 5.92 (s, 1H, *t*BuCC*H*), 5.61 (s, 1H, *t*BuCC*H*), 3.63 (s, 1H, ArC*H*), 1.30 (s, 3H, CHCC*H*$_3$), 1.28 (s, 9H, *t*Bu), 1.22 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.7, 162.2 (d, *J* = 246.6 Hz), 161.8, 158.8, 152.3, 150.4, 141.5, 133.5, 133.4, 132.6 (d, *J* = 3.3 Hz), 132.1, 131.7, 130.8 (d, *J* = 6.1 Hz), 130.2, 127.8, 115.1 (d, *J* = 21.3 Hz), 94.6, 92.6, 52.8, 46.5, 35.5, 35.4, 29.2, 29.1, 20.2; IR v3063 (w), 2961 (w), 2931 (w), 2871 (w), 2256 (w), 1779 (s), 1702 (w), 1604 (w), 1584 (w), 1509 (m), 1471 (w), 1431 (w), 1364 (w), 1273 (w), 1234 (s), 1187 (w), 1146 (w), 1093 (s), 1033 (w), 1006 (m), 912 (m), 900 (w); HRMS (ESI) calcd. for $C_{32}H_{32}FINaO_4^+$ $[M+Na]^+$ 649.1222; found 649.1229. One carbon was not resolved at 100 MHz.

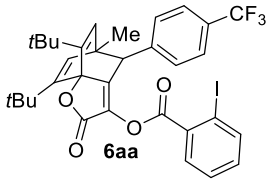
4-(4-Bromophenyl)-7,8-di-*tert*-butyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6z)



Following general procedure **C**, 1-[4-bromophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9e**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6z** as a white solid (102 mg, 0.149 mmol, 99%). Mp: 196.5–199.3 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.37, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 7.91 (dd, *J* = 8.0, 1.2 Hz, 1H, Ar*H*), 7.39 – 7.30 (m, 3H, Ar*H*), 7.29 – 7.23 (m, 1H,

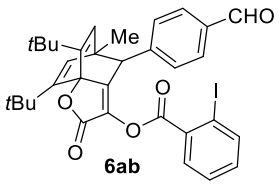
Ar*H*), 7.11 (td, *J* = 7.6, 1.8 Hz, 1H, Ar*H*), 6.88 (d, *J* = 8.4 Hz, 2H, Ar*H*), 5.91 (s, 1H, *t*BuCC*H*), 5.60 (s, 1H, *t*BuCC*H*), 3.60 (s, 1H, ArC*H*), 1.30 (s, 3H, CHCCH_3), 1.27 (s, 9H, *t*Bu), 1.21 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.6, 162.0, 158.4, 152.5, 151.0, 141.5, 135.9, 133.5, 133.3, 132.2, 131.7, 131.4, 130.9, 130.9, 130.1, 127.8, 121.6, 94.5, 92.6, 53.0, 46.5, 35.5, 35.4, 29.2, 29.1, 20.2; IR ν 3062 (w), 2961 (m), 2930 (w), 2871 (w), 2255 (w), 1779 (s), 1704 (w), 1585 (w), 1484 (w), 1464 (w), 1431 (w), 1363 (w), 1272 (w), 1236 (s), 1183 (w), 1146 (w), 1091 (s), 1034 (w), 1008 (m), 911 (m), 850 (w), 737 (s); HRMS (ESI) calcd. for $C_{32}H_{32}BrINaO_4^+$ $[M+Na]^+$ 709.0421; found 709.0433.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-(4-(trifluoromethyl)phenyl)-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6aa)



Following general procedure **C**, 1-[4-trifluoromethylphenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9f**) (62.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6aa** as a white solid (92.0 mg, 0.136 mmol, 91%). Mp: 190.0–191.5 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.35, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.47 (d, *J* = 8.1 Hz, 2H, Ar*H*), 7.30 – 7.24 (m, 1H, Ar*H*), 7.20 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.14 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.08 (td, *J* = 7.6, 1.8 Hz, 1H, Ar*H*), 5.93 (s, 1H, *t*BuCC*H*), 5.61 (s, 1H, *t*BuCC*H*), 3.70 (s, 1H, ArC*H*), 1.32 (s, 3H, CHCCH_3), 1.29 (s, 9H, *t*Bu), 1.22 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.4, 161.9, 158.0, 152.7, 150.9, 141.5, 141.0, 133.5, 133.2, 132.1, 131.6, 131.0, 130.0, 129.8 (q, *J* = 32.3 Hz), 129.6 (q, *J* = 2.0 Hz), 127.7, 125.2 (q, *J* = 3.0 Hz), 123.9 (q, *J* = 272.7 Hz), 94.4, 92.5, 53.3, 46.5, 35.5, 35.4, 29.2, 29.1, 20.2; IR ν 3061 (w), 2963 (m), 2872 (w), 2257 (w), 1781 (s), 1703 (w), 1619 (w), 1584 (w), 1465 (w), 1425 (w), 1364 (w), 1326 (s), 1272 (w), 1236 (m), 1168 (m), 1129 (s), 1092 (s), 1006 (m), 912 (m); HRMS (ESI) calcd. for $C_{33}H_{32}F_3INaO_4^+$ $[M+Na]^+$ 699.1190; found 699.1195.

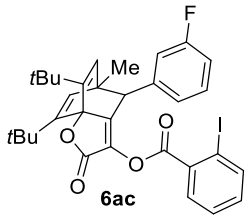
7,8-Di-*tert*-butyl-4-(4-formylphenyl)-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ab)



6ab

Following general procedure **C**, **1**-((4-formylphenyl)ethynyl)-1,2-benziodoxol-3(1*H*)-one (**9g**) (56.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:5 as mobile phase to afford **6ab** as a white solid (57 mg, 0.09 mmol, 60%). Mp: 99.0–103.4 °C; TLC (Et_2O:pentane, 1:4 v/v): R_f = 0.19, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 9.94 (s, 1H, C*H*O), 7.92 – 7.85 (m, 1H, Ar*H*), 7.75 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.47 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 7.25 – 7.22 (m, 3H, Ar*H*), 7.10 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.97 (s, 1H, *t*BuCC*H*), 5.63 (s, 1H, *t*BuCC*H*), 3.78 (s, 1H, ArC*H*), 1.35 (s, 3H, CHCC*H*$_3$), 1.32 (s, 9H, *t*Bu), 1.25 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.6, 168.4, 161.7, 157.9, 152.8, 150.9, 143.9, 141.6, 135.6, 133.6, 133.3, 133.1, 131.8, 131.8, 131.0, 130.0, 129.6, 127.8, 94.7, 92.6, 53.6, 46.7, 35.5, 35.4, 29.2, 29.1, 20.3; IR ν 3060 (w), 2962 (m), 2871 (w), 2256 (w), 1777 (s), 1702 (m), 1607 (w), 1582 (w), 1465 (w), 1428 (w), 1364 (w), 1269 (m), 1235 (s), 1186 (m), 1090 (s), 1032 (w), 1006 (m); HRMS (ESI) calcd. for $C_{33}H_{33}INaO_5^+$ $[M+Na]^+$ 659.1265; found 659.1268.

7,8-Di-*tert*-butyl-4-(3-fluorophenyl)-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ac)

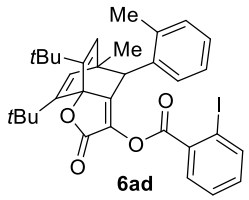


6ac

Following general procedure **C**, 1-[3-fluorophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9h**) (55.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:25 as mobile phase to afford **6ac** as a white solid (78.0 mg, 0.125 mmol, 83%). Mp: 175.5–177.8 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.36, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.44 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 7.26 – 7.21

(m, 1H, Ar*H*), 7.19 – 7.06 (m, 2H, Ar*H*), 6.87 (tdd, *J* = 8.4, 2.6, 1.0 Hz, 1H, Ar*H*), 6.81 (d, *J* = 7.7, 1.6 Hz, 1H, Ar*H*), 6.72 (dt, *J* = 10.1, 2.1 Hz, 1H, Ar*H*), 5.92 (s, 1H, *t*BuCC*H*), 5.63 (s, 1H, *t*BuCC*H*), 3.65 (s, 1H, ArC*H*), 1.32 (s, 3H, CHCC*H*$_3$), 1.29 (s, 9H, *t*Bu), 1.22 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.6, 162.4 (d, *J* = 246.2 Hz), 161.8, 158.3, 152.6, 150.5, 141.5, 139.4 (d, *J* = 7.1 Hz), 133.5, 133.3, 132.1, 131.8, 130.8, 130.3, 129.6 (d, *J* = 8.3 Hz), 127.8, 125.2 (d, *J* = 2.1 Hz), 116.1 (d, *J* = 22.1 Hz), 114.5 (d, *J* = 21.0 Hz), 94.6, 92.6, 53.3, 46.5, 35.5, 35.4, 29.2, 29.1, 20.2; IR v3062 (w), 2961 (m), 2871 (w), 2255 (w), 1777 (s), 1702 (w), 1614 (w), 1587 (m), 1485 (m), 1440 (w), 1390 (w), 1364 (w), 1266 (m), 1235 (s), 1191 (w), 1152 (m), 1091 (s), 1034 (w), 1006 (m), 959 (w), 912 (m); HRMS (ESI) calcd. for $C_{32}H_{32}FINaO_4^+$ $[M+Na]^+$ 649.1222; found 649.1229.

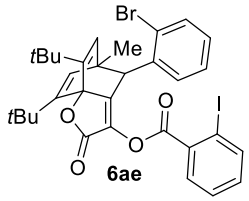
7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-(o-tolyl)-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ad)



6ad

Following general procedure **C**, 1-[*o*-tolylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9i**) (54.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6ad** as a white solid (82.0 mg, 0.132 mmol, 88%). Mp: 200.0–202.5 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.38, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.20 – 6.96 (m, 6H, Ar*H*), 6.80 – 6.70 (m, 1H, Ar*H*), 5.95 (s, 1H, *t*BuCC*H*), 5.67 (s, 1H, *t*BuCC*H*), 3.95 (s, 1H, ArC*H*), 2.36 (s, 3H, ArC*H*$_3$), 1.32 (s, 3H, CHCC*H*$_3$), 1.30 (s, 9H, *t*Bu), 1.24 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.9, 161.9, 160.2, 152.4, 149.8, 141.3, 138.0, 135.3, 133.8, 133.2, 132.3, 131.7, 131.0, 130.4, 130.3, 127.6, 127.6, 127.3, 125.9, 94.4, 92.8, 48.5, 47.5, 35.5, 35.3, 29.1, 29.1, 20.8, 19.4; IR v 3060 (w), 2961 (m), 2931 (w), 2872 (w), 2254 (w), 1776 (s), 1697 (w), 1584 (w), 1465 (m), 1364 (w), 1232 (s), 1188 (m), 1147 (m), 1091 (s), 1006 (m), 912 (m); HRMS (ESI) calcd. for $C_{33}H_{35}INaO_4^+$ $[M+Na]^+$ 645.1472; found 645.1481.

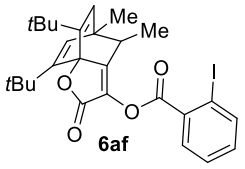
4-(2-Bromophenyl)-7,8-di-*tert*-butyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ae)



6ae

Following general procedure **C**, 1-[2-bromophenylethynyl]-1,2-benziodoxol-3(1*H*)-one (**9j**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6ae** as a white solid (94.0 mg, 0.137 mmol, 91%). Mp: 212.5–214.0 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.37, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, *J* = 7.9 Hz, 1H, Ar*H*), 7.46 (dd, *J* = 8.0, 1.3 Hz, 1H, Ar*H*), 7.35 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.16 (td, *J* = 7.6, 1.3 Hz, 1H, Ar*H*), 7.08 (td, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 7.02 (td, *J* = 7.6, 1.7 Hz, 1H, Ar*H*), 6.85 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 5.96 (s, 1H, *t*BuCC*H*), 5.63 (s, 1H, *t*BuCC*H*), 4.36 (s, 1H, ArC*H*), 1.42 (s, 3H, CHCC*H*$_3$), 1.30 (s, 9H, *t*Bu), 1.23 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.5, 161.9, 159.2, 152.6, 150.5, 141.4, 136.6, 133.5, 133.3, 132.9, 132.5, 131.7, 130.9, 130.6, 129.3, 129.0, 127.6, 127.5, 127.1, 94.4, 92.7, 50.9, 47.6, 35.5, 35.4, 29.2, 29.1, 19.4; IR ν 3062 (w), 2961 (m), 2871 (w), 2255 (w), 1779 (s), 1707 (w), 1584 (w), 1565 (w), 1467 (m), 1435 (w), 1390 (w), 1364 (w), 1313 (w), 1272 (w), 1234 (s), 1187 (m), 1146 (m), 1089 (s), 1029 (m), 1005 (s), 911 (s); HRMS (ESI) calcd. for $C_{32}H_{32}BrINaO_4^+$ $[M+Na]^+$ 709.0421; found 709.0423.

7,8-Di-*tert*-butyl-4,5-dimethyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6af)

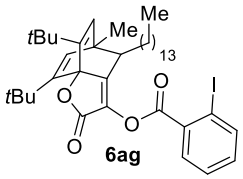


6af

Following general procedure **D**, propynyl-1,2-benziodoxol-3(1*H*)-one (**9k**) (43.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:30 as mobile phase to afford **6af** as a white solid (43.0 mg, 0.079 mmol, 53%). Mp: 170.5–174.8 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.27, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 8.0, 3.2, 1.4 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.7, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7

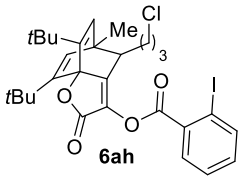
Hz, 1H, Ar*H*), 5.80 (s, 1H, *t*BuCC*H*), 5.70 (s, 1H, *t*BuCC*H*), 2.56 (q, *J* = 7.0 Hz, 1H, C*H*CH$_3$), 1.51 (s, 3H, CHCC*H$_3$*), 1.18 (s, 9H, *t*Bu), 1.17 (s, 9H, *t*Bu), 1.04 (d, *J* = 7.0 Hz, 3H, CHC*H$_3$*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.4, 161.5, 151.5, 150.4, 141.7, 133.6, 132.9, 132.6, 132.2, 130.0, 129.9, 128.1, 94.9, 92.5, 44.9, 42.5, 35.2, 35.2, 29.2, 29.1, 19.5, 15.3; IR ν 3059 (w), 2962 (m), 2872 (w), 2255 (w), 1778 (s), 1704 (w), 1583 (w), 1469 (w), 1430 (w), 1390 (w), 1365 (w), 1271 (m), 1235 (s), 1154 (m), 1091 (s), 1043 (m), 1008 (m), 958 (w), 912 (m); HRMS (ESI) calcd. for $C_{27}H_{31}INaO_4^+$ $[M+Na]^+$ 569.1159; found 569.1161.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-tetradecyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ag)



Following general procedure **D**, hexadecynyl-1,2-benziodoxol-3(1*H*)-one (**9l**) (70.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:50 as mobile phase to afford **6ag** (86.0 mg, 0.118 mmol, 79%) as a colourless oil. TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.34, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 8.05 (dd, *J* = 8.0, 1.2 Hz, 1H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.79 (s, 1H, *t*BuCC*H*), 5.70 (s, 1H, *t*BuCC*H*), 2.50 (dd, *J* = 6.2, 4.3 Hz, 1H, C*H*CH$_2$), 1.62 – 1.54 (m, 4H, CHC*H^a*$_2$ and CHCC*H$_3$*), 1.31 – 1.09 (m, 43H, CHC*H^b*$_2$, 12 x C*H$_2$*, and 2 x *t*Bu), 0.88 (t, *J* = 6.8 Hz, 3H, CH$_2$C*H$_3$*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.1, 162.0, 161.4, 152.0, 149.6, 142.0, 133.7, 133.5, 132.5, 132.0, 130.8, 130.0, 128.0, 95.3, 92.8, 48.0, 45.2, 35.2, 35.2, 31.9, 31.2, 30.1, 29.7, 29.7, 29.6, 29.5, 29.4, 29.4, 29.2, 29.1, 28.7, 22.7, 20.2, 14.1; IR ν 3057 (w), 2957 (m), 2924 (s), 2854 (m), 1781 (s), 1698 (w), 1583 (w), 1464 (m), 1433 (w), 1389 (w), 1363 (w), 1270 (w), 1234 (s), 1154 (w), 1089 (s), 1035 (w), 1006 (m); HRMS (ESI) calcd. for $C_{40}H_{57}INaO_4^+$ $[M+Na]^+$ 751.3194; found 751.3200. Two carbons were not resolved at 100 MHz.

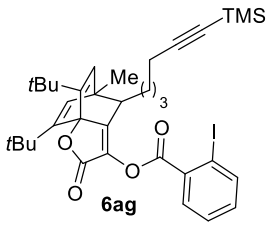
7,8-Di-*tert*-butyl-4-(3-chloropropyl)-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ah)



6ah

Following general procedure **D**, (5-chloropent-1-ynyl)-1,2-benziodoxol-3(1*H*)-one (**9m**) (52.5 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:30 as mobile phase to afford **6ah** as a white solid (66.0 mg, 0.108 mmol, 72%). Mp: 124.0–128.2 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.29, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 8.05 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.80 (s, 1H, *t*BuCC*H*), 5.72 (s, 1H, *t*BuCC*H*), 3.46 – 3.37 (m, 2H, ClC*H*$_2$CH$_2$), 2.62 – 2.49 (m, 1H, C*H*CH$_2$), 1.85 – 1.66 (m, 3H, ClCH$_2$C*H*$_2$ and ClCH$_2$CH$_2$C*H*^{a}$_2$), 1.61 – 1.49 (m, 4H, ClCH$_2$CH$_2$C*H*^{b}$_2$ and CHCC*H*$_3$), 1.18 (s, 9H, *t*Bu), 1.16 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.8, 162.3, 160.2, 152.2, 150.1, 141.9, 133.9, 133.4, 132.5, 131.9, 130.6, 130.3, 128.2, 95.2, 92.7, 47.2, 45.1, 45.0, 35.3, 35.2, 31.1, 29.1, 29.1, 28.1, 20.2; IR ν 3060 (w), 2960 (m), 2870 (w), 2254 (w), 1778 (s), 1698 (w), 1583 (w), 1464 (w), 1390 (w), 1364 (w), 1274 (w), 1235 (s), 1192 (w), 1154 (w), 1128 (w), 1093 (s), 1034 (w), 1007 (m), 913 (m); HRMS (ESI) calcd. for $C_{29}H_{34}ClINaO_4^+$ $[M+Na]^+$ 631.1083; found 631.1090.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-(6-(trimethylsilyl)hex-5-yn-1-yl)-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ag)

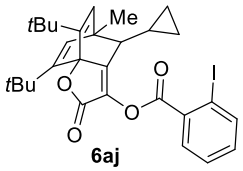


6ag

Following general procedure **D**, 8-(trimethylsilyl)octa-1,7-diyn-1-yl-1,2-benziodoxol-3(1*H*)-one (**9n**) (64.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:35 as mobile phase to afford **6ag** as a yellow thick oil (73.0 mg, 0.107 mmol, 71%). TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.27, $KMnO_4$; ^{1}H NMR (400 MHz,

$CDCl_3$): δ 8.09 (dd, *J* = 7.8, 1.7 Hz, 1H, Ar*H*), 8.05 (d, *J* = 7.9 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.7, 1.2 Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.79 (s, 1H, *t*BuCC*H*), 5.71 (s, 1H, *t*BuCC*H*), 2.54 (t, *J* = 5.0 Hz, 1H, C*H*CH_2), 2.08 (t, *J* = 6.4 Hz, 2H, CCCH_2), 1.61 – 1.55 (m, 4H, CHC$H^a{}_2$ and CHCCH_3), 1.44 – 1.31 (m, 5H, CHC$H^b{}_2$, $CHCH_2CH_2CH_2CH_2CC$), 1.18 (s, 9H, *t*Bu), 1.16 (s, 9H, *t*Bu), 0.11 (s, 9H, TMS); ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.9, 162.2, 160.8, 152.1, 149.6, 141.9, 133.8, 133.4, 132.4, 132.1, 130.8, 130.1, 128.1, 107.0, 95.2, 92.8, 84.7, 47.8, 45.1, 35.2, 35.2, 30.3, 29.1, 29.1, 28.9, 27.4, 20.2, 19.6, 0.2; IR ν 3058 (w), 2960 (m), 2870 (w), 2173 (w), 1781 (s), 1700 (w), 1578 (w), 1465 (w), 1430 (w), 1392 (w), 1364 (w), 1270 (w), 1235 (s), 1190 (w), 1154 (w), 1092 (s), 1034 (w), 1007 (m); HRMS (ESI) calcd. for $C_{35}H_{45}INaO_4Si^+$ $[M+Na]^+$ 707.2024; found 707.2043.

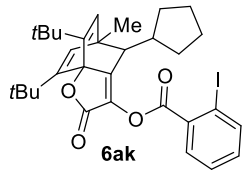
7,8-Di-*tert*-butyl-4-cyclopropyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6aj)



6aj

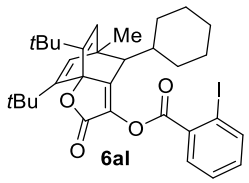
Following general procedure **D**, 2-cyclopropylethynyl-1,2-benziodoxol-3(1*H*)-one (**9o**) (47.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:35 as mobile phase to afford **6aj** as a white solid (80.0 mg, 0.140 mmol, 93%). Mp: 185.4–188.5 °C; TLC (Et_2O:pentane, 1:10 v/v): R_f = 0.37, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 8.07 (dd, *J* = 8.0, 1.2 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.82 (s, 1H, *t*BuCC*H*), 5.76 (s, 1H, *t*BuCC*H*), 1.71 (d, *J* = 9.5 Hz, 1H, C*H*CCH_3), 1.64 (s, 3H, CHCCH_3), 1.21 (s, 9H, *t*Bu), 1.16 (s, 9H, *t*Bu), 0.66 – 0.52 (m, 1H, cyclopropyl-C*H*), 0.47 – 0.28 (m, 3H, cyclopropyl-CH_2 and C$H^a{}_2$), 0.22 – 0.10 (m, 1H, cyclopropyl-C$H^b{}_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.1, 162.2, 160.3, 151.5, 150.3, 142.1, 133.8, 132.9, 132.6, 131.8, 130.7, 130.6, 128.1, 95.4, 92.4, 52.9, 46.4, 35.2, 35.2, 29.3, 29.1, 20.9, 12.9, 5.6, 3.0; IR ν 3061 (w), 2997 (w), 2960 (m), 2931 (w), 2871 (w), 2254 (w), 1773 (s), 1701 (w), 1583 (w), 1467 (w), 1429 (w), 1389 (w), 1364 (w), 1318 (w), 1272 (w), 1235 (s), 1192 (w), 1156 (w), 1091 (s), 1033 (m), 1007 (m), 962 (w), 912 (m); HRMS (ESI) calcd. for $C_{29}H_{33}INaO_4^+$ $[M+Na]^+$ 595.1316; found 595.1325.

7,8-Di-*tert*-butyl-4-cyclopentyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6ak)



Following general procedure **D**, 2-cyclopentylethynyl-1,2-benziodoxol-3(1*H*)-one (**9p**) (51.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:35 as mobile phase to afford **6ak** as a white solid (83.0 mg, 0.138 mmol, 92%). Mp: 169.0–171.2 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.27, $KMnO_4$;^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 (td, *J* = 7.4, 6.8, 1.4 Hz, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.80 (s, 1H, *t*BuCC*H*), 5.69 (s, 1H, *t*BuCC*H*), 2.75 (d, *J* = 2.9 Hz, 1H, C*H*CCH$_3$), 2.15 – 2.02 (m, 1H, cyclopentyl-*H*), 1.77 (dt, *J* = 11.0, 7.3 Hz, 1H, cyclopentyl-*H*), 1.62 – 1.56 (m, 4H, cyclopentyl-*H* and CHCC*H*$_3$), 1.49 – 1.31 (m, 6H, cyclopentyl-*H*), 1.18 (s, 9H, *t*Bu), 1.16 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.2, 159.1, 152.2, 148.8, 142.0, 134.1, 133.7, 132.4, 132.1, 131.1, 130.9, 128.1, 95.3, 93.2, 51.3, 45.5, 41.1, 35.2, 35.1, 33.0, 30.1, 29.2, 29.1, 25.1, 23.9, 21.1; IR ν 3059 (w), 2956 (m), 2866 (w), 2254 (w), 1775 (s), 1690 (w), 1583 (w), 1464 (w), 1431 (w), 1390 (w), 1363 (w), 1272 (w), 1234 (s), 1186 (m), 1153 (w), 1094 (s), 1034 (w), 1005 (m), 912 (m); HRMS (ESI) calcd. for $C_{31}H_{38}IO_4^+$ $[M+H]^+$ 601.1809; found 601.1818.

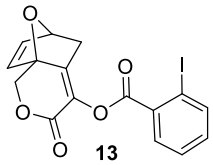
7,8-Di-*tert*-butyl-4-cyclohexyl-5-methyl-2-oxo-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (6al)



Following general procedure **D**, 2-cyclohexylethynyl-1,2-benziodoxol-3(1*H*)-one (**9q**) (53.0 mg, 0.150 mmol, 1.00 equiv) and 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (65.0 mg, 0.225 mmol, 1.50 equiv) were stirred for 12 h. Next, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added and the reaction mixture further stirred for 20 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using Et_2O:pentane 1:35 as mobile phase to afford **6al** as a white solid (55.0 mg, 0.089 mmol, 60%). Mp: 185.0–190.5 °C; TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.27, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.11 (dd, *J* = 7.9, 1.7 Hz, 1H, Ar*H*), 8.06 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2

Hz, 1H, Ar*H*), 7.22 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 5.78 (s, 1H, *t*BuCC*H*), 5.72 (s, 1H, *t*BuCC*H*), 2.45 (d, *J* = 2.0 Hz, 1H, C*H*CCH$_3$), 1.75 – 1.54 (m, 8H, cyclohexyl-*H* and CHCC*H*$_3$), 1.47 – 1.43 (m, 1H, cyclohexyl-*H*), 1.34 – 1.22 (m, 2H, cyclohexyl-*H*), 1.17 (s, 9H, *t*Bu), 1.16 (s, 9H, *t*Bu), 1.11 – 0.93 (m, 3H, cyclohexyl-*H*); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 162.1, 159.4, 152.6, 148.8, 142.0, 134.4, 133.7, 132.4, 132.2, 131.0, 130.6, 128.1, 95.2, 93.1, 54.4, 45.5, 39.1, 35.2, 35.1, 34.3, 31.2, 29.2, 29.1, 27.2, 26.9, 26.1, 21.2; IR ν 3060 (w), 2967 (w), 2958 (m), 2929 (m), 2855 (w), 2255 (w), 1774 (s), 1689 (w), 1583 (w), 1464 (w), 1390 (w), 1364 (w), 1271 (w), 1234 (s), 1187 (m), 1093 (s), 1034 (w), 1006 (m), 912 (m); HRMS (ESI) calcd. for $C_{32}H_{39}INaO_4^+$ $[M+Na]^+$ 637.1785; found 637.1789.

3-Oxo-5,6-dihydro-1*H*,3*H*-6,8a-epoxyisochromen-4-yl 2-iodobenzoate (13)

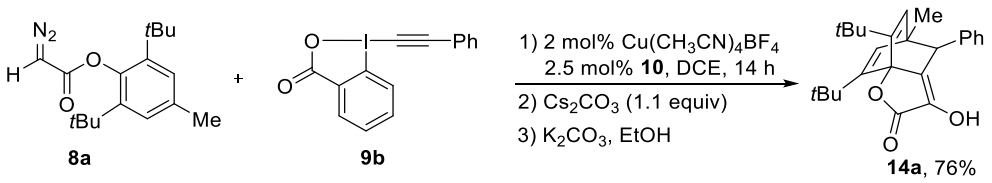


13

Following general procedure **B**, 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (64.0 mg, 0.150 mmol, 1.00 equiv) and furan-2-ylmethyl 2-diazoacetate (**12**) (30 mg, 0.18 mmol, 1.2 equiv) were stirred for 12 h. Next, triethylamine trihydrofluoride (24 µL, 0.15 mmol, 1.0 equiv) was added and the reaction mixture further stirred for 36 h. The crude reaction mixture was concentrated in vacuo and purified by flash chromatography using EtOAc:pentane 1:3 as mobile phase to afford **13** as a white solid (51.0 mg, 0.124 mmol, 83%). Mp: 203.5–205.5 °C; TLC (EtOAc:pentane, 1:3 v/v): R_f = 0.3, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.03 (dd, *J* = 7.7, 1.7 Hz, 2H, Ar*H*), 7.45 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H, Ar*H*), 6.67 (dt, *J* = 5.9, 1.4 Hz, 1H, OCHC*H*), 6.63 (d, *J* = 5.7 Hz, 1H, OCC*H*), 5.28 (dd, *J* = 4.3, 1.7 Hz, 1H, OC*H*), 4.90 (d, *J* = 11.3 Hz, 1H, OCCH^a_2), 4.80 (d, *J* = 11.2 Hz, 1H, OCCH^b_2), 2.88 (dd, *J* = 16.1, 4.2 Hz, 1H, OCHCH^a_2), 2.35 (d, *J* = 16.2 Hz, 1H, OCHCH^b_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.3, 158.8, 144.5, 141.6, 140.2, 133.6, 132.8, 132.1, 132.0, 130.6, 128.1, 94.8, 83.0, 79.4, 67.7, 33.1; IR ν 2952 (w), 2366 (w), 1738 (s), 1623 (w), 1583 (w), 1563 (w), 1467 (w), 1429 (w), 1401 (w), 1331 (w), 1275 (m), 1239 (s), 1209 (m), 1149 (s), 1130 (m), 1104 (s), 1074 (m), 1039 (m), 1014 (m), 988 (w), 952 (w), 912 (w); HRMS (ESI) calcd. for $C_{16}H_{11}INaO_5^+$ $[M+Na]^+$ 432.9543; found 432.9547.

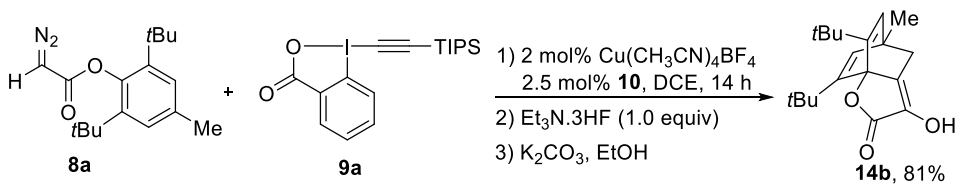
6. Product derivatization and applications

7,8-Di-*tert*-butyl-3-hydroxy-5-methyl-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-2-one (19a)



A flame dried 20 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (25 mg, 0.08 mmol, 0.02 equiv), ligand **10** (37 mg, 0.10 mmol, 0.025 equiv) and dry DCE (10 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of Ph-EBX (**9b**) (1.4 g, 4.0 mmol, 1.0 equiv), 2,6-di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (1.73 g, 6.00 mmol, 1.50 equiv) and dry DCE (150 mL) in 250 mL round-bottom flask over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, the reaction mixture was cooled down to room temperature and Cs_2CO_3 (1.44 g, 4.40 mmol, 1.10 equiv) was added and the reaction mixture stirred. After 20 h, the reaction mixture was filtered and the filtrate was evaporated under reduced pressure. The crude residue was dissolved in EtOH (80 mL) and K_2CO_3 (0.83 g, 6.0 mmol, 1.5 equiv) was added and the reaction mixture stirred at room temperature for 20 h. The solvent was evaporated under reduced pressure and the crude product was purified by flash chromatography using EtOAc:pentane 1:10 as mobile phase to afford **14a** as a white solid (1.15 g, 3.04 mmol, 76%). Mp: 178.5–182.3 °C; TLC (EtOAc:pentane, 1:6 v/v): R_f = 0.44, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27 (dd, *J* = 5.0, 1.9 Hz, 3H, Ar*H*), 7.05 – 6.98 (m, 2H, Ar*H*), 5.84 (d, *J* = 0.8 Hz, 1H, *t*BuCC*H*), 5.50 (d, *J* = 0.8 Hz, 1H, *t*BuCC*H*), 4.80 (s, 1H, O*H*), 3.46 (s, 1H, ArC*H*), 1.30 (s, 3H, CHCC*H*$_3$), 1.22 (s, 9H, *t*Bu), 1.15 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.8, 152.8, 150.8, 142.3, 137.3, 133.4, 133.0, 129.6, 129.1, 128.1, 127.4, 92.5, 51.5, 46.5, 35.2, 35.2, 29.2, 29.1, 20.5; IR ν 3350 (w), 3060 (w), 2962 (m), 2872 (w), 2255 (w), 1747 (s), 1735 (m), 1603 (w), 1458 (w), 1387 (w), 1365 (m), 1313 (w), 1242 (w), 1200 (m), 1150 (w), 1101 (s), 1046 (w), 912 (m); HRMS (ESI) calcd. for $C_{25}H_{31}O_3^+$ $[M+H]^+$ 379.2268; found 379.2273.

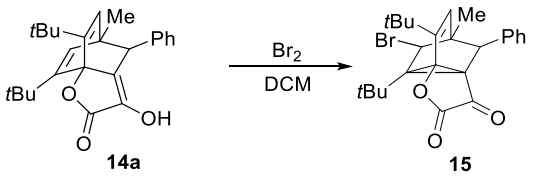
7,8-Di-*tert*-butyl-3-hydroxy-5-methyl-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-2-one (14b)



A flame dried 20 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (25 mg, 0.08 mmol, 0.02 equiv), ligand **10** (37 mg, 0.10 mmol, 0.025 equiv) and dry DCE (10 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of TIPS-EBX (**9a**) (1.72 g, 4.00 mmol, 1.00 equiv), 2,6-

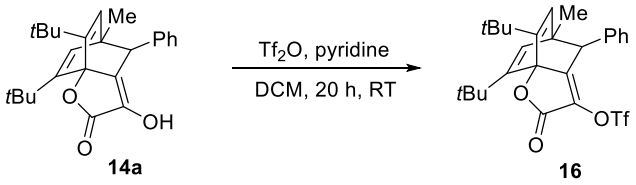
di-*tert*-butyl-4-methylphenyl 2-diazoacetate (**8a**) (1.4 g, 4.8 mmol, 1.2 equiv) and dry DCE (150 mL) in 250 mL round-bottom flask over 2 min and the resulting reaction mixture was stirred at 50 °C for 14 h. Next, the reaction mixture was cooled down to room temperature and triethylamine trihydrofluoride (0.67 mL, 4.0 mmol, 1.0 equiv) was added and the reaction mixture stirred. After 24 h, the solvent was evaporated under reduced pressure. The crude residue was dissolved in EtOH (80 mL) and K_2CO_3 (0.83 g, 6.0 mmol, 1.5 equiv) was added and the reaction mixture stirred at room temperature. After 20 h, the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography using EtOAc:pentane 1:10 as mobile phase to afford **14b** as a white solid (0.980 g, 3.24 mmol, 81%). Mp: 189.0–190.3 °C; TLC (EtOAc:pentane, 1:6 v/v): R_f = 0.43, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.72 (s, 2H, 2 x *t*BuCC*H*), 5.04 (brs, 1H, O*H*), 2.18 (s, 2H, CH_3CCH_2), 1.60 (s, 3H, CHCC*H*$_3$), 1.10 (s, 18H, 2 x *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.3, 151.8, 140.8, 132.4, 131.6, 92.7, 41.5, 36.0, 35.0, 29.2, 22.5; IR ν 3348 (m), 3298 (w), 3054 (w), 2958 (w), 2929 (w), 2866 (w), 1747 (s), 1711 (s), 1461 (w), 1384 (m), 1376 (m), 1328 (w), 1241 (m), 1221 (m), 1202 (m), 1160 (m), 1104 (s), 1046 (w), 900 (w); HRMS (ESI) calcd. for $C_{19}H_{26}NaO_3^+$ $[M+Na]^+$ 325.1774; found 325.1786..

3-Bromo-7,8-di-*tert*-butyl-5-methyl-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-2,3(3a*H*)-dione (15)



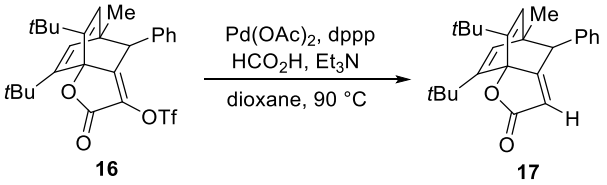
A solution of bromine (16 mg, 0.10 mmol, 2.0 equiv) in dry CH_2Cl_2 (1 mL) was slowly added to a vigorously stirred solution of **14a** (19 mg, 0.05 mmol, 1.0 equiv) in dry CH_2Cl_2 (1 mL) at 0 °C under nitrogen. The reaction mixture was allowed to warm to room temperature and stirred for 14 h. Next, an aqueous solution of Na_2SO_3 (5 mL) was added to the reaction mixture and extracted with CH_2Cl_2 (3 x 10 mL). The organic layers were combined, dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:15 EtOAc:pentane as mobile phase to afford **15** as a pale yellow solid (20.0 mg, 0.044 mmol, 87%). Mp: 201.5–205.3 °C; TLC (EtOAc:pentane, 1:15 v/v): R_f = 0.35, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24 – 7.15 (m, 3H, Ar*H*), 6.74 – 6.68 (m, 2H, Ar*H*), 4.92 (d, *J* = 1.1 Hz, 1H, *t*BuCC*H*), 4.17 (d, *J* = 1.2 Hz, 1H, *t*BuCC*H*Br), 3.39 (s, 1H, ArC*H*), 1.35 (s, 9H, *t*Bu), 1.34 (s, 9H, *t*Bu), 1.25 (s, 3H, CHCC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 186.2, 161.8, 141.4, 133.6, 128.9, 128.0, 127.7, 123.4, 63.9, 62.9, 49.6, 46.6, 46.1, 35.5, 33.9, 32.1, 29.1, 19.9; IR ν 2967 (m), 2932 (m), 2875 (m), 1806 (s), 1751 (s), 1601 (w), 1492 (w), 1457 (w), 1370 (m), 1325 (m), 1265 (m), 1235 (m), 1173 (w), 1147 (m), 1090 (m), 1062 (m), 1032 (w), 946 (w); HRMS (ESI) calcd. for $C_{25}H_{30}BrO_3^+$ $[M+H]^+$ 457.1373; found 457.1373. One carbon was not resolved at 100 MHz.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl trifluoromethanesulfonate (16)



To a solution of **14a** (303 mg, 0.800 mmol, 1.00 equiv.) and pyridine (0.129 mL, 1.60 mmol, 2.00 equiv.) in CH_2Cl_2 (40 mL) was added triflic anhydride (2.4 mL, 1.0 M, 2.4 mmol, 3.0 equiv) at 0 °C in 10 min. The mixture was allowed to warm to room temperature and stirred for 20 h. Next, the reaction mixture was quenched with water (30 mL) and the layers were separated. The aqueous layer was extracted with DCM (3 x 20 mL). The combined organic layers were washed with brine (40 mL), dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:40 EtOAc:pentane as mobile phase to afford **16** as a white solid (408 mg, 0.800 mmol, quant.). Mp: 187.5–191.5 °C; TLC (EtOAc:pentane, 1:40 v/v): R_f = 0.5, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32 – 7.28 (m, 3H, Ar*H*), 7.01 – 6.98 (m, 2H, Ar*H*), 5.95 (s, 1H, *t*BuCC*H*), 5.67 (m, 1H, *t*BuCC*H*), 3.65 (s, 1H, ArC*H*), 1.32 (s, 3H, CHCC*H*$_3$), 1.24 (s, 9H, *t*Bu), 1.17 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): 166.2, 162.8, 151.6, 149.1, 135.3, 134.2, 131.1, 130.5, 129.1, 128.4, 128.1, 118.0 (q, *J* = 321.2 Hz), 92.6, 53.7, 46.7, 35.4, 35.3, 29.0, 28.9, 20.0; IR ν 3064 (w), 2964 (m), 2874 (w), 1788 (s), 1697 (w), 1603 (w), 1432 (s), 1392 (w), 1365 (w), 1316 (w), 1214 (s), 1182 (m), 1138 (s), 1072 (s), 1035 (w); HRMS (ESI) calcd. for $C_{26}H_{30}F_3O_5S^+$ $[M+H]^+$ 511.1761; found 511.1765.

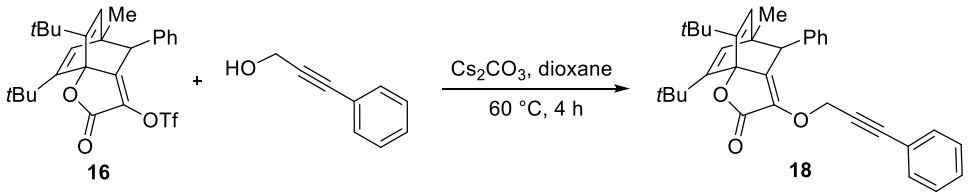
7,8-Di-*tert*-butyl-5-methyl-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-2-one (17)



A mixture of **16** (51 mg, 0.10 mmol, 1.0 equiv), $Pd(OAc)_2$ (5.6 mg, 25 µmol, 0.25 equiv), dppp (25 mg, 0.06 mmol, 0.60 equiv), and dioxane (1.0 mL) was placed in a 2 mL microwave vial under nitrogen. Formic acid (15 µL, 0.40 mmol, 4.0 equiv.) and triethylamine (55 µL, 0.40 mmol, 4.0 equiv.) were added to the reaction mixture. The resulting mixture was stirred at 90 °C for 18 h and then quenched with water (5 mL). The layers were separated and the aqueous layer was extracted with EtOAc (3 x 10 mL). The combined organic layers were washed with brine (20 mL), dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:30 Et_2O:pentane as mobile phase to afford **17** as a colorless semi solid (32.0 mg, 0.088 mmol, 88%). TLC

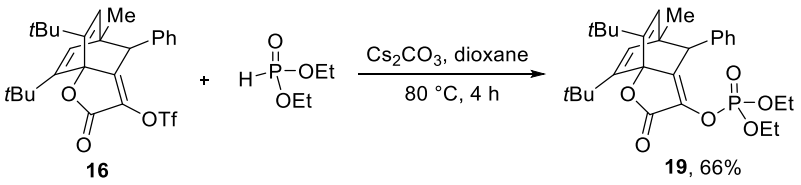
(Et_2O:pentane, 1:20 v/v): R_f = 0.28, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 7.32 – 7.20 (m, 3H, Ar*H*), 7.03 – 6.99 (m, 2H, Ar*H*), 5.84 (s, 1H, *t*BuCC*H*), 5.54 – 5.51 (m, 2H, *t*BuCC*H* and C(O)C*H*), 3.47 (d, *J* = 1.9 Hz, 1H, ArC*H*), 1.29 (s, 3H, CHCC*H*$_3$), 1.24 (s, 9H, *t*Bu), 1.17 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 179.0, 175.4, 152.4, 150.0, 139.1, 132.6, 129.3, 129.2, 128.2, 127.4, 109.7, 96.6, 52.9, 46.4, 35.4, 35.4, 29.1, 29.1, 20.5; IR ν 2961 (m), 2872 (w), 1797 (w), 1762 (s), 1652 (w), 1457 (w), 1390 (w), 1363 (w), 1314 (w), 1247 (w), 1218 (w), 1128 (w), 1097 (w), 1047 (w); HRMS (ESI) calcd. for $C_{25}H_{31}O_2^+$ $[M+H]^+$ 363.2319; found 363.2316.

7,8-Di-*tert*-butyl-5-methyl-4-phenyl-3-((3-phenylprop-2-yn-1-yl)oxy)-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-2-one (18)



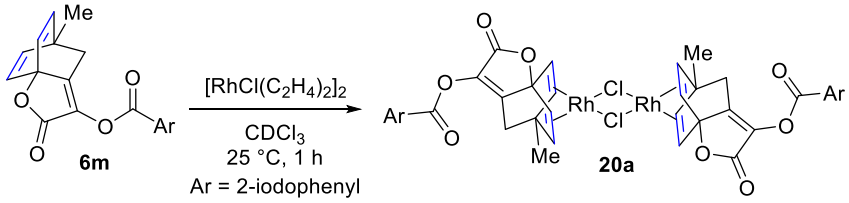
A mixture of **16** (51 mg, 0.10 mmol, 1.0 equiv), Cs_2CO_3 (65.5 mg, 0.200 mmol, 2.00 equiv), and dioxane (1.0 mL) was placed in a 2 mL microwave vial under nitrogen. 3-Phenylprop-2-yn-1-ol (66 mg, 0.50 mmol, 5.0 equiv.) was added slowly to the reaction mixture over 5 min and it was stirred at 60 °C for 4 h. The reaction mixture was quenched with water (10 mL) and transferred to a separating funnel. The layers were separated and the aqueous layer was extracted with EtOAc (3 x 10 mL). The combined organic layers were washed with brine (20 mL), dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:15 Et_2O:pentane as mobile phase to afford **18** as a pale yellow thick gel (44.5 mg, 0.090 mmol, 90%). TLC (Et_2O:pentane, 1:15 v/v): R_f = 0.33, $KMnO_4$; ^1H NMR (400 MHz, $CDCl_3$): δ 7.38 – 7.26 (m, 8H, Ar*H*), 7.38 – 7.26 (m, 2H, Ar*H*), 5.82 (s, 1H, *t*BuCC*H*), 5.48 (s, 1H, *t*BuCC*H*), 4.53 (d, *J* = 15.9 Hz, 1H, OCH^a_2), 4.37 (d, *J* = 15.9 Hz, 1H, OCH^b_2), 3.74 (s, 1H, ArC*H*), 1.30 (s, 3H, CHCC*H*$_3$), 1.23 (s, 9H, *t*Bu), 1.11 (s, 9H, *t*Bu); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.5, 153.3, 150.7, 148.3, 139.1, 135.9, 132.8, 131.7, 129.5, 129.1, 128.8, 128.3, 128.2, 127.5, 122.1, 92.2, 87.6, 84.1, 58.6, 52.7, 46.4, 35.3, 35.2, 29.2, 29.1, 20.8; IR ν 3061 (w), 2961 (m), 2871 (w), 2252 (w), 1769 (s), 1684 (w), 1601 (w), 1491 (w), 1453 (w), 1389 (w), 1366 (w), 1316 (w), 1244 (w), 1191 (w), 1148 (w), 1099 (s), 1034 (w), 988 (w), 954 (w), 913 (m); HRMS (ESI) calcd. for $C_{34}H_{37}O_3^+$ $[M+H]^+$ 493.2737; found 493.2741.

7,8-Di-*tert*-butyl-5-methyl-2-oxo-4-phenyl-4,5-dihydro-2*H*-5,7a-ethenobenzofuran-3-yl diethyl phosphate (19)



A mixture of **16** (51 mg, 0.10 mmol, 1.0 equiv), Cs_2CO_3 (65.5 mg, 0.200 mmol, 2.00 equiv), and dioxane (1.0 mL) was placed in a 2 mL microwave vial under nitrogen. Diethyl phosphonate (69 mg, 0.50 mmol, 5.0 equiv.) was added slowly to the reaction mixture over 5 min and the reaction mixture stirred at 80 °C for 4 h. The reaction mixture was quenched with water (10 mL) and transferred to a separating funnel. The layers were separated and the aqueous layer was extracted with EtOAc (3 x 10 mL). The combined organic layers were washed with brine (20 mL), dried over $MgSO_4$, and concentrated under reduced pressure. The crude product was purified by flash column chromatography using 1:10 EtOAc:pentane as mobile phase to afford **19** as a colorless thick gel (34.0 mg, 0.066 mmol, 66%). TLC (EtOAc:pentane, 1:6 v/v): R_f = 0.25, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24 – 7.11 (m, 3H, Ar*H*), 7.02 – 6.91 (m, 2H, Ar*H*), 5.80 (s, 1H, *t*BuCC*H*), 5.47 (s, 1H, *t*BuCC*H*), 4.09 – 3.80 (m, 2H, OC*H*$_2$CH$_3$), 3.73 (d, *J* = 3.4 Hz, 1H, ArC*H*), 3.49 – 3.26 (m, 2H, OC*H*$_2$CH$_3$), 1.23 (s, 3H, CHCC*H*$_3$), 1.19 – 1.04 (m, 12H, *t*Bu and OCH$_2$C*H*$_3$), 1.10 (s, 9H, *t*Bu), 0.90 (td, *J* = 7.1, 1.2 Hz, 3H, OCH$_2$C*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2 (d, *J* = 3.1 Hz), 157.0 (d, *J* = 4.8 Hz), 152.0, 149.9, 137.4, 133.5, 130.6 (d, *J* = 7.5 Hz), 130.2, 129.6, 127.9, 127.2, 92.2, 64.9 (d, *J* = 6.6 Hz), 64.3 (d, *J* = 6.2 Hz), 52.6, 46.4, 35.3, 35.2, 29.1, 29.0, 20.3, 15.9 (d, *J* = 7.3 Hz), 15.7 (d, *J* = 7.1 Hz); IR ν 2962 (m), 2872 (w), 2246 (w), 1779 (s), 1703 (w), 1601 (w), 1481 (w), 1456 (w), 1393 (w), 1365 (w), 1295 (m), 1265 (w), 1189 (w), 1149 (w), 1099 (m), 1056 (s), 1033 (s), 967 (w), 918 (m); HRMS (ESI) calcd. for $C_{29}H_{39}NaO_6P^+$ $[M+Na]^+$ 537.2376; found 537.2390.

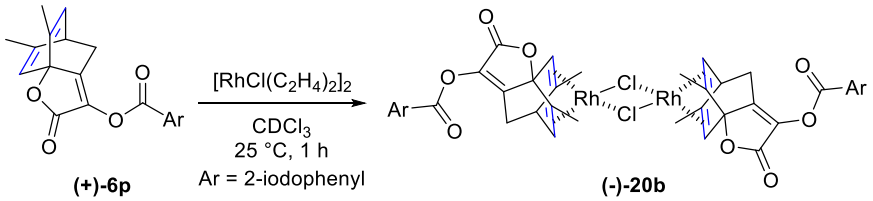
Preparation of [RhCl(6m)]$_2$ (20a)



Under inert atmosphere, $[RhCl(C_2H_4)_2]_2$ (6.5 mg, 17 µmol, 1.0 equiv) and 5-methyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate **6m** (14.1 mg, 33.0 µmol, 2.0 equiv) were stirred in $CDCl_3$ (1.7 mL) at 25 °C. Within 1 h, $[RhCl(C_2H_4)_2]_2$ was fully converted into [RhCl(**6m**)]$_2$ (**20a**). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (td, *J* = 7.5, 1.4 Hz, 4H, Ar*H*), 7.47 (td, *J* = 7.6, 1.2 Hz, 2H, Ar*H*), 7.28 – 7.20 (m, 2H, Ar*H*), 3.77 (dd, *J* = 5.5, 1.9 Hz, 4H, 2 x OCC*H*), 3.54 (dd, *J* = 5.9, 1.9 Hz, 4H, 2 x H$_3$CCC*H*), 2.30 (s, 4H, CHC*H*$_2$), 2.25 (s, 6H, C*H*$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4, 161.6, 149.2, 142.1, 134.2, 132.5, 131.8, 128.9, 128.4, 95.5, 88.8 (d, *J* = 3.9 Hz), 56.3 (d, *J* = 10.8 Hz), 49.2 (d, *J* = 11.0 Hz), 47.5 (d, *J* = 2.5 Hz), 39.2, 21.4. The complex can be isolated by precipitation in Et_2O to furnish **20a** as a yellow solid (18.6 mg, 17.0 µmol,

100%). The crystal structure of **20a** has been deposited at the Cambridge Crystallographic Data Centre and allocated the deposition number: CCDC 1945514.

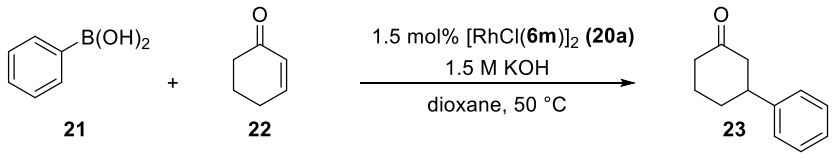
Preparation of [RhCl((+)-6p)]$_2$ (-)-(20b)



(+)-6p **(-)-20b**

Under inert atmosphere, [RhCl(C_2H_4)$_2$]$_2$ (15.9 mg, 41.0 µmol, 1.0 equiv) and (+)-(5R,7aS)-6,8-dimethyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate **(+)-(6p)** (35.6 mg, 82.0 µmol, 2.00 equiv) were stirred in $CDCl_3$ (4.1 mL) at 25 °C for 1 h. After complete complexation (monitored by ^{1}H NMR), the reaction mixture was directly loaded and purified by flash column chromatography using EtOAc:pentane 1:2 as eluent to furnish **(-)-20b** as a yellow solid (41.0 mg, 36.0 µmol, 87%). TLC (EtOAc:pentane, 1:1 v/v): R_f = 0.45; $[\alpha]_D^{20}$ = -26.11 (c = 0.3, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (dd, *J* = 7.8, 1.4 Hz, 4H, Ar*H*), 7.47 (td, *J* = 7.6, 1.2 Hz, 2H, Ar*H*), 7.28 – 7.21 (m, 2H, Ar*H*), 4.42 (s, 2H, OCC*H*=C), 3.50 (d, *J* = 5.3 Hz, 2H, C*H*CH_2), 3.39 (s, 2H, CH_3C=C*H*CH), 2.45 – 2.26 (m, 4H, CH_2), 1.62 (s, 6H, CH_3), 1.51 (s, 6H, CH_3); ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5, 161.7, 147.9 (br s), 142.1, 134.2, 132.5, 131.9, 129.2, 128.4, 95.4, 91.4 (d, *J* = 4.2 Hz), 64.4 (d, *J* = 9.3 Hz), 61.7 (d, *J* = 12.3 Hz), 47.6 (d, *J* = 10.8 Hz), 47.4 (d, *J* = 3.6 Hz), 46.0 (d, *J* = 11.1 Hz), 31.7 (d, *J* = 1.7 Hz), 21.4, 15.7. The crystal structure of **(-)-20b** has been deposited at the Cambridge Crystallographic Data Centre and allocated the deposition number: CCDC 2027174. The complex **(-)-20b** decomposed in the mass spectrometer and therefore the accurate mass was not obtained.

1,4-Addition of boronic acid 21 to enone 22 catalyzed by [RhCl(6m)]$_2$ (20a).

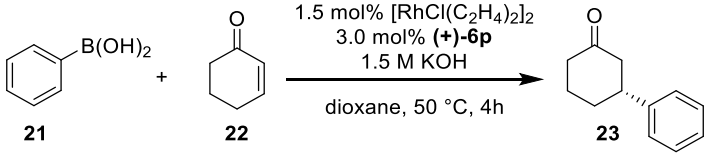


21 **22** **23**

An oven-dried 10 mL microwave vial was successively charged with [RhCl(**6m**)]$_2$ **20a** (8.4 mg, 7.5 µmol, 0.015 equiv), degassed dioxane (2.0 mL) and a 1.5 M degassed solution of KOH in water (167 µL, 0.250 mmol, 0.50 equiv) and the resulting mixture was stirred for a further 10 minutes at room temperature. Subsequently, phenylboronic acid (**21**) (122 mg, 1.00 mmol, 2.00 equiv) and 2-cyclohexenone (**22**) (48.5 µL, 0.50 mmol, 1.00 equiv) was added to this solution. After stirring at 50 °C for 3 h, the reaction mixture was quenched with saturated NH_4Cl in water (5 mL) and extracted with Et_2O (3 x 15 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using Et_2O:pentane 1:20 as mobile phase to afford 3-

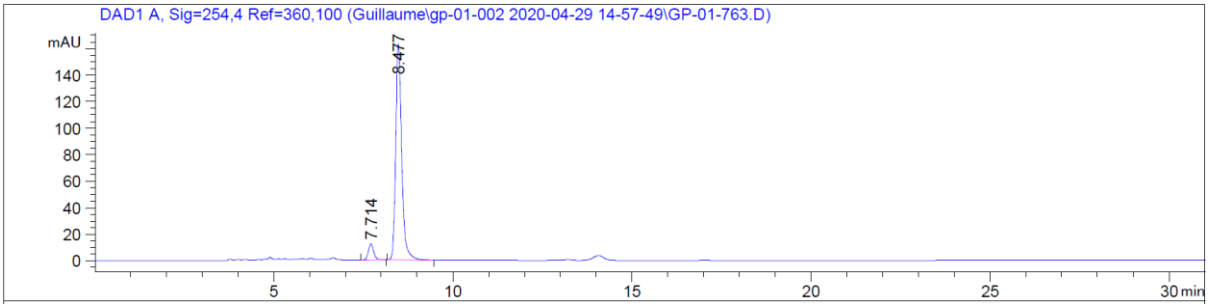
phenylcyclohexanone (**23**) as a colorless oil (67.0 mg, 0.385 mmol, 77%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37 – 7.30 (m, 2H), 7.27 – 7.20 (m, 3H), 3.02 (tt, *J* = 11.6, 4.0 Hz, 1H), 2.65 – 2.33 (m, 4H), 2.21 – 2.04 (m, 2H), 1.94 – 1.69 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 211.2, 144.5, 128.8, 126.8, 126.7, 49.1, 44.9, 41.3, 32.9, 25.7. The value of the NMR spectra are in accordance with reported literature data.[27]

Enantioselective Rh-catalyzed 1,4-addition of boronic acid 21 to enone 22.



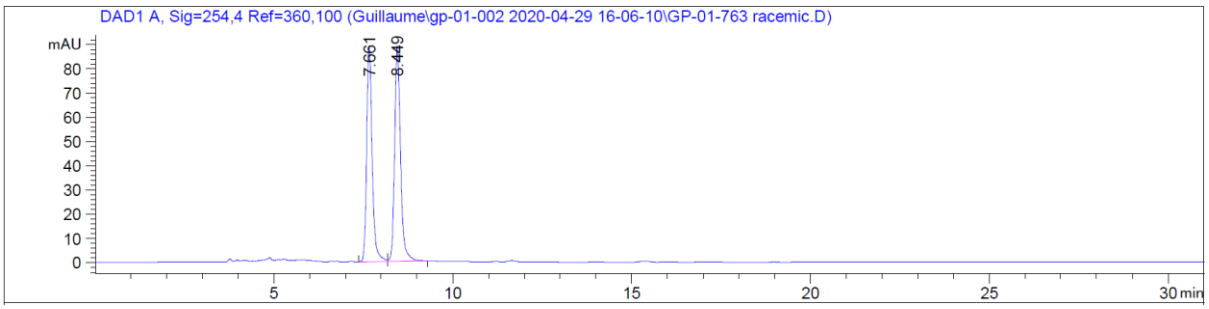
An oven-dried 10 mL microwave vial was charged with $[RhCl(C_2H_4)_2]_2$ (1.6 mg, 4.1 µmol, 0.015 equiv) and (+)-(5S,7aR)-6,8-dimethyl-2-oxo-4,5-dihydro-2H-5,7a-ethenobenzofuran-3-yl 2-iodobenzoate (**6p**) (3.6 mg, 8.2 µmol, 0.030 equiv) and degassed dioxane (1.1 mL) under inert atmosphere. After stirring 1 h at room temperature, a 1.5 M degassed solution of KOH in water (91 µL, 0.14 mmol, 0.50 equiv) was added and the reaction mixture was stirred for further 10 minutes at room temperature. Subsequently, phenylboronic acid (**21**) (67 mg, 0.55 mmol, 2.00 equiv) and 2-cyclohexenone (**22**) (26 µL, 0.27 mmol, 1.00 equiv) were added to this solution. After stirring at 50 °C for 4 h, the reaction mixture was quenched with saturated NH_4Cl in water (5 mL) and extracted with Et_2O (3 x 15 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography using Et_2O:pentane 1:20 as mobile phase to afford 3-phenylcyclohexanone (**23**) as a colorless oil (36.0 mg, 0.207 mmol, 75%). $[\alpha]_D^{20}$ = +17.00 (c = 0.5, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37 – 7.30 (m, 2H, Ar*H*), 7.27 – 7.20 (m, 3H, Ar*H*), 3.02 (tt, *J* = 11.6, 4.0 Hz, 1H, C*H*Ph), 2.65 – 2.33 (m, 4H, 2 x COCH_2), 2.21 – 2.04 (m, 2H, CH_2), 1.94 – 1.69 (m, 2H, CH_2); ^{13}C NMR (101 MHz, $CDCl_3$) δ 211.2, 144.5, 128.8, 126.8, 126.7, 49.1, 44.9, 41.3, 32.9, 25.7; Chiral HPLC conditions: ee = 87%, Chiralpak IA 95:5, Hexane/iPrOH, 0.8 mL/min, 30 min. tr (minor) = 7.7 min. and tr (major) = 8.5 min, λ = 254 nm. The value of the NMR spectra are in accordance with reported literature data.[27] Absolute configuration of the major enantiomer (drawn) was determined by comparison with $[\alpha]_D$ given in the literature.[28]

[27] Y. Takaya, M. Ogasawara, T. Hayashi, M. Sakai, N. Miyaura, *J. Am. Chem. Soc.* **1998**, *120*, 5579.
[28] M. Pucheault, S. Darses, J.-P. Genet, *Tetrahedron Lett.* **2002**, *43*, 6155.



Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.714	BB	0.1599	128.21254	12.26813	6.3354
2	8.477	BB	0.1759	1895.54675	162.76753	93.6646
Totals :				2023.75929	175.03567	

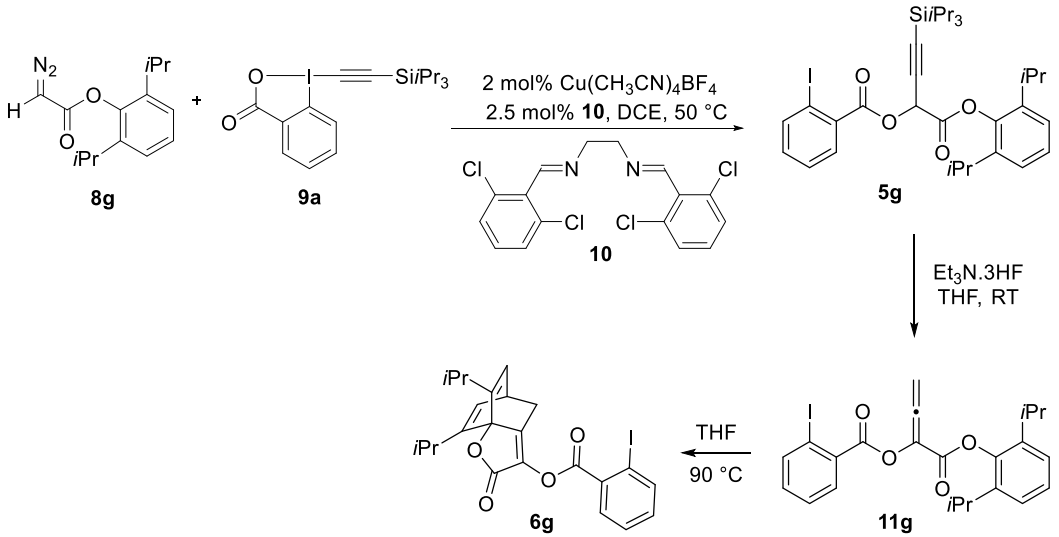


Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.661	BV	0.1597	943.93439	89.04942	47.9240
2	8.449	VB	0.1745	1025.71448	89.00008	52.0760
Totals :				1969.64886	178.04950	

7. Control experiments

Isolation of the reaction intermediates



A flame dried 5 mL microwave vial was charged under nitrogen with $Cu(CH_3CN)_4BF_4$ (1.9 mg, 6.0 µmol, 0.02 equiv), ligand **10** (2.8 mg, 7.5 µmol, 0.025 equiv) and dry DCE (2 mL). The resulting solution was stirred at 30 °C for 1 h and then added to a mixture of 1-[(tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (**9a**) (129 mg, 0.300 mmol, 1.00 equiv), 2,6-di*iso*propylphenyl 2-diazoacetate (**8g**) (89,0 mg, 0.180 mmol, 1.20 equiv) and dry DCE (10 mL) in 20 mL microwave vial over 2 min and the resulting reaction mixture was stirred at 50 °C for 4 h. After this time, the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography using EtOAc:pentane 1:50 as eluent to afford **5g** as a colorless oil (185 mg, 0.286 mmol, 95%). TLC (EtOAc:pentane, 1:30 v/v): R_f = 0.53, $KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 – 7.96 (m, 2H, Ar*H*), 7.44 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.25 – 7.13 (m, 4H, Ar*H*), 6.31 (s, 1H, OC*H*), 3.11 (hept, J = 6.8 Hz, 2H, 2 x C*H*$(CH_3)_2$), 1.30 – 1.15 (m, 12H, 2 x CH(C*H*$_3)_2$), 1.16 – 1.08 (m, 21H, TIPS); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.1, 164.4, 145.1, 141.7, 140.7, 133.5, 133.4, 132.0, 128.2, 127.2, 124.2, 96.9, 94.6, 91.7, 64.0, 27.2, 23.7 (br), 18.7, 11.3; IR ν 3685 (m), 3662 (m), 2970 (s), 2901 (s), 1781 (m), 1740 (m), 1464 (m), 1407 (m), 1393 (m), 1384 (m), 1241 (s), 1066 (s), 1016 (s), 882 (m), 791 (m), 740 (m), 679 (m); HRMS (ESI) calcd. for $C_{32}H_{43}INaO_4Si^+$ $[M+Na]^+$ 669.1868; Found 669.1875.

In a flame dried 20 mL microwave vial, 1-(2,6-diisopropylphenoxy)-1-oxo-4-(triisopropylsilyl)but-3-yn-2-yl 2-iodobenzoate (**5g**) (129 mg, 0.200 mmol, 1.00 equiv) was dissolved in THF (8 mL) under nitrogen. Then, triethylamine trihydrofluoride (33 µL, 0.200 mmol, 1.00 equiv) was added and the reaction mixture was stirred at room temperature for 16 h. After this time, the solvent was evaporated and the crude product was purified by flash column chromatography using EtOAc:pentane 1:30 as eluent to afford **11g** as a colorless oil (100 mg, 0.204 mmol, 100%). TLC (EtOAc:pentane, 1:30 v/v): R_f = 0.29,

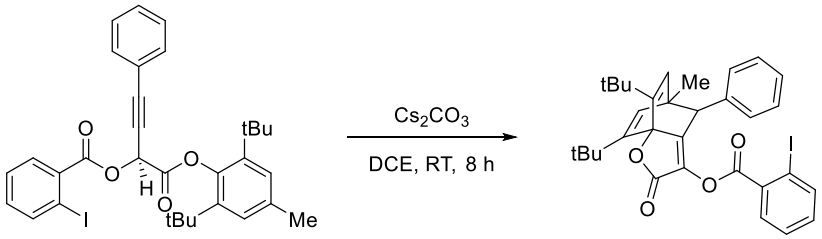
$KMnO_4$; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (ddd, *J* = 7.9, 3.6, 1.4 Hz, 2H, Ar*H*), 7.43 (td, *J* = 7.6, 1.2 Hz, 1H, Ar*H*), 7.25 – 7.14 (m, 4H, Ar*H*), 5.94 (s, 2H, CCH_2), 3.02 (hept, *J* = 6.9 Hz, 2H, 2 x C*H*$(CH_3)_2$), 1.21 (d, *J* = 6.9 Hz, 12H, 2 x CH(CH_3)$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 207.6, 163.9, 161.1, 145.5, 141.8, 140.6, 133.6, 133.3, 132.1, 128.2, 126.9, 124.2, 116.2, 95.0, 90.7, 27.7, 24.0 (br), 22.9 (br); IR ν 3661 (m), 2970 (s), 2901 (s), 1739 (s), 1465 (m), 1384 (m), 1276 (m), 1246 (m), 1225 (s), 1085 (s), 1065 (s), 1011 (s), 880 (m), 794 (m), 738 (s); HRMS (ESI) calcd. for $C_{23}H_{23}INaO_4^+$ $[M+Na]^+$ 513.0533; Found 513.0538.

In a flame dried 20 mL microwave vial, THF (6 mL) was added to 1-(2,6-diisopropylphenoxy)-1-oxobuta-2,3-dien-2-yl 2-iodobenzoate (**11g**) (73 mg, 0.15 mmol, 1.00 equiv) under nitrogen. The resulting reaction mixture was stirred at 90 °C for 12 h. After this time, the solvent was evaporated under reduced pressure and the crude product was purified by flash chromatography using Et_2O:pentane 1:9 as eluent to furnish **6g** as a white solid (67 mg, 0.137 mmol, 91%).

The oxyalkynylated and allene intermediates were successfully isolated and submitted to the next reaction step. It confirms the role of the copper catalyst for the oxyalkynylation of the diazo compound, the role of Et_3N•3HF for the desilylation/allene formation step and the need of thermal activation for the cycloaddition.

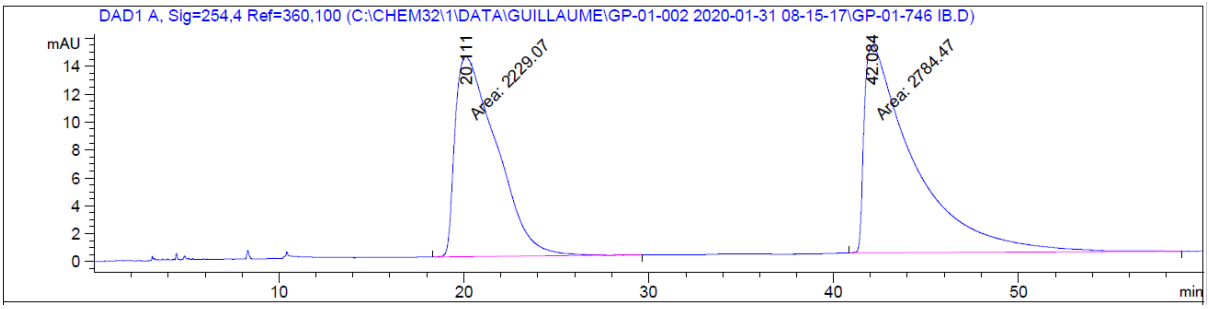
Racemization of the intermediate product

Enantioenriched (81% ee) (**5r**) was prepared according to a procedure of our previously reported work.[1]



5r, 81% ee **6r**, 91%, 0% ee

In a flame dried 20 mL microwave vial, Cs_2CO_3 (54.0 mg, 0.165 mmol, 1.10 equiv) was added to a solution of of (*S*)-1-(2,6-di-tert-butyl-4-methylphenoxy)-1-oxo-4-phenylbut-3-yn-2-yl 2-iodobenzoate (81% ee, **5r**) (91 mg, 0.15 mmol, 1.00 equiv) in DCE (5 mL) and the reaction mixture was stirred at room temperature for 8 h. After this time, the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography using Et_2O:pentane 1:20 as mobile phase to afford **6r** as a white solid (83.0 mg, 0.137 mmol, 91%). Chiral HPLC conditions: ee = 0%; Chiralpak IB 99.75:0.25 Hexane/iPrOH, 1 mL/min, 60 min. tr (1) = 20.1 min. and tr (2) = 42.0 min. λ = 254 cm^{-1}.



Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.111	MM	2.5997	2229.07227	14.29075	44.4611
2	42.084	MM	3.1237	2784.46704	14.85644	55.5389
Totals :				5013.53931	29.14719	

When an enantioenriched sample of **5r** was submitted to the cycloaddition reaction, a racemic mixture of the cycloadduct **6r** was obtained. It supports the formation of a racemic allene intermediate.

8. Crystal structures

Bragg-intensities of **6a**, **6p**, **20a** and **20b** were collected at low temperature using Mo*Kα*/Cu*Kα* radiation. A Rigaku SuperNova dual system diffractometer with an Atlas CCD detector was used for compound **6p** and one equipped with an Atlas S2 CCD detector for compounds **6a**, **20a** and **20b**. The datasets were reduced and corrected for absorption, with the help of a set of faces enclosing the crystal as snugly as possible, with the latest available version of *CrysAlis*^{Pro}.[1]

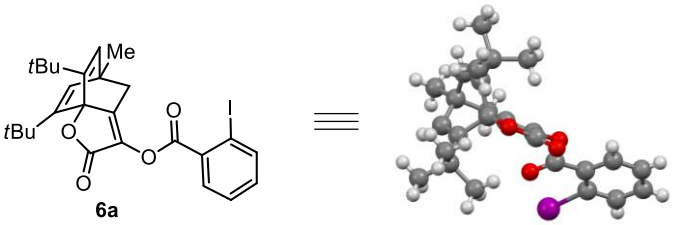
Bragg intensities of **6r** and **15** were measured, at low temperature using Mo*Kα* radiation, on a Bruker APEX II CCD diffractometer equipped with a κ-geometry goniometer. The datasets were reduced by EvalCCD[2] and then corrected for absorption.[3]

The solutions and refinements of the structures were performed by the latest available version of *ShelXT* [4] and *ShelXL*.[5] All non-hydrogen atoms were refined anisotropically using full-matrix least-squares based on $|F|^2$. The hydrogen atoms were placed at calculated positions by means of the "riding" model in which each H-atom was assigned a fixed isotropic displacement parameter with a value equal to 1.2 U_{eq} of its parent C-atom (1.5 U_{eq} for the methyl groups). Crystallographic and refinement data are summarized in Tables below.

Citations

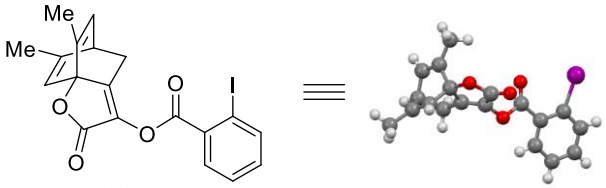
1. CrysAlis^{Pro} Software System, Rigaku Oxford Diffraction, (2020).
2. Duisenberg, A. J. M.; Kroon-Batenburg, L. M. J.; Schreurs, A. M. M. *J. Appl. Crystallogr.* **2003**, 36, 220−229.
3. Blessing, R. H. *Acta Crystallogr. A* **1995** , 51 ,33−38.
4. Sheldrick, G.M., ShelXT-Integrated space-group and crystal-structure determination, *Acta Cryst.*, (2015), **A71**, 3-8.
5. Sheldrick, G.M., Crystal structure refinement with ShelXL, *Acta Cryst.*, (2015), **C71**, 3-8.

CCDC 1848760



Empirical formula	$C_{26}H_{29}IO_4$	
Formula weight	532.39	
Temperature	292(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	$P\bar{1}$	
Unit cell dimensions	a = 8.7662(4) Å	α = 94.559(3)°.
	b = 11.9386(6) Å	β = 98.326(3)°.
	c = 12.1637(4) Å	γ = 106.805(4)°.
Volume	1195.86(9) $Å^3$	
Z	2	
Density (calculated)	1.479 Mg/m^3	
Absorption coefficient	1.368 mm^{-1}	
F(000)	540	
Crystal size	0.412 x 0.276 x 0.145 mm^3	
Θ range for data collection	2.570 to 29.772°.	
Index ranges	-11 ≤ h ≤ 12, -12 ≤ k ≤ 16, -16 ≤ l ≤ 16	
Reflections collected	9791	
Independent reflections	5617 [R_{int} = 0.0224]	
Completeness to *Θ* = 25.242°	99.9 %	
Absorption correction	Gaussian	
Max. and min. transmission	0.855 and 0.730	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5617 / 0 / 287	
Goodness-of-fit on F^2	1.030	
Final *R* indices [I>2σ(I)]	R_1 = 0.0366, wR_2 = 0.0751	
R indices (all data)	R_1 = 0.0515, wR_2 = 0.0825	
Largest diff. peak and hole	0.501 and -0.675 $e.Å^{-3}$	

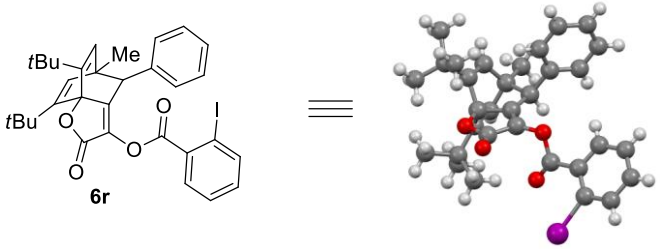
CCDC 2027173



(+)-6p

Empirical formula	$C_{19}H_{15}IO_4$	
Formula weight	434.21	
Colour	Colourless	
Shape	Needle	
Temperature	140.00(10) K	
Wavelength	0.71073 Å	
Radiation type	Mo*Kα*	
Crystal system	Orthorhombic	
Flack Parameter	-0.015(15)	
Hooft Parameter	-0.006(14)	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 7.4295(3) Å	α = 90°.
	b = 14.3717(5) Å	β = 90°.
	c = 31.6622(12) Å	γ = 90°.
Volume	3380.7(2) Å^3	
Z	8	
Z'	2	
Density (calculated)	1.706 g/cm^3	
Absorption coefficient	1.914 mm^{-1}	
Crystal size	0.53 x 0.06 x 0.03 mm^3	
Θ range for data collection	3.029 to 29.429°.	
Mesured reflections	36614	
Independent reflections	8423	
Refl's I≥2σ(I)	6816	
R_{int}	0.0357	
Parameters / restraints	437 / 0	
Goodness-of-fit on F^2	1.064	
Final *R* indices [I > 2σ(I)]	R_1 = 0.0333, wR_2 = 0.0670	
R indices (all data)	R_1 = 0.0493, wR_2 = 0.0742	
Largest diff. peak and hole	0.616 and -0.674 e.Å^{-3}	

CCDC 1848773



Empirical formula	$C_{32}H_{33}IO_4$	
Formula weight	608.48	
Temperature	120(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	$P\bar{1}$	
Unit cell dimensions	a = 9.3288(15) Å	α = 65.569(4)°.
	b = 12.5347(10) Å	β = 87.392(9)°.
	c = 13.9206(11) Å	γ = 69.207(9)°.
Volume	1375.7(3) $Å^3$	
Z	2	
Density (calculated)	1.469 Mg/m^3	
Absorption coefficient	1.199 mm^{-1}	
F(000)	620	
Crystal size	0.520 x 0.441 x 0.206 mm^3	
Theta range for data collection	2.980 to 34.999°.	
Index ranges	-15 ≤ h ≤ 15, -20 ≤ k ≤ 20, -21 ≤ l ≤ 22	
Reflections collected	32700	
Independent reflections	11876 [R_{int} = 0.0225]	
Completeness to Θ = 25.242°	98.2 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7469 and 0.5376	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	11876 / 0 / 351	
Goodness-of-fit on F^2	1.093	
Final *R* indices [I > 2σ(I)]	R_1 = 0.0361, wR_2 = 0.0799	
R indices (all data)	R_1 = 0.0485, wR_2 = 0.0885	
Largest diff. peak and hole	2.927 and -2.092 $e.Å^{-3}$	

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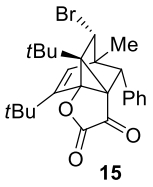
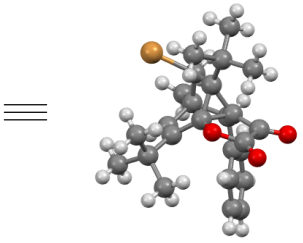
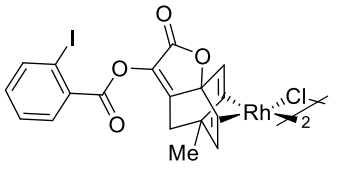


15

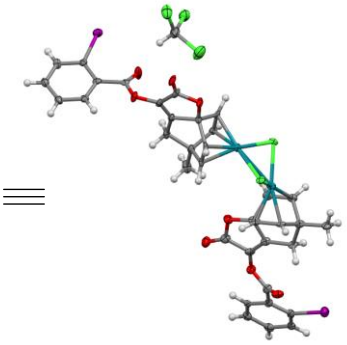


Empirical formula	$C_{25}H_{29}BrO_3$	
Formula weight	457.39	
Temperature	120(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	$P2_1/c$	
Unit cell dimensions	a = 15.6484(15) Å	α = 90°.
	b = 9.8378(7) Å	β = 112.228(8)°.
	c = 15.4117(12) Å	γ = 90°.
Volume	2196.3(3) Å^3	
Z	4	
Density (calculated)	1.383 Mg/m^3	
Absorption coefficient	1.895 mm^{-1}	
F(000)	952	
Crystal size	0.365 x 0.363 x 0.360 mm^3	
Theta range for data collection	1.406 to 34.998°.	
Index ranges	-25 ≤ h ≤ 25, -15 ≤ k ≤ 11, -24 ≤ l ≤ 24	
Reflections collected	45712	
Independent reflections	9569 [R_{int} = 0.0416]	
Completeness to Θ = 25.242°	99.6 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7469 and 0.6329	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	9569 / 0 / 269	
Goodness-of-fit on F^2	1.148	
Final R indices [I > 2σ(I)]	R_1 = 0.0406, wR_2 = 0.0686	
R indices (all data)	R_1 = 0.0870, wR_2 = 0.0856	
Largest diff. peak and hole	0.573 and -0.542 e.Å^{-3}	

CCDC 1945514



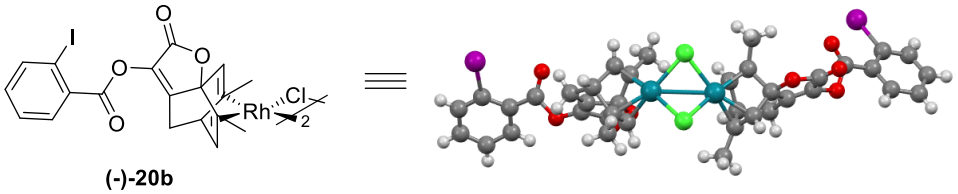
20a



Empirical formula	$C_{37}H_{27}Cl_5I_2O_8Rh_2$	
Formula weight	1236.45	
Temperature	100.00(10) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	$P\bar{1}$	
Unit cell dimensions	a = 7.9093(11) Å	α = 108.577(12)°.
	b = 13.7923(19) Å	β = 92.892(11)°.
	c = 19.266(3) Å	γ = 91.997(12)°.
Volume	1986.8(5) $Å^3$	
Z	2	
Density (calculated)	2.067 Mg/m^3	
Absorption coefficient	2.772 mm^{-1}	
F(000)	1188	
Crystal size	0.220 x 0.097 x 0.068 mm^3	
Θ range for data collection	2.582 to 26.372°.	
Index ranges	-9 ≤ h ≤ 9, -17 ≤ k ≤ 13, -24 ≤ l ≤ 23	
Reflections collected	8493	
Independent reflections	8493	
Completeness to *Θ* = 25.242°	98.6 %	
Absorption correction	Gaussian	
Max. and min. transmission	1.000 and 0.588	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	8493 / 737 / 491	
Goodness-of-fit on F^2	0.933	
Final *R* indices [I > 2σ(I)]	R_1 = 0.0697, wR_2 = 0.1388	
R indices (all data)	R_1 = 0.1395, wR_2 = 0.1508	

Largest diff. peak and hole	1.499 and -1.374 e.Å^{-3}

CCDC 2027174



(-)-20b

The structure was determined as a twin with three molecules of CH_2Cl_2. One unit of **(-)-20b**, as well as, the three molecules of CH_2Cl_2 were removed from the above representation for clarity reason.

Empirical formula	$C_{39.5}H_{33}Cl_5I_2O_8Rh_2$	
Formula weight	1272.53	
Colour	Clear intense yellow	
Shape	Needle	
Temperature	140.00(10) K	
Wavelength	1.54184 Å	
Radiation type	Cu*Kα*	
Crystal system	Triclinic	
Flack Parameter	-0.016(7)	
Space group	*P*1	
Unit cell dimensions	a = 8.0196(2) Å	α = 93.373(5)°.
	b = 15.8266(11) Å	β = 97.318(3)°.
	c = 17.0926(9) Å	γ = 96.178(4)°.
Volume	2133.47(19) Å^3	
Z	2	
Z'	2	
Density (calculated)	1.981 g/cm^3	
Absorption coefficient	20.924 mm^{-1}	
Crystal size	0.37×0.02×0.02 mm^3	
Θ range for data collection	2.816 to 72.429°.	
Mesured reflections	10540	
Independent reflections	10540	
Refl's I≥2σ(I)	8334	
R_{int}	n/a	
Parameters / restraints	992 / 1052	

Goodness-of-fit on F^2	1.151
Final R indices [I > 2σ(I)]	R_1 = 0.0635, wR_2 = 0.1680
R indices (all data)	R_1 = 0.0842, wR_2 = 0.1890
Largest diff. peak and hole	2.128 and -2.547 e.Å^{-3}

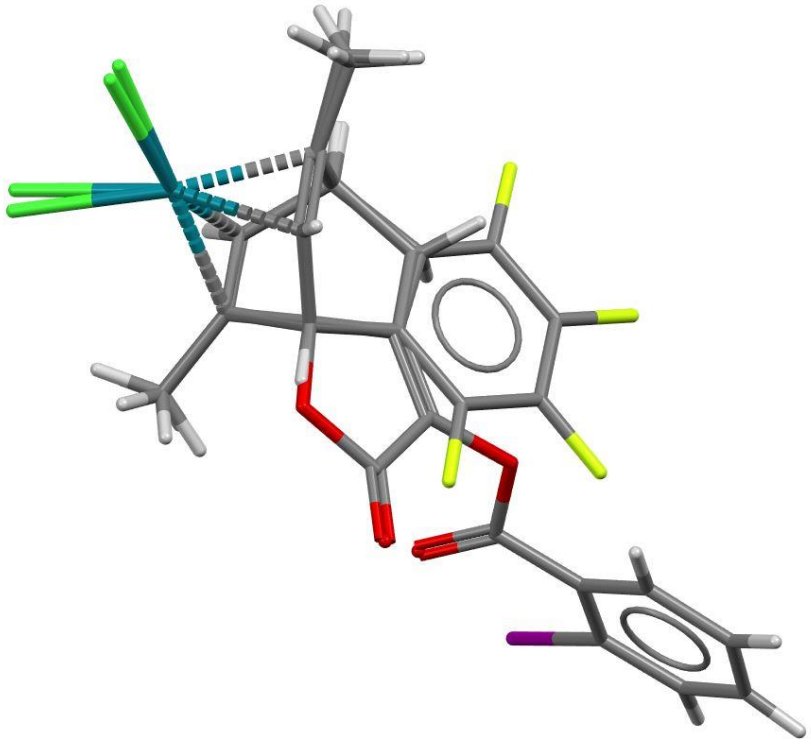


Figure S1. Overlay of the crystal structures of **20b** and **20c**. The mirror image of the reported structure for **20c** was used in order to have the same absolute configuration.

9. Computational details

The geometries of all structures were optimized using the M06-2X[29,30] density functional in tandem with the def2-SVP basis set[31] using the "ultrafine" integration grid and the SMD implicit solvent model[32] (in tetrahydrofuran) as implemented in Gaussian09.[33] Refined energy estaimtes were obtained on the M06-2X/def2-SVP geometries through single point energy computations using the PBE0[34,35] density functional appended with a density dependent dispersion correction[36] (-dDSC) and the TZ2P basis set as implementd in ADF.[37] Reported free energies include PBE0-dDsC/TZ2P electronic energies, M06/def2-SVP uncorrected free energy corrections, and solvation correction (at the PBE0-dDsC/TZ2P level) using COSMO-RS.[38]

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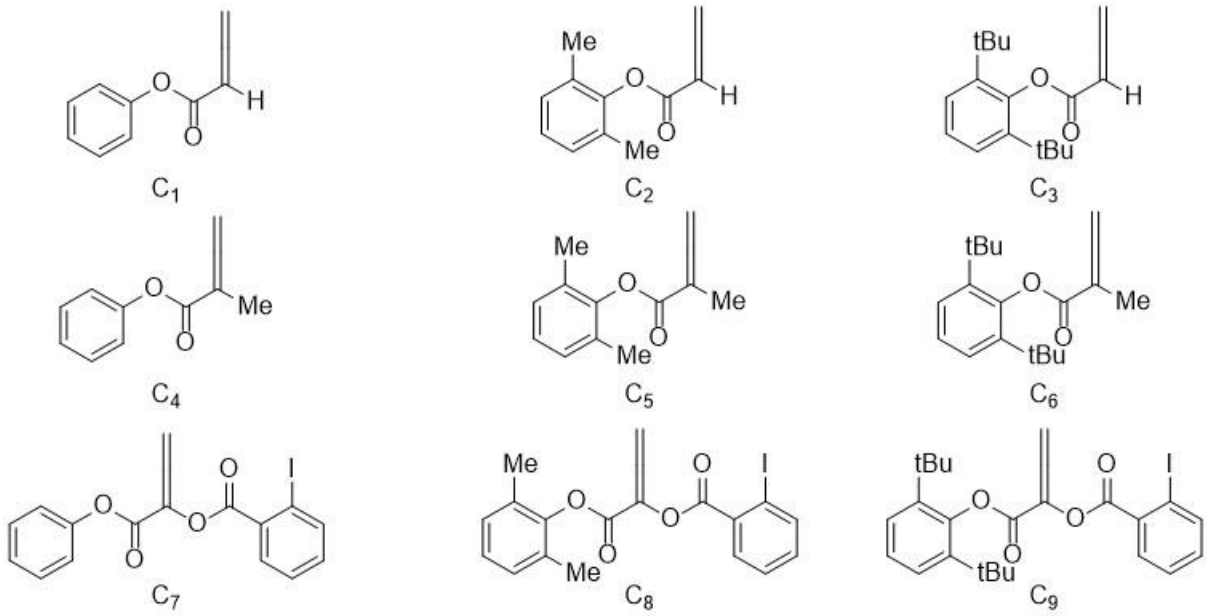

Figure S2. Schematic depiction of relevant compounds.

Table S1. Computed free energies for reactant, transition state, and product of C1 – C9 relevant to the reactant. Values in kcal/mol.

Compound	Reactant	Transition State	Product
C1	0.00	25.29	-36.07
C2	0.00	25.28	-37.15
C3	0.00	18.30	-41.38
C4	0.00	23.25	-36.32
C5	0.00	22.15	-38.71
C6	0.00	16.25	-41.31
C7	0.00	22.07	-33.96
C8	0.00	20.29	-36.51
C9	0.00	14.68	-40.71

Table S2. Computed energies, free energies and solvation corrections (in hartree) of relevant compounds.

Compound	M06-2X/def2-SVP Electronic Energy	M06-2X/def2-SVP Free Energy Correction	PBE0-dDsC/TZ2P//M06-2X/def2-SVP Electronic Energy	Solvation Correction
C1 – Reactant	-535.660485	0.115453	-5.882364	-0.014746
C1 – TS	-535.617528	0.119650	-5.846487	-0.014519
C1 – Product	-535.680127	0.124302	-5.907232	-0.015909
C2 – Reactant	-614.199300	0.165579	-7.351969	-0.015602
C2 – TS	-614.157995	0.171586	-7.317906	-0.015381
C2 – Product	-614.223114	0.176433	-7.382658	-0.014683
C3 – Reactant	-849.772979	0.331232	-11.711835	-0.018823
C3 – TS	-849.738859	0.333412	-11.684717	-0.018951
C3 – Product	-849.808169	0.337372	-11.761901	-0.011665
C4 – Reactant	-574.928934	0.141236	-6.615322	-0.014856
C4 – TS	-574.887718	0.144938	-6.581929	-0.014908
C4 – Product	-574.951522	0.150158	-6.644298	-0.015631
C5 – Reactant	-653.467394	0.193920	-8.084606	-0.015760
C5 – TS	-653.428103	0.197060	-8.052369	-0.015832

C5 – Product	-653.494318	0.201848	-8.118429	-0.016245
C6 – Reactant	-889.040804	0.356440	-12.444611	-0.019038
C6 – TS	-889.008836	0.358190	-12.428794	-0.010703
C6 – Product	-889.079516	0.363561	-12.490830	-0.019871
C7 – Reactant	-1251.829112	0.187822	-9.901926	-0.026683
C7 – TS	-1251.788131	0.190415	-9.867835	-0.028202
C7 – Product	-1251.849800	0.197190	-9.928381	-0.028557
C8 – Reactant	-1330.367868	0.239743	-11.370473	-0.028151
C8 – TS	-1330.329533	0.241703	-11.339615	-0.028642
C8 – Product	-1330.393078	0.246804	-11.402967	-0.028571
C9 – Reactant	-1565.940676	0.402229	-15.729831	-0.031708
C9 – TS	-1565.910105	0.403203	-15.707217	-0.031909
C9 – Product	-1565.978305	0.407324	-15.776023	-0.032103

Cartesian Coordinates

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Compound 1 - Reactant

C	-2.89486	0.36350	-0.13603
C	-0.18102	0.90589	-0.11991
C	-2.22251	0.59221	-1.33864
C	-2.20738	0.44544	1.07684
C	-0.84272	0.72517	1.09136
C	-0.85802	0.87270	-1.33625
O	1.17364	1.16571	-0.10951
C	2.10779	0.19874	-0.26412
O	3.26090	0.52300	-0.28960
C	1.71526	-1.23493	-0.38924
C	0.53184	-1.81259	-0.35051
C	-0.58800	-2.48032	-0.32620
H	-0.99768	-2.84832	0.61967
H	-3.96248	0.13850	-0.14310
H	-2.76389	0.54922	-2.28519
H	-2.73630	0.28630	2.01801
H	-0.27877	0.78171	2.02370
H	-0.30676	1.04398	-2.26241
H	2.59436	-1.87367	-0.52005
H	-1.14747	-2.66727	-1.24825

20

Compound 1 - TS

C	-2.49347	-0.24107	-0.16806
C	-0.05845	0.79404	-0.15977
C	-2.06100	0.41335	-1.36600
C	-2.00085	0.25209	1.08271
C	-0.75133	0.79518	1.09462
C	-0.81180	0.95734	-1.36779
O	1.26722	1.16361	-0.16781
C	2.16260	0.13621	-0.25649
O	3.33657	0.35473	-0.27017

C	1.49842	-1.18817	-0.32754
C	0.17425	-1.24078	-0.29966
C	-1.02544	-1.89652	-0.31347
H	-1.35746	-2.41267	0.58981
H	-3.45354	-0.76056	-0.17870
H	-2.66647	0.36167	-2.27221
H	-2.56143	0.08013	2.00285
H	-0.22228	1.08890	2.00236
H	-0.32682	1.36912	-2.25402
H	2.15015	-2.06124	-0.40062
H	-1.40295	-2.29041	-1.25947

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Compound 1 - Product

C	-0.90998	2.06559	-0.30677
C	-0.42740	-0.41316	-0.02548
C	-1.58854	1.43835	0.90040
C	-1.24166	1.22978	-1.53256
C	-0.98481	-0.07270	-1.39405
C	-1.33440	0.13749	1.05791
O	-0.02364	-1.74593	0.14633
C	1.32989	-1.80456	0.34422
O	1.89390	-2.84541	0.51394
C	1.87026	-0.42539	0.30311
C	0.85331	0.41405	0.08619
C	0.63405	1.88154	-0.07085
H	1.20497	2.27290	-0.92429
H	-1.15877	3.12337	-0.43292
H	-2.19788	2.03208	1.58321
H	-1.62331	1.68661	-2.44672
H	-1.09818	-0.84834	-2.15246
H	-1.67218	-0.50322	1.87341
H	2.92876	-0.21248	0.43577
H	0.95488	2.42323	0.82976

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Compound 2 - Reactant

C	-2.88706	0.44791	-0.10467
C	-0.16699	0.84175	-0.02346
C	-2.18947	0.71214	-1.28348
C	-2.21793	0.41336	1.11890
C	-0.83711	0.61700	1.18278
C	-0.80813	0.92122	-1.26329
O	1.20027	1.04784	0.01836
C	2.09692	0.04160	-0.09613
O	3.26401	0.31079	-0.04892
C	1.64650	-1.36942	-0.27674
C	0.43637	-1.88515	-0.35560
C	-0.70958	-2.50155	-0.44625
H	-1.21717	-2.87167	0.45007
H	-3.96531	0.28238	-0.13802
H	-2.71957	0.75396	-2.23739
H	-2.77029	0.22186	2.04135
C	-0.06698	0.55467	2.47134
C	-0.00796	1.17403	-2.50956
H	2.50058	-2.04984	-0.35078
H	-1.19411	-2.63968	-1.41794
H	-0.66558	1.25458	-3.38417
H	0.57886	2.10033	-2.42402
H	0.70639	0.35539	-2.69419
H	-0.74509	0.42067	3.32348
H	0.64514	-0.28640	2.46661
H	0.51907	1.47198	2.62883

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Compound 2 - TS

C	-2.53028	-0.24167	-0.18656
C	-0.03714	0.59318	-0.05294
C	-2.01123	0.43365	-1.33345
C	-2.04047	0.13112	1.10261

C	-0.75302	0.57879	1.19585
C	-0.72325	0.88676	-1.28390
O	1.31039	0.88439	-0.00060
C	2.14342	-0.19152	-0.12433
O	3.32908	-0.04830	-0.09239
C	1.39777	-1.46185	-0.29102
C	0.07088	-1.42658	-0.30258
C	-1.15946	-2.01715	-0.39043
H	-1.55322	-2.55782	0.47254
H	-3.52392	-0.68914	-0.25406
H	-2.58372	0.46507	-2.26289
H	-2.63486	-0.06405	1.99771
C	-0.02189	0.83807	2.47803
C	0.03723	1.44965	-2.44605
H	1.99243	-2.37146	-0.39686
H	-1.53138	-2.32940	-1.36832
H	-0.63486	1.62718	-3.29534
H	0.53259	2.39490	-2.18028
H	0.82664	0.75300	-2.77256
H	-0.71441	0.80449	3.32879
H	0.76155	0.08033	2.64281
H	0.47691	1.81811	2.46333

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Compound 2 - Product

C	0.53816	2.17931	0.70877
C	-0.19579	-0.11239	-0.07201
C	-0.48637	1.52037	1.61725
C	0.00520	2.15724	-0.71414
C	-0.38190	0.95273	-1.14880
C	-0.88252	0.30414	1.22550
O	-0.46996	-1.42524	-0.48845
C	0.67540	-2.17823	-0.45266
O	0.67631	-3.33201	-0.76761
C	1.78469	-1.31664	0.01663

C	1.29470	-0.09353	0.24742
C	1.79175	1.23412	0.71489
H	2.57355	1.61634	0.04358
H	0.81187	3.18532	1.04130
H	-0.83340	2.00150	2.53369
H	-0.01845	3.05733	-1.33142
C	-0.87125	0.55882	-2.50281
C	-1.80266	-0.64790	1.91464
H	2.80061	-1.68904	0.12912
H	2.21912	1.15716	1.72454
H	-2.19912	-0.20463	2.83746
H	-2.64371	-0.92684	1.26174
H	-1.27572	-1.58040	2.17133
H	-0.93410	1.43432	-3.16223
H	-0.19345	-0.17824	-2.96156
H	-1.86279	0.08490	-2.44196

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Compound 3 - Reactant

C	-0.16779	2.80949	-0.17375
C	-0.49197	0.09111	-0.35084
C	-1.07223	2.16775	0.66641
C	0.48253	2.10265	-1.18033
C	0.31965	0.71942	-1.31794
C	-1.28372	0.78655	0.58631
O	-0.57146	-1.29245	-0.36889
C	0.25055	-2.08953	0.35153
O	0.09972	-3.27710	0.26672
C	1.31246	-1.51646	1.22603
C	1.64437	-0.26386	1.46010
C	2.05529	0.93619	1.76313
H	2.83028	1.42824	1.16685
H	-0.00818	3.88487	-0.07725
H	-1.62056	2.76416	1.39308
H	1.12473	2.64926	-1.86825

C	0.94852	-0.04135	-2.50354
C	-2.37060	0.09772	1.43734
H	1.87718	-2.30622	1.73121
H	1.61747	1.48111	2.60549
C	-3.16693	1.13444	2.24181
C	-3.36342	-0.62293	0.50795
C	-1.79312	-0.90468	2.45243
C	1.64059	0.93284	-3.46688
C	2.01215	-1.06354	-2.06472
C	-0.16087	-0.75781	-3.29396
H	-3.97571	0.62056	2.78108
H	-2.54134	1.64503	2.98912
H	-3.62623	1.89457	1.59316
H	-4.16212	-1.08478	1.10897
H	-3.83094	0.09027	-0.18797
H	-2.87796	-1.41374	-0.07802
H	-2.58997	-1.20536	3.15004
H	-1.42520	-1.82744	1.98650
H	-0.98034	-0.45625	3.04350
H	2.01590	0.36923	-4.33320
H	0.94976	1.70242	-3.84108
H	2.50084	1.43395	-2.99848
H	2.55311	-1.41999	-2.95487
H	2.74806	-0.61122	-1.38282
H	1.58447	-1.95315	-1.58559
H	0.27884	-1.27241	-4.16246
H	-0.68266	-1.50588	-2.68361
H	-0.90099	-0.03341	-3.66682

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Compound 3 - TS

C	0.33392	2.54468	0.25885
C	-0.22691	-0.00026	-0.12472
C	-0.84514	2.04082	0.88094
C	0.72601	1.97622	-0.98780

C	0.43564	0.65980	-1.22923
C	-1.17763	0.72615	0.68963
O	-0.35275	-1.37372	-0.18296
C	0.52126	-2.09529	0.57789
O	0.47102	-3.29024	0.57776
C	1.46126	-1.24344	1.33861
C	1.37678	0.07384	1.22127
C	1.75634	1.35314	1.49606
H	2.65680	1.75429	1.02644
H	0.64021	3.56879	0.48096
H	-1.39558	2.67727	1.57279
H	1.33399	2.56501	-1.67365
C	0.85205	-0.08204	-2.50352
C	-2.38581	0.05119	1.34713
H	2.18820	-1.76103	1.96811
H	1.46325	1.80338	2.44668
C	-3.24420	1.09534	2.07052
C	-3.25444	-0.60960	0.26350
C	-1.96205	-1.00018	2.38885
C	1.45236	0.90199	-3.51431
C	1.91451	-1.15991	-2.22151
C	-0.38679	-0.72735	-3.14714
H	-4.14998	0.60908	2.46150
H	-2.71251	1.54403	2.92295
H	-3.56000	1.90312	1.39382
H	-4.13563	-1.07942	0.72755
H	-3.60968	0.14010	-0.46019
H	-2.70175	-1.38625	-0.28127
H	-2.84900	-1.32784	2.95346
H	-1.52473	-1.89893	1.93488
H	-1.24209	-0.58053	3.10822
H	1.66430	0.36981	-4.45326
H	0.75973	1.72572	-3.74207
H	2.39868	1.33303	-3.15467
H	2.30602	-1.54071	-3.17782

H	2.76128	-0.74543	-1.65305
H	1.51221	-2.02371	-1.67647
H	-0.09728	-1.24677	-4.07393
H	-0.85572	-1.46074	-2.47803
H	-1.13397	0.03885	-3.40529

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Compound 3 - Product

C	1.32383	2.24756	-0.34417
C	0.35641	-0.06483	0.04313
C	0.39808	2.16113	0.85254
C	0.60016	1.67482	-1.54620
C	0.08083	0.45075	-1.38039
C	-0.12748	0.95199	1.09198
O	-0.01085	-1.40205	0.28330
C	1.09716	-2.16904	0.53222
O	1.00327	-3.34013	0.76171
C	2.28853	-1.30115	0.45660
C	1.88022	-0.05990	0.17052
C	2.51117	1.27256	-0.04648
H	3.21440	1.23793	-0.89071
H	1.68950	3.26392	-0.51942
H	0.21363	3.03772	1.47343
H	0.54659	2.23648	-2.47873
C	-0.63474	-0.37862	-2.43600
C	-1.03010	0.57268	2.25628
H	3.29628	-1.67727	0.61776
H	3.06807	1.59015	0.84654
C	-1.35889	1.81821	3.08491
C	-2.34470	-0.02635	1.73277
C	-0.32718	-0.44021	3.17838
C	-0.78551	0.43806	-3.72299
C	0.17402	-1.64573	-2.76867
C	-2.03513	-0.77124	-1.94015
H	-2.03502	1.54240	3.90774

H	-0.45380	2.26094	3.52694
H	-1.85974	2.58683	2.47769
H	-3.01086	-0.25572	2.57920
H	-2.86469	0.68610	1.07375
H	-2.16845	-0.95616	1.17750
H	-0.94771	-0.61256	4.07172
H	-0.17638	-1.41321	2.69287
H	0.64892	-0.05666	3.51342
H	-1.32916	-0.15647	-4.47216
H	-1.35227	1.36487	-3.54933
H	0.19274	0.70477	-4.15019
H	-0.30011	-2.17034	-3.61295
H	1.20320	-1.38988	-3.06441
H	0.21318	-2.34977	-1.92725
H	-2.56367	-1.33174	-2.72711
H	-1.98066	-1.40769	-1.04801
H	-2.63089	0.12320	-1.70078

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Compound 4 - Reactant

C	-2.95559	0.77248	-0.26280
C	-0.20858	0.67814	0.14799
C	-2.08105	0.88040	-1.34490
C	-2.44395	0.63436	1.02895
C	-1.06783	0.58606	1.24080
C	-0.70144	0.84511	-1.14563
O	1.14437	0.66876	0.39846
C	2.04555	0.01426	-0.38267
O	3.12475	0.50359	-0.55347
C	1.68989	-1.33206	-0.92904
C	0.68839	-2.02549	-0.42598
C	-0.31345	-2.71088	0.04992
H	-0.19009	-3.36576	0.91833
H	-4.03382	0.80546	-0.42497
H	-2.47265	1.00406	-2.35604

H	-3.12156	0.55921	1.88108
H	-0.64578	0.46650	2.23939
H	-0.01079	0.94461	-1.98559
C	2.62284	-1.86359	-1.98611
H	-1.30668	-2.63012	-0.40593
H	2.29795	-2.85318	-2.32793
H	2.65514	-1.17945	-2.84670
H	3.64404	-1.93770	-1.58628

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Compound 4 - TS

C	-2.45371	-0.23068	-0.08173
C	-0.04078	0.85171	-0.18616
C	-2.16605	0.60924	-1.20332
C	-1.82077	0.06807	1.16579
C	-0.58317	0.63751	1.12236
C	-0.93032	1.18160	-1.25956
O	1.26952	1.26480	-0.28277
C	2.15971	0.29551	-0.63373
O	3.32273	0.54809	-0.74535
C	1.52530	-1.03700	-0.84573
C	0.21050	-1.11754	-0.67262
C	-0.96728	-1.81255	-0.65974
H	-1.19532	-2.46724	0.18442
H	-3.40157	-0.77219	-0.06728
H	-2.87136	0.68236	-2.03264
H	-2.26842	-0.26263	2.10431
H	0.04531	0.79963	1.99926
H	-0.55478	1.74013	-2.11818
C	2.44948	-2.15483	-1.23570
H	-1.45616	-2.05840	-1.60514
H	1.89443	-3.09074	-1.36958
H	2.97240	-1.90945	-2.17193
H	3.21994	-2.30063	-0.46410

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Compound 4 - Product

C	-0.63965	2.29621	-0.41051
C	-0.74440	-0.24054	-0.35272
C	-1.78092	1.74531	0.42947
C	-0.70053	1.65024	-1.78549
C	-0.75128	0.31649	-1.76292
C	-1.83948	0.41225	0.46806
O	-0.67432	-1.64073	-0.25845
C	0.50268	-2.00445	0.33122
O	0.78963	-3.15119	0.52031
C	1.28299	-0.78129	0.65935
C	0.55789	0.27032	0.26057
C	0.68026	1.75792	0.25641
H	1.56043	2.08010	-0.31830
H	-0.63365	3.38936	-0.45450
H	-2.45921	2.40572	0.97165
H	-0.66955	2.24823	-2.69742
H	-0.75354	-0.35387	-2.62339
H	-2.54060	-0.19662	1.04035
C	2.61861	-0.87294	1.31464
H	0.78127	2.14867	1.27910
H	3.04548	0.12437	1.48130
H	2.54124	-1.38917	2.28321
H	3.31625	-1.45532	0.69436

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Compound 5 - Reactant

C	-2.95648	0.67824	-0.27325
C	-0.21346	0.75918	0.01880
C	-2.14443	0.89459	-1.38433
C	-2.38582	0.52543	0.99093
C	-1.00029	0.56698	1.15988
C	-0.75143	0.95255	-1.25851
O	1.15419	0.84962	0.20865

C	2.06589	0.05368	-0.40299
O	3.18228	0.46481	-0.54476
C	1.67721	-1.32673	-0.83437
C	0.66108	-1.96606	-0.29086
C	-0.33394	-2.63067	0.22894
H	-0.20124	-3.22214	1.14061
H	-4.04080	0.64108	-0.39029
H	-2.59048	1.03681	-2.37106
H	-3.02113	0.36700	1.86505
C	-0.34294	0.37103	2.49496
C	0.14263	1.21862	-2.43761
C	2.61122	-1.96513	-1.83186
H	-1.32863	-2.59363	-0.22844
H	2.25858	-2.96566	-2.10796
H	2.68493	-1.34772	-2.73940
H	3.62125	-2.04382	-1.40556
H	-0.44349	1.58192	-3.29128
H	0.90707	1.97144	-2.19457
H	0.67085	0.30796	-2.76378
H	-1.09421	0.23127	3.28241
H	0.31362	-0.51369	2.47822
H	0.28744	1.23254	2.75986

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Compound 5 - TS

C	-2.49002	-0.31014	-0.19444
C	-0.05285	0.68770	-0.15907
C	-2.10084	0.48812	-1.31155
C	-1.92858	-0.01751	1.08453
C	-0.67100	0.51624	1.12918
C	-0.84630	1.03083	-1.30962
O	1.27020	1.08238	-0.17097
C	2.16422	0.09023	-0.44385
O	3.33743	0.31914	-0.47919
C	1.51677	-1.23095	-0.67643

C	0.19006	-1.27974	-0.59167
C	-0.98981	-1.96915	-0.65254
H	-1.28945	-2.60181	0.18578
H	-3.45185	-0.82553	-0.23404
H	-2.74123	0.55248	-2.19386
H	-2.43996	-0.33182	1.99690
C	0.13484	0.71822	2.37638
C	-0.21320	1.74018	-2.46794
C	2.43654	-2.37753	-0.98431
H	-1.41917	-2.21941	-1.62509
H	1.86644	-3.30122	-1.13918
H	3.02712	-2.16429	-1.88768
H	3.14980	-2.52959	-0.16063
H	-0.95299	1.92423	-3.25740
H	0.22466	2.70076	-2.15942
H	0.60387	1.13771	-2.89745
H	-0.48423	0.54746	3.26633
H	0.98565	0.01825	2.41115
H	0.55333	1.73423	2.42350

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Compound 5 - Product

C	-0.34403	2.40131	0.06523
C	-0.45489	-0.12169	-0.06591
C	-1.16746	1.76477	1.17254
C	-0.84599	1.87756	-1.27012
C	-0.90399	0.54420	-1.36238
C	-1.23157	0.42933	1.12539
O	-0.38013	-1.52487	-0.12085
C	0.91932	-1.92248	0.03195
O	1.23460	-3.07740	0.02026
C	1.77806	-0.72071	0.20050
C	0.97741	0.35151	0.14453
C	1.11329	1.83617	0.23095
H	1.77102	2.21799	-0.56319

H	-0.34301	3.49457	0.11585
H	-1.62943	2.36337	1.96002
H	-1.09604	2.55051	-2.09259
C	-1.26010	-0.29609	-2.54356
C	-1.87080	-0.51020	2.09324
C	3.25108	-0.85080	0.38866
H	1.53905	2.13663	1.19919
H	3.72598	0.13289	0.49437
H	3.47561	-1.44805	1.28501
H	3.70620	-1.37117	-0.46727
H	-2.36177	0.04341	2.90421
H	-2.61575	-1.14783	1.59352
H	-1.11857	-1.18390	2.53335
H	-1.53177	0.33454	-3.40013
H	-0.41154	-0.93577	-2.83371
H	-2.10095	-0.96773	-2.31311

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Compound 6 - Reactant

C	-0.17544	2.83554	-0.19123
C	-0.59310	0.12670	-0.30105
C	-1.14440	2.25465	0.62088
C	0.49591	2.07321	-1.14201
C	0.28790	0.69322	-1.24509
C	-1.40350	0.88029	0.57282
O	-0.73391	-1.25071	-0.29031
C	0.00030	-2.08584	0.47871
O	-0.22500	-3.26202	0.39020
C	1.06034	-1.58059	1.41303
C	1.40654	-0.32153	1.60570
C	1.84822	0.87306	1.89389
H	2.66744	1.32192	1.32262
H	0.02030	3.90694	-0.11937
H	-1.70485	2.89365	1.30058
H	1.19200	2.57321	-1.81274

C	0.94711	-0.12759	-2.37245
C	-2.55443	0.25969	1.39102
C	1.75222	-2.69022	2.17084
H	1.39058	1.46297	2.69484
C	-3.35243	1.35161	2.11704
C	-3.52683	-0.46249	0.44137
C	-2.06032	-0.72107	2.46929
C	1.71716	0.79098	-3.33133
C	1.95436	-1.16539	-1.84599
C	-0.14362	-0.83634	-3.19522
H	-4.20592	0.88583	2.63035
H	-2.74806	1.86790	2.87773
H	-3.74949	2.10339	1.41944
H	-4.37092	-0.87002	1.01915
H	-3.93148	0.23793	-0.30516
H	-3.04362	-1.29367	-0.08749
H	-2.89794	-0.96824	3.13985
H	-1.70319	-1.67304	2.05619
H	-1.26005	-0.27663	3.08031
H	2.11292	0.18709	-4.16053
H	1.07144	1.57031	-3.76164
H	2.57088	1.27963	-2.83853
H	2.52954	-1.56871	-2.69384
H	2.66746	-0.71170	-1.14108
H	1.47481	-2.02487	-1.36040
H	0.32260	-1.38894	-4.02570
H	-0.71595	-1.55064	-2.59005
H	-0.84344	-0.10300	-3.62426
H	2.51750	-2.28189	2.84096
H	1.02075	-3.25988	2.76203
H	2.22407	-3.39279	1.46883

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Compound 6 - TS

C	0.34716	2.48197	0.33135

C	-0.37677	-0.01735	-0.08494
C	-0.89234	2.06522	0.89386
C	0.76681	1.88165	-0.88930
C	0.39207	0.58972	-1.15006
C	-1.31178	0.77824	0.68116
O	-0.60939	-1.37728	-0.16139
C	0.16312	-2.16277	0.63826
O	0.02356	-3.35175	0.63080
C	1.13612	-1.40221	1.46530
C	1.14599	-0.08023	1.33839
C	1.61899	1.15888	1.65092
H	2.56556	1.49868	1.22515
H	0.71995	3.47864	0.57561
H	-1.42725	2.74104	1.56025
H	1.45541	2.42210	-1.53789
C	0.82400	-0.18308	-2.40033
C	-2.59731	0.19545	1.27677
C	2.01556	-2.21984	2.36775
H	1.30451	1.63822	2.58047
C	-3.40968	1.30000	1.96275
C	-3.46126	-0.39469	0.14952
C	-2.30436	-0.88562	2.33323
C	1.55436	0.75079	-3.37244
C	1.78402	-1.33796	-2.06085
C	-0.42096	-0.73104	-3.11809
H	-4.36409	0.88032	2.31292
H	-2.88587	1.71219	2.83803
H	-3.63577	2.12615	1.27241
H	-4.39906	-0.79217	0.56787
H	-3.71842	0.38153	-0.58745
H	-2.94685	-1.21261	-0.37138
H	-3.24115	-1.15245	2.84694
H	-1.90617	-1.81164	1.89857
H	-1.59714	-0.51752	3.09252
H	1.78508	0.20001	-4.29605

H	0.93660	1.62029	-3.64178
H	2.50498	1.11575	-2.95588
H	2.19382	-1.75383	-2.99453
H	2.62932	-0.98512	-1.44998
H	1.28916	-2.16514	-1.53559
H	-0.11907	-1.26561	-4.03220
H	-0.98131	-1.43010	-2.48385
H	-1.09251	0.09103	-3.40964
H	2.69644	-1.57428	2.93493
H	1.40390	-2.80436	3.07123
H	2.60647	-2.93729	1.77888

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Compound 6 - Product

C	1.03776	2.34623	0.49846
C	0.14818	0.02547	0.00114
C	0.25992	1.72786	1.64281
C	0.18499	2.26978	-0.75211
C	-0.29900	1.05609	-1.04959
C	-0.22192	0.49789	1.41747
O	-0.17638	-1.31383	-0.29170
C	0.96214	-2.04269	-0.49208
O	0.92277	-3.21099	-0.75527
C	2.13869	-1.15791	-0.32878
C	1.67570	0.06463	-0.03773
C	2.26405	1.40463	0.24704
H	2.86276	1.76058	-0.60401
H	1.36807	3.36590	0.71885
H	0.14269	2.26317	2.58489
H	0.01912	3.15663	-1.36350
C	-1.12120	0.68619	-2.27506
C	-0.97465	-0.37424	2.41115
C	3.52627	-1.67787	-0.48983
H	2.91705	1.36799	1.13116
C	-1.20993	0.40234	3.71057

C	-2.33859	-0.77940	1.83151
C	-0.15941	-1.63536	2.75184
C	-1.42394	1.94317	-3.09680
C	-0.34431	-0.29364	-3.17369
C	-2.45303	0.05166	-1.84604
H	-1.77662	-0.22482	4.41482
H	-0.26146	0.67899	4.19490
H	-1.78872	1.32107	3.53303
H	-2.89463	-1.37560	2.57187
H	-2.94062	0.11018	1.59020
H	-2.22537	-1.38501	0.92338
H	-0.66353	-2.18876	3.55968
H	-0.06689	-2.31845	1.89727
H	0.84961	-1.36921	3.10305
H	-2.03989	1.67240	-3.96728
H	-1.97914	2.68760	-2.50675
H	-0.50273	2.41485	-3.47042
H	-0.90300	-0.45203	-4.10952
H	0.64530	0.11193	-3.43539
H	-0.20983	-1.27686	-2.70399
H	-3.06014	-0.17558	-2.73629
H	-2.29336	-0.88423	-1.29568
H	-3.02795	0.74206	-1.20978
H	4.26683	-0.88319	-0.33322
H	3.72189	-2.48821	0.22832
H	3.66791	-2.09792	-1.49687

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Compound 7 - Reactant

C	-4.67498	2.36696	-0.46680
C	-3.38403	0.04816	0.33502
C	-5.10646	1.68445	0.67164
C	-3.60054	1.87116	-1.20761
C	-2.95132	0.70047	-0.81809
C	-4.46126	0.51822	1.07986

O	-2.79764	-1.13524	0.74571
C	-1.46791	-1.34305	0.76586
O	-1.02608	-2.44456	0.62244
C	-0.56653	-0.17937	1.05900
C	-0.92848	0.91589	1.68857
C	-1.32342	1.99439	2.30225
H	-1.65978	2.86461	1.72708
H	-5.18017	3.28135	-0.78102
H	-5.95095	2.06215	1.25047
H	-3.26445	2.39470	-2.10413
H	-2.10532	0.30543	-1.38471
H	-4.77472	-0.02910	1.96972
O	0.76067	-0.42626	0.76317
H	-1.33208	2.05226	3.39550
C	1.03638	-0.68662	-0.53935
C	2.42315	-1.21134	-0.69952
O	0.23263	-0.51946	-1.41164
C	2.92328	-2.04309	0.31329
C	4.18014	-2.62668	0.20192
C	4.96010	-2.36742	-0.92319
C	3.21594	-0.95830	-1.83019
C	4.48411	-1.53158	-1.93234
H	2.29807	-2.24089	1.18422
H	4.54890	-3.28135	0.99219
H	5.95095	-2.81358	-1.02276
I	2.63292	0.33000	-3.39550
H	5.10505	-1.32301	-2.80403

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Compound 7 - TS

C	-3.87578	2.47352	0.72474
C	-3.44509	-0.06475	0.11392
C	-4.16927	1.50178	1.73345
C	-4.03981	2.09501	-0.64593
C	-3.83198	0.78754	-0.96919

C	-3.96288	0.19067	1.42428
O	-3.05433	-1.35747	-0.18580
C	-1.71827	-1.57421	-0.14147
O	-1.24076	-2.64900	-0.34137
C	-0.96248	-0.33136	0.18637
C	-1.60471	0.79670	0.42472
C	-1.68526	2.12057	0.74928
H	-1.45761	2.86898	-0.01286
H	-3.95092	3.53111	0.98403
H	-4.43149	1.81861	2.74395
H	-4.20240	2.85550	-1.41112
H	-3.80311	0.40863	-1.99163
H	-4.03546	-0.62465	2.14539
O	0.40423	-0.49758	0.26046
H	-1.52710	2.42305	1.78710
C	1.03815	-0.75489	-0.91435
C	2.44098	-1.20858	-0.67331
O	0.50294	-0.62830	-1.97577
C	2.68952	-1.98360	0.46917
C	3.95624	-2.49627	0.72479
C	4.99895	-2.22195	-0.15782
C	3.49854	-0.94048	-1.55663
C	4.77361	-1.44165	-1.29066
H	1.86295	-2.19238	1.14841
H	4.12783	-3.10709	1.61175
H	6.00007	-2.61285	0.03165
I	3.30507	0.26445	-3.27702
H	5.59579	-1.21972	-1.97150

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Compound 7 - Product

C	-3.59976	2.69424	2.10716
C	-3.83255	0.41053	1.02117
C	-4.42589	1.70667	2.91528
C	-4.15099	2.73685	0.69094

C	-4.27207	1.54078	0.11122
C	-4.55029	0.50241	2.35321
O	-3.82867	-0.87112	0.42846
C	-2.56046	-1.35371	0.37250
O	-2.28133	-2.43416	-0.05252
C	-1.65976	-0.31801	0.94078
C	-2.37390	0.73067	1.34317
C	-2.16561	2.05659	1.98742
H	-1.50773	2.69037	1.37652
H	-3.54373	3.68241	2.57256
H	-4.84281	1.97534	3.88679
H	-4.38485	3.68231	0.19981
H	-4.59597	1.33498	-0.90961
H	-5.05726	-0.36824	2.77106
O	-0.31991	-0.55088	1.04316
H	-1.70712	1.94118	2.97962
C	0.35606	-0.69893	-0.13327
C	1.73793	-1.21005	0.10692
O	-0.13988	-0.43935	-1.18817
C	1.94787	-2.04736	1.21321
C	3.19507	-2.60882	1.46091
C	4.25827	-2.32312	0.60693
C	2.81732	-0.92883	-0.74719
C	4.07259	-1.48148	-0.48835
H	1.10780	-2.26543	1.87238
H	3.33529	-3.26685	2.31911
H	5.24453	-2.75296	0.78987
I	2.69592	0.36512	-2.40868
H	4.91132	-1.25102	-1.14572

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Compound 8 - Reactant

C	-5.19880	2.35815	0.42296
C	-3.78648	0.01919	0.15401
C	-5.08703	1.48781	1.50766

C	-4.62492	2.03283	-0.80602
C	-3.90986	0.84268	-0.96899
C	-4.37750	0.29029	1.39018
O	-3.07469	-1.16645	0.02643
C	-1.73573	-1.22830	0.08695
O	-1.18116	-2.26909	-0.12057
C	-0.93204	0.00136	0.42136
C	-1.33110	1.17674	0.86229
C	-1.63668	2.35958	1.31569
H	-1.84552	3.18469	0.62647
H	-5.75173	3.29273	0.53222
H	-5.55018	1.73971	2.46394
H	-4.73031	2.70841	-1.65748
C	-3.26174	0.45626	-2.26858
C	-4.18366	-0.65372	2.54244
O	0.42813	-0.24578	0.31357
H	-1.70330	2.54655	2.39261
C	0.89640	-0.45284	-0.94276
C	2.27419	-1.02671	-0.90859
O	0.25295	-0.20733	-1.92160
C	2.56882	-1.94294	0.11160
C	3.80677	-2.57319	0.16929
C	4.77351	-2.27716	-0.78961
C	3.25414	-0.73723	-1.87044
C	4.50186	-1.35828	-1.80224
H	1.79808	-2.16685	0.84932
H	4.01529	-3.29273	0.96183
H	5.75173	-2.75951	-0.75447
I	2.98426	0.67390	-3.41456
H	5.26593	-1.12105	-2.54284
H	-4.76411	-0.32750	3.41456
H	-4.49085	-1.67560	2.27720
H	-3.12244	-0.70203	2.83688
H	-3.50511	1.18470	-3.05223
H	-2.16477	0.40857	-2.17390

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Compound 8 - TS

C	-4.12784	2.53774	0.74571
C	-3.64625	0.02478	0.12778
C	-4.39150	1.55980	1.75199
C	-4.27537	2.16665	-0.62560
C	-4.04268	0.86525	-0.97083
C	-4.16538	0.24610	1.45112
O	-3.25499	-1.26892	-0.18378
C	-1.91542	-1.46943	-0.18255
O	-1.42967	-2.53421	-0.41656
C	-1.17233	-0.22170	0.14898
C	-1.82816	0.89320	0.41919
C	-1.89705	2.21447	0.75984
H	-1.68712	2.97258	0.00267
H	-4.22011	3.59289	1.01029
H	-4.64281	1.86835	2.76884
H	-4.43324	2.93057	-1.38966
C	-3.94374	0.35165	-2.37474
C	-4.21872	-0.88221	2.43563
O	0.19896	-0.36425	0.18455
H	-1.72958	2.50545	1.79930
C	0.80913	-0.56344	-1.01223
C	2.23237	-0.97451	-0.82000
O	0.24484	-0.42625	-2.05775
C	2.52810	-1.81190	0.26551
C	3.81757	-2.29041	0.46885
C	4.83434	-1.91840	-0.40833
C	3.26386	-0.60690	-1.69763
C	4.56134	-1.07401	-1.48334
H	1.72107	-2.09695	0.94065
H	4.02699	-2.95099	1.31091
H	5.85267	-2.28126	-0.25913
I	2.99190	0.70956	-3.32269

H	5.36378	-0.77516	-2.15839
H	-4.64308	-0.53942	3.38772
H	-4.82472	-1.71761	2.05609
H	-3.20951	-1.27865	2.63344
H	-4.28878	1.11222	-3.08648
H	-2.89845	0.10042	-2.61964
H	-4.53842	-0.56289	-2.51260

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Compound 8 - Product

C	-1.85289	2.43873	3.41862
C	-2.84323	0.58433	2.01410
C	-2.65923	1.42656	4.21399
C	-2.70285	2.93358	2.26007
C	-3.22762	1.96811	1.49740
C	-3.18895	0.43382	3.49017
O	-3.27723	-0.48261	1.19553
C	-2.20478	-1.11314	0.64918
O	-2.28850	-2.05850	-0.07627
C	-0.98440	-0.42185	1.13352
C	-1.32043	0.57440	1.95129
C	-0.66765	1.63706	2.76658
H	-0.05086	2.29175	2.13499
H	-1.46838	3.25375	4.03911
H	-2.75967	1.49992	5.29842
H	-2.82158	3.99807	2.04994
C	-3.99819	2.09032	0.22542
C	-3.96271	-0.75456	3.95606
O	0.24570	-0.87173	0.75175
H	-0.02006	1.19536	3.53708
C	0.54679	-0.73082	-0.57144
C	1.75883	-1.52546	-0.92716
O	-0.10995	-0.05911	-1.30915
C	1.93336	-2.76621	-0.29689
C	2.99905	-3.59392	-0.63173

C	3.91577	-3.17724	-1.59482
C	2.68791	-1.11557	-1.89619
C	3.76615	-1.94008	-2.21969
H	1.20503	-3.08088	0.45080
H	3.11282	-4.56097	-0.14073
H	4.76008	-3.81367	-1.86500
I	2.60514	0.75486	-2.86624
H	4.49469	-1.61358	-2.96233
H	-4.10942	-0.71804	5.04330
H	-4.94612	-0.80380	3.46441
H	-3.43288	-1.68702	3.70510
H	-4.17826	3.14535	-0.01812
H	-3.43913	1.63029	-0.60552
H	-4.96356	1.56668	0.29205

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Compound 9 - Reactant

C	-5.01536	1.07666	2.38753
C	-3.68021	0.00736	0.24779
C	-4.65592	-0.26736	2.40270
C	-4.81016	1.84890	1.24851
C	-4.15687	1.32841	0.12533
C	-3.99593	-0.85395	1.31748
O	-2.90253	-0.50310	-0.78610
C	-1.56710	-0.37661	-0.83455
O	-0.97332	-0.81154	-1.78094
C	-0.81775	0.31445	0.27234
C	-1.25822	0.82358	1.40437
C	-1.59535	1.37074	2.53809
H	-1.86506	2.43093	2.58868
H	-5.51123	1.51456	3.25563
H	-4.89806	-0.86238	3.28118
H	-5.17348	2.87464	1.24302
C	-4.03443	2.15168	-1.17428
C	-3.68257	-2.36315	1.29739

O	0.52436	0.45001	-0.04880
H	-1.62661	0.77825	3.45854
C	1.27523	-0.68168	-0.01976
C	2.58103	-0.46662	-0.71305
O	0.90301	-1.69395	0.49533
C	2.58832	0.36489	-1.84250
C	3.74963	0.55590	-2.58271
C	4.92729	-0.07521	-2.18729
C	3.77268	-1.09804	-0.32458
C	4.94170	-0.89376	-1.05890
H	1.65676	0.84568	-2.14100
H	3.73380	1.19583	-3.46559
H	5.84805	0.06734	-2.75536
I	3.93809	-2.31474	1.39127
H	5.86887	-1.37555	-0.74744
C	-4.26739	-3.05388	2.53635
C	-4.33795	-3.00578	0.06217
C	-2.17158	-2.65047	1.29383
C	-4.81002	3.47074	-1.05158
C	-2.57983	2.52284	-1.51505
C	-4.65558	1.36455	-2.34177
H	-2.00875	-3.72182	1.48894
H	-1.68624	-2.43469	0.33464
H	-1.64863	-2.08342	2.07820
H	-4.08748	-4.13567	2.45681
H	-3.79277	-2.70484	3.46559
H	-5.35314	-2.89980	2.62056
H	-4.13620	-4.08815	0.06028
H	-5.42932	-2.86397	0.08286
H	-3.94993	-2.58709	-0.87508
H	-2.58222	3.27635	-2.31750
H	-2.06042	2.95736	-0.64761
H	-1.99229	1.67562	-1.89167
H	-4.76772	3.99814	-2.01540
H	-5.86887	3.30289	-0.80640

H	-4.37690	4.13567	-0.28970
H	-4.59864	1.96652	-3.26189
H	-4.13534	0.41588	-2.52434
H	-5.71609	1.14805	-2.14200

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Compound 9 - TS

C	-3.78298	-0.93523	2.33787
C	-2.99499	-0.18312	-0.06033
C	-3.49066	-1.96461	1.39768
C	-4.29569	0.29855	1.84387
C	-3.92503	0.71268	0.59171
C	-3.09732	-1.61226	0.13348
O	-2.39172	0.26252	-1.22789
C	-1.12312	0.71498	-1.09937
O	-0.51244	1.15152	-2.02899
C	-0.62078	0.61278	0.29655
C	-1.39021	0.13182	1.25443
C	-1.67815	-0.22238	2.53630
H	-1.89934	0.55577	3.27000
H	-4.01819	-1.22101	3.36486
H	-3.48525	-3.00185	1.73036
H	-4.88656	0.93095	2.50543
C	-4.37012	2.04084	-0.02966
C	-2.69752	-2.62309	-0.94550
O	0.64802	1.12405	0.48008
H	-1.29204	-1.16572	2.92841
C	1.66717	0.44218	-0.10311
C	2.91350	1.26608	-0.12560
O	1.54135	-0.66565	-0.53492
C	2.77744	2.64740	-0.32679
C	3.89429	3.46891	-0.43045
C	5.16741	2.91449	-0.31509
C	4.20064	0.71838	-0.01259
C	5.32120	1.54576	-0.09977

H	1.77474	3.06513	-0.41776
H	3.76966	4.53893	-0.60010
H	6.05395	3.54646	-0.38894
I	4.56508	-1.32402	0.36779
H	6.31939	1.11920	0.00288
C	-2.99090	-4.04926	-0.46535
C	-3.52696	-2.37218	-2.21610
C	-1.19581	-2.54199	-1.27274
C	-5.40926	2.71939	0.87056
C	-3.19609	3.02239	-0.20311
C	-5.02928	1.76990	-1.39252
H	-0.91732	-3.40032	-1.90404
H	-0.92478	-1.63644	-1.83029
H	-0.58202	-2.57851	-0.36072
H	-2.77742	-4.75381	-1.28234
H	-2.35991	-4.33145	0.39051
H	-4.04531	-4.17434	-0.17716
H	-3.25398	-3.10812	-2.98817
H	-4.60229	-2.48014	-2.00636
H	-3.35165	-1.36953	-2.62776
H	-3.59287	4.01578	-0.46383
H	-2.61923	3.12461	0.72901
H	-2.51327	2.73356	-1.01293
H	-5.78007	3.62645	0.37145
H	-6.27052	2.06291	1.06366
H	-4.97932	3.02219	1.83681
H	-5.37008	2.71830	-1.83614
H	-4.33139	1.29759	-2.09626
H	-5.90519	1.11364	-1.27605

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Compound 9 - Product

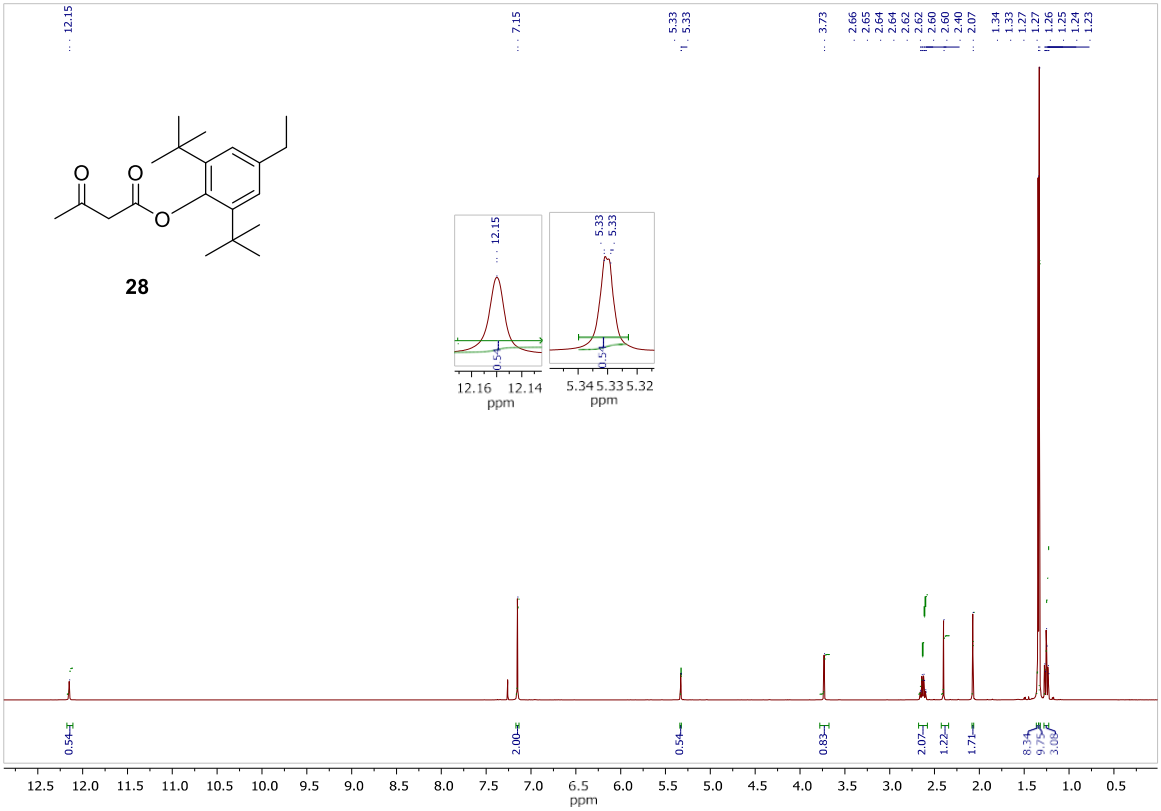
C	-2.04702	3.36676	0.31099
C	-2.50694	0.90754	-0.09882
C	-2.45352	2.60131	1.55402

C	-3.07731	3.10345	-0.76826
C	-3.34455	1.81392	-1.01601
C	-2.69906	1.29578	1.37837
O	-2.59951	-0.47781	-0.37395
C	-1.40160	-0.96283	-0.79306
O	-1.22956	-2.10066	-1.11620
C	-0.43879	0.16010	-0.78109
C	-1.05373	1.27668	-0.39467
C	-0.71404	2.70920	-0.18549
H	-0.37105	3.16869	-1.12350
H	-1.90310	4.43415	0.50245
H	-2.49910	3.10253	2.52047
H	-3.53504	3.93185	-1.30837
C	-4.28255	1.27317	-2.08470
C	-3.04146	0.28475	2.46190
O	0.84982	-0.02738	-1.18773
H	0.08424	2.81829	0.56216
C	1.60455	-0.86707	-0.42214
C	2.88558	-1.20460	-1.10974
O	1.24223	-1.25651	0.64734
C	2.86738	-1.32742	-2.50710
C	4.00843	-1.70334	-3.20674
C	5.19194	-1.94389	-2.51177
C	4.08320	-1.45044	-0.41955
C	5.23198	-1.81150	-1.12473
H	1.93403	-1.13893	-3.03811
H	3.97259	-1.80667	-4.29174
H	6.09743	-2.23464	-3.04694
I	4.29217	-1.23513	1.66812
H	6.16390	-1.98843	-0.58709
C	-3.17913	0.99926	3.80998
C	-4.37518	-0.40645	2.13927
C	-1.92390	-0.76702	2.59336
C	-4.99875	2.43440	-2.78142
C	-3.49145	0.49313	-3.15052

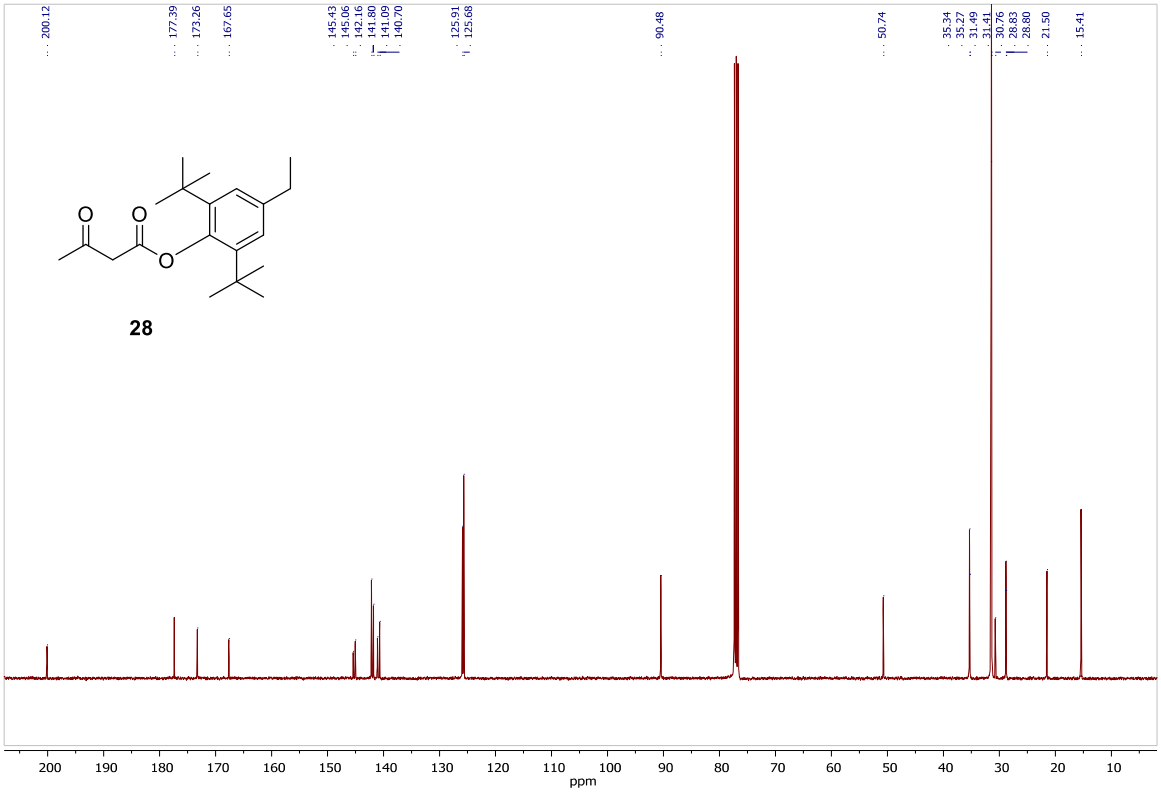
C	-5.34182	0.35960	-1.44887
H	-2.12505	-1.40217	3.47026
H	-1.86090	-1.42939	1.72042
H	-0.94340	-0.28928	2.73876
H	-3.46010	0.26886	4.58308
H	-2.23247	1.46824	4.11697
H	-3.95724	1.77635	3.77779
H	-4.62894	-1.11406	2.94399
H	-5.19023	0.33005	2.06523
H	-4.32253	-0.96895	1.19816
H	-4.16848	0.20255	-3.96891
H	-2.69026	1.11523	-3.57862
H	-3.04720	-0.42887	-2.75290
H	-5.69342	2.03591	-3.53565
H	-5.58148	3.03497	-2.06722
H	-4.28838	3.09903	-3.29539
H	-6.04091	0.00885	-2.22401
H	-4.88682	-0.52205	-0.97976
H	-5.92239	0.90426	-0.68846

10. Spectra for new compounds

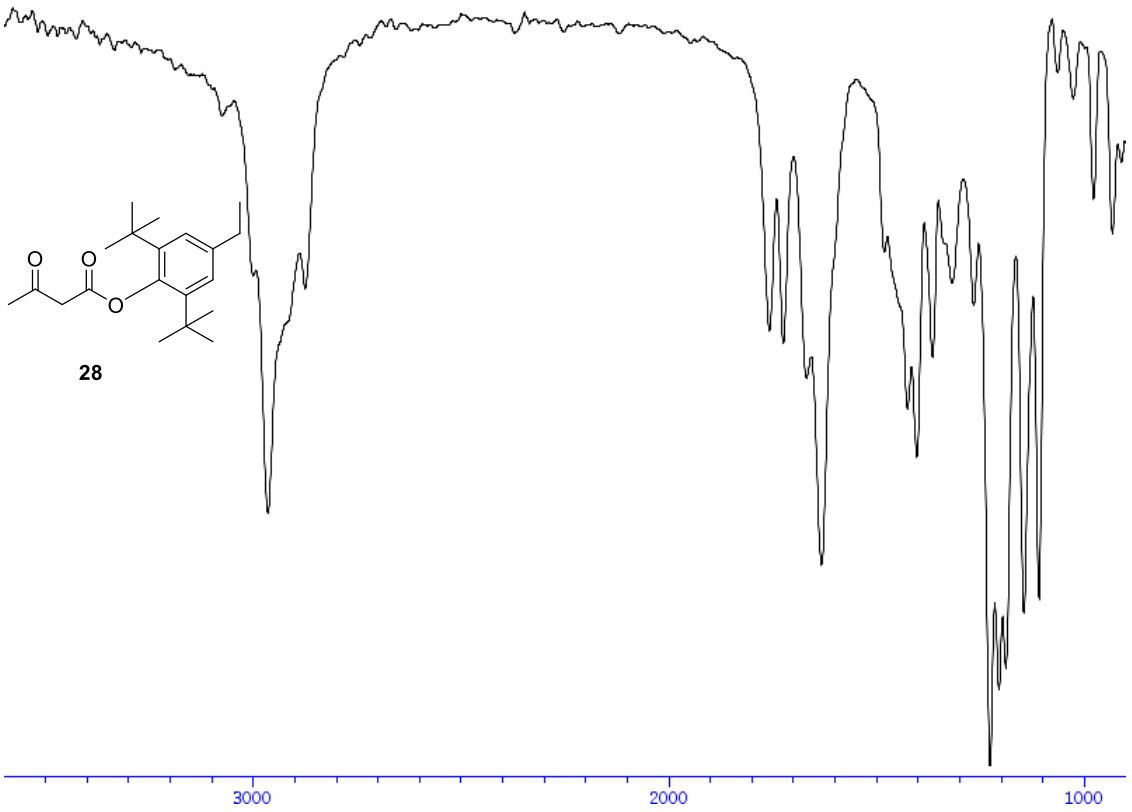
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **28**



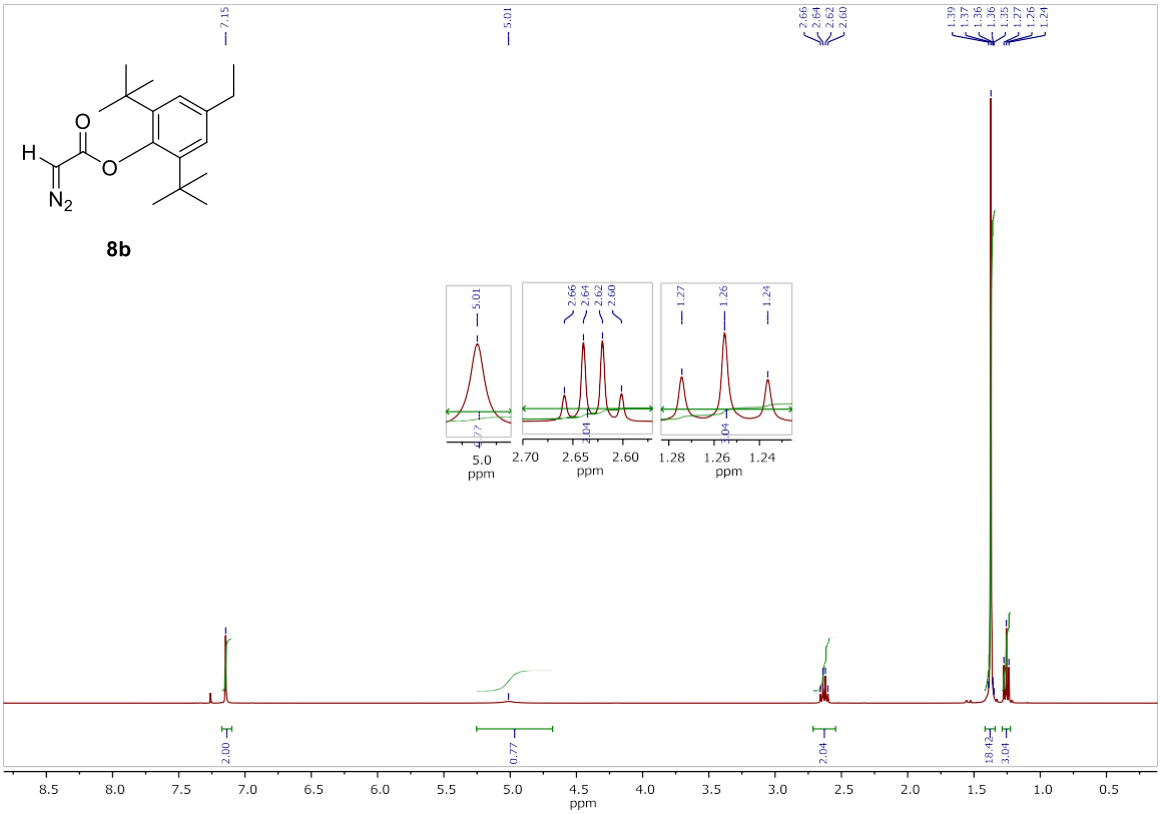
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **28**



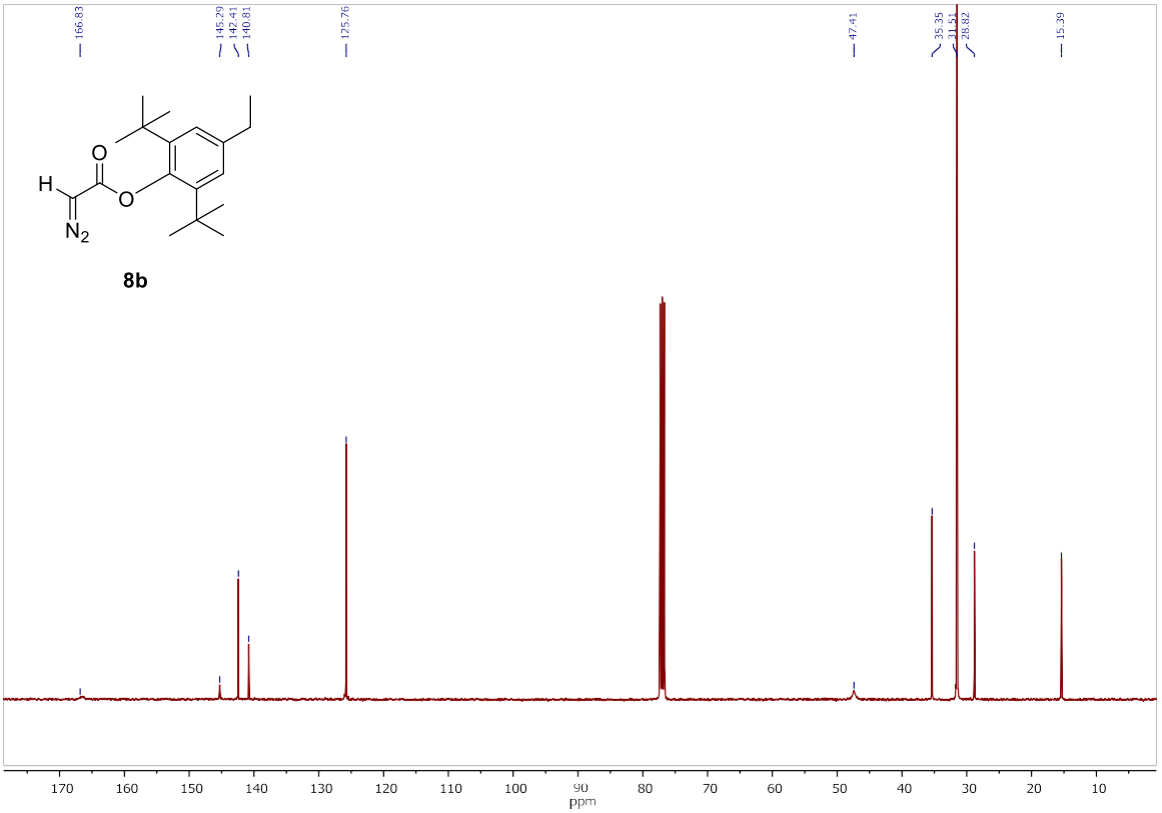
IR of compound **28**



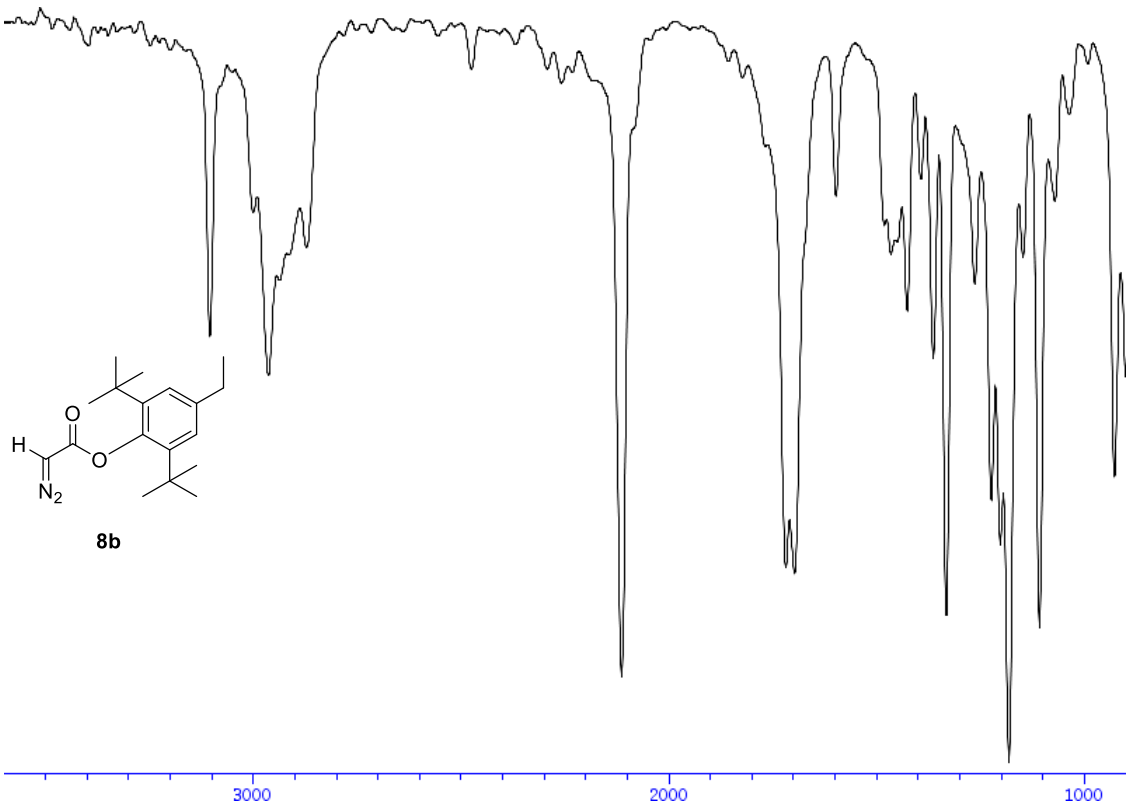
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8b**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8b**

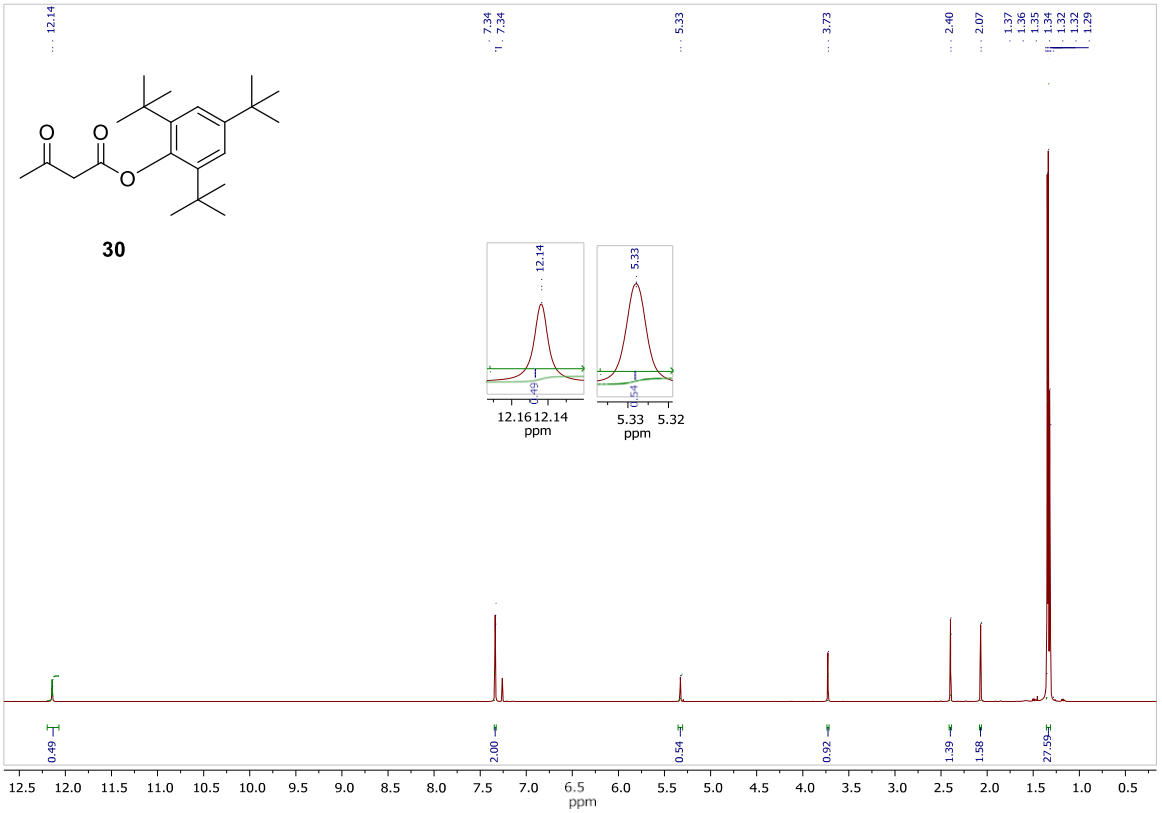


IR of compound **8b**

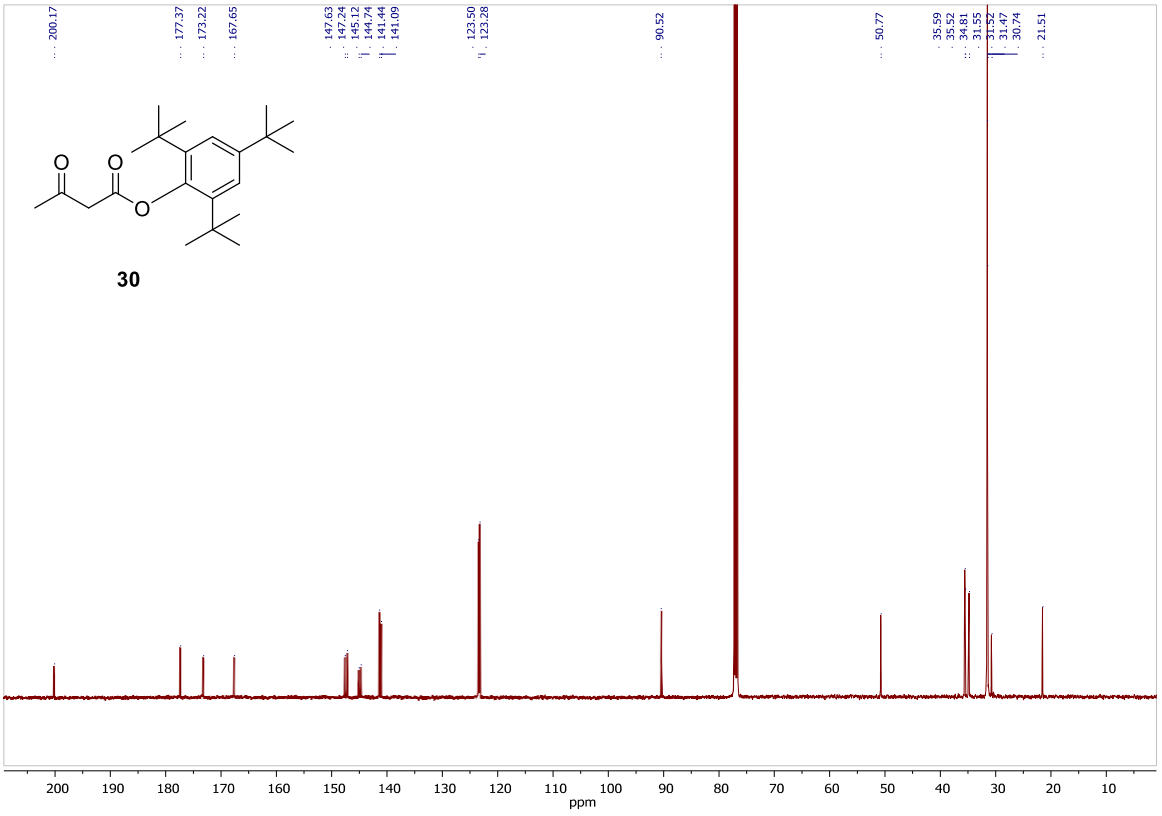


8b

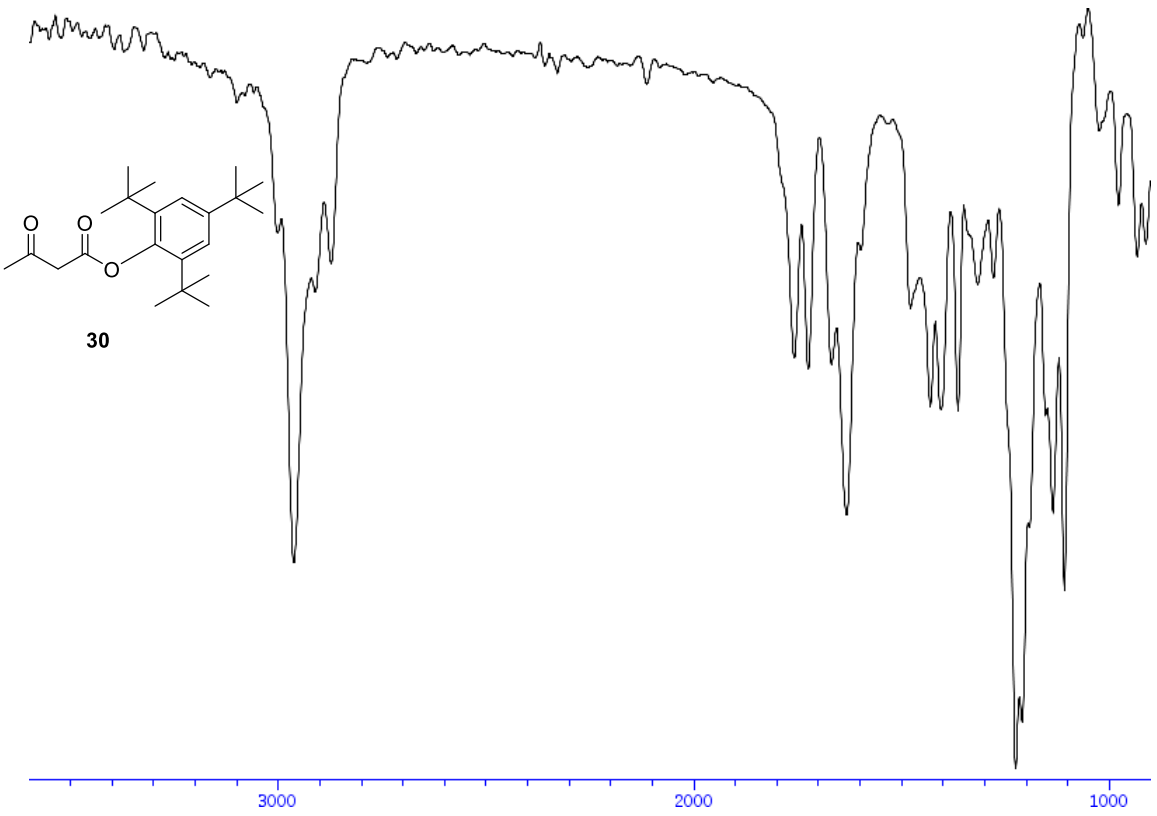
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **30**



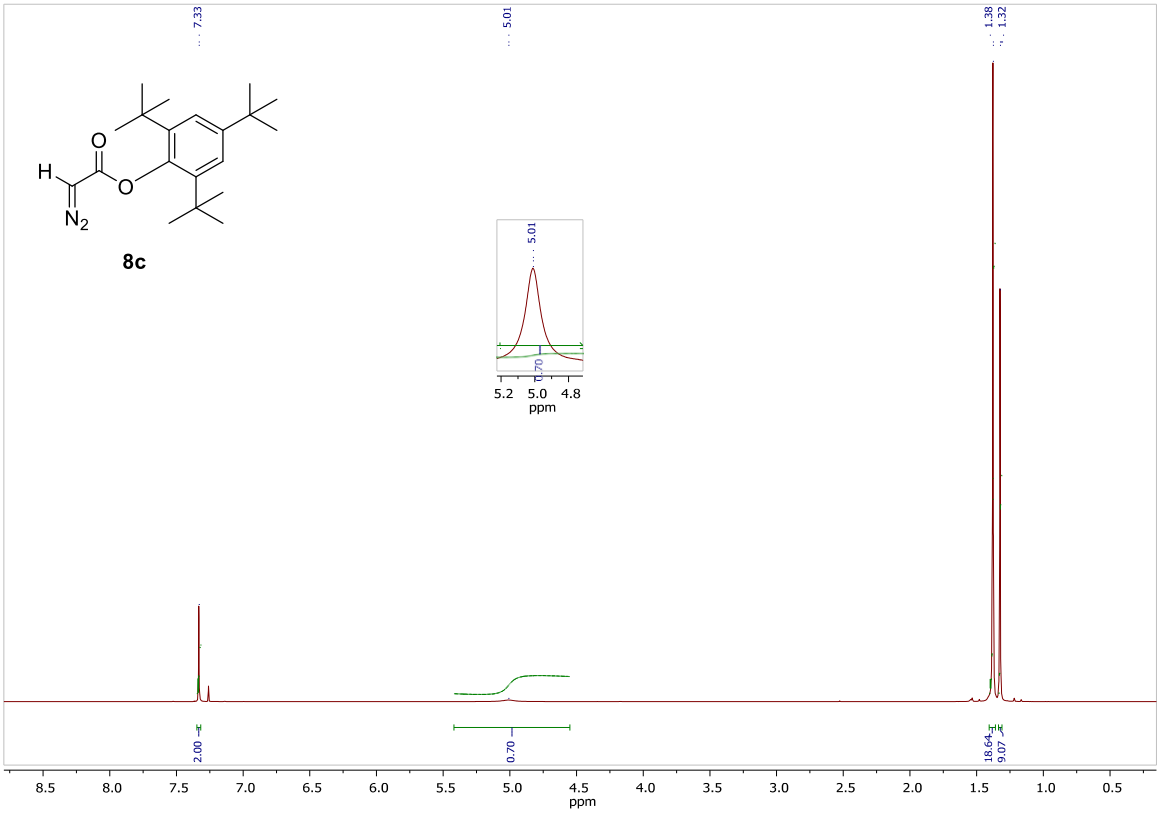
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **30**



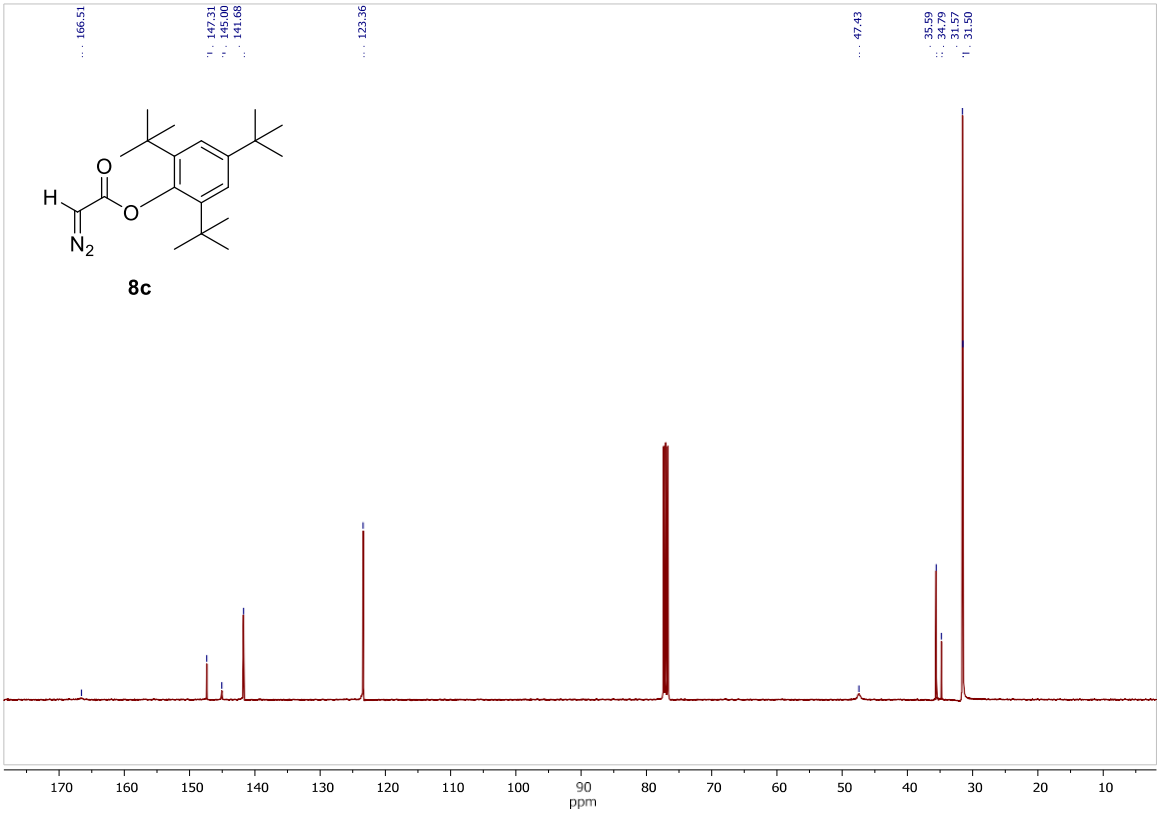
IR of compound **30**



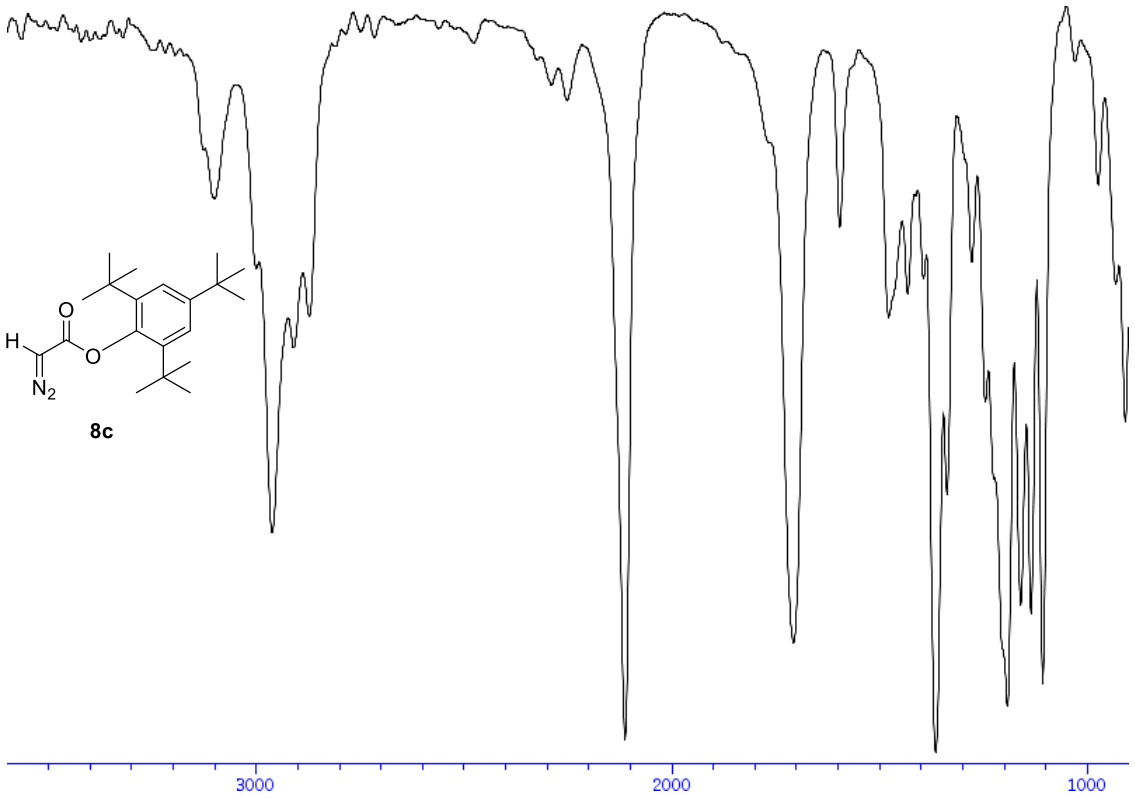
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8c**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8c**

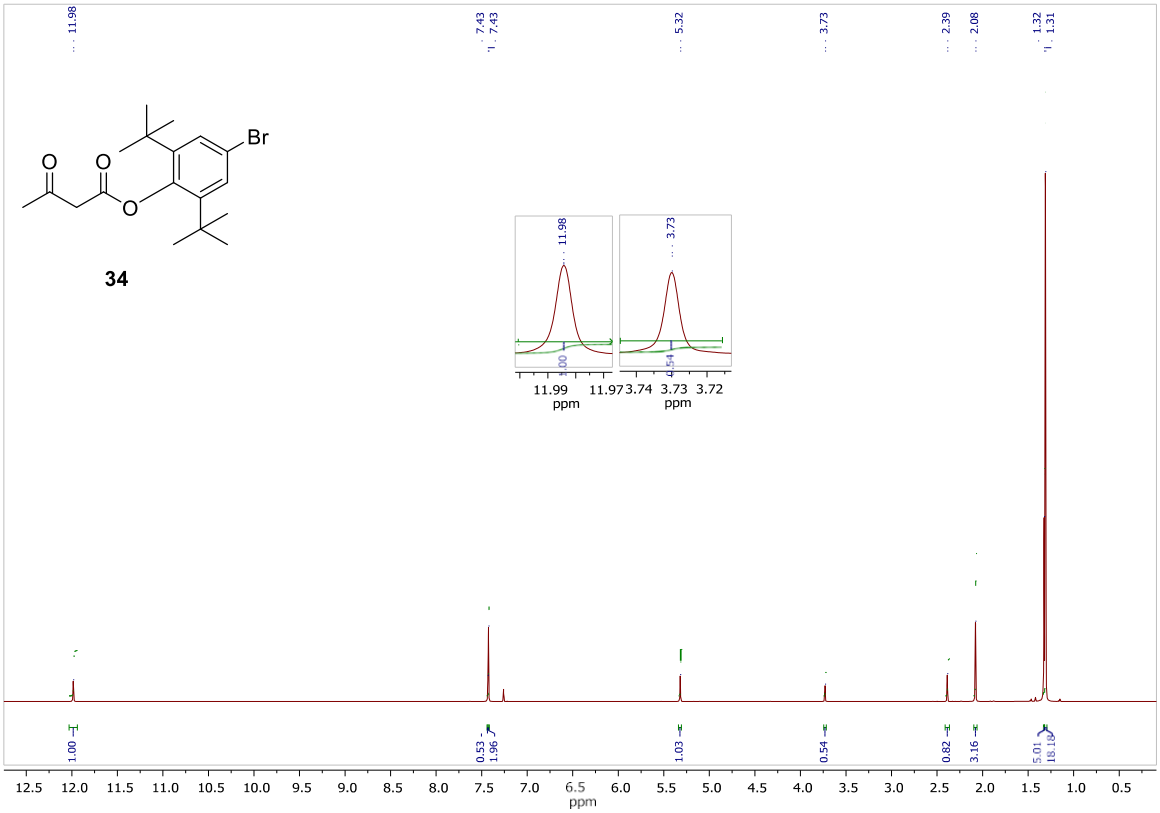


IR of compound **8c**

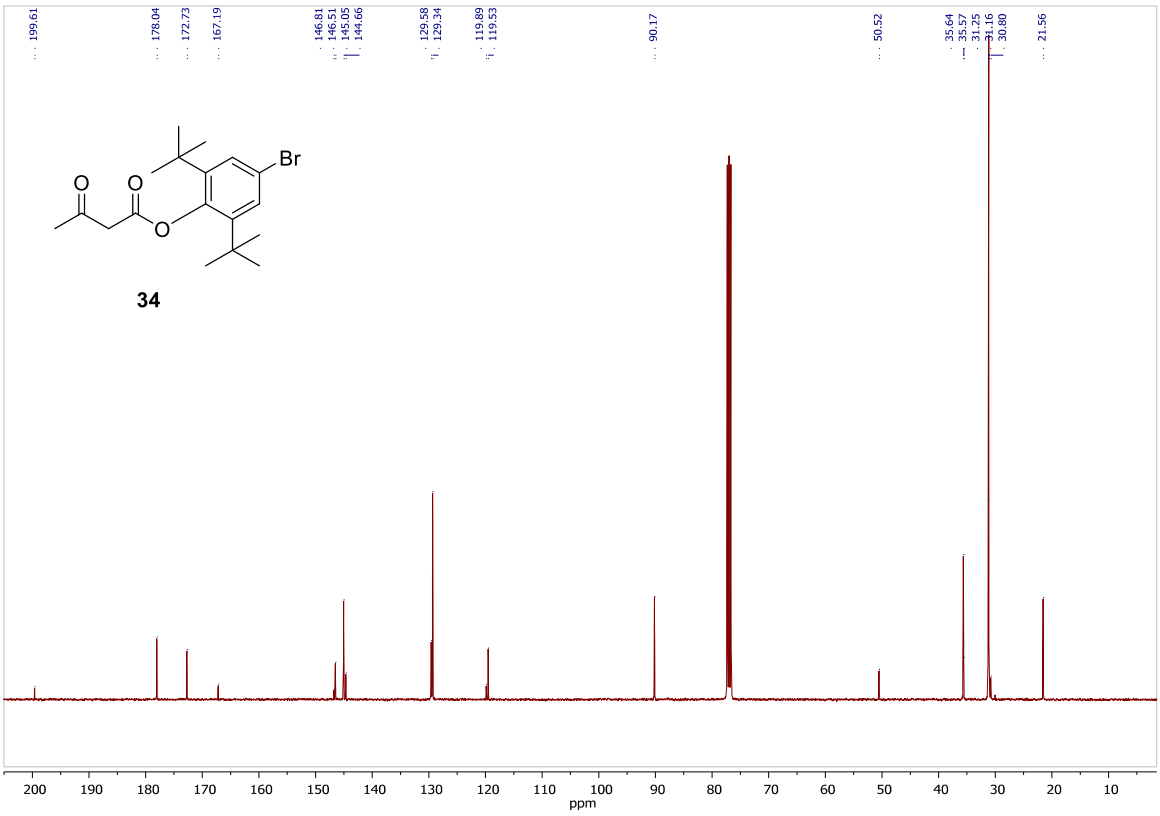


8c

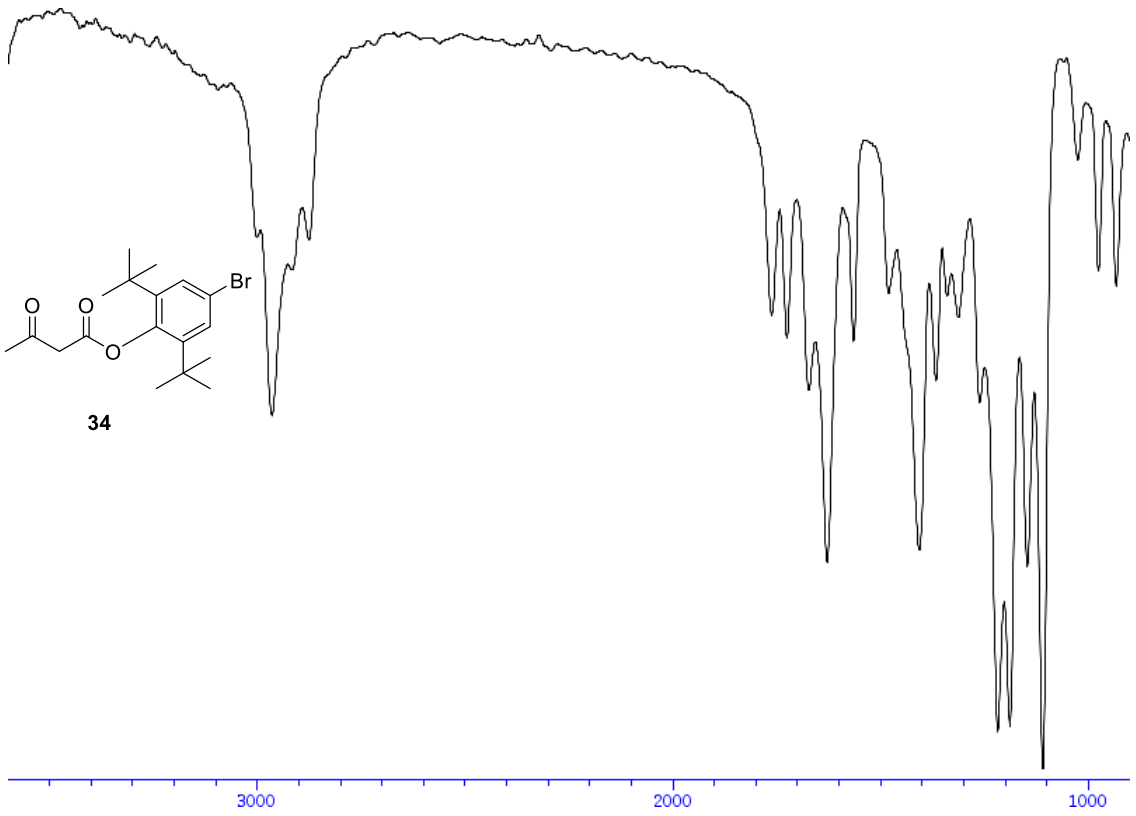
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **34**



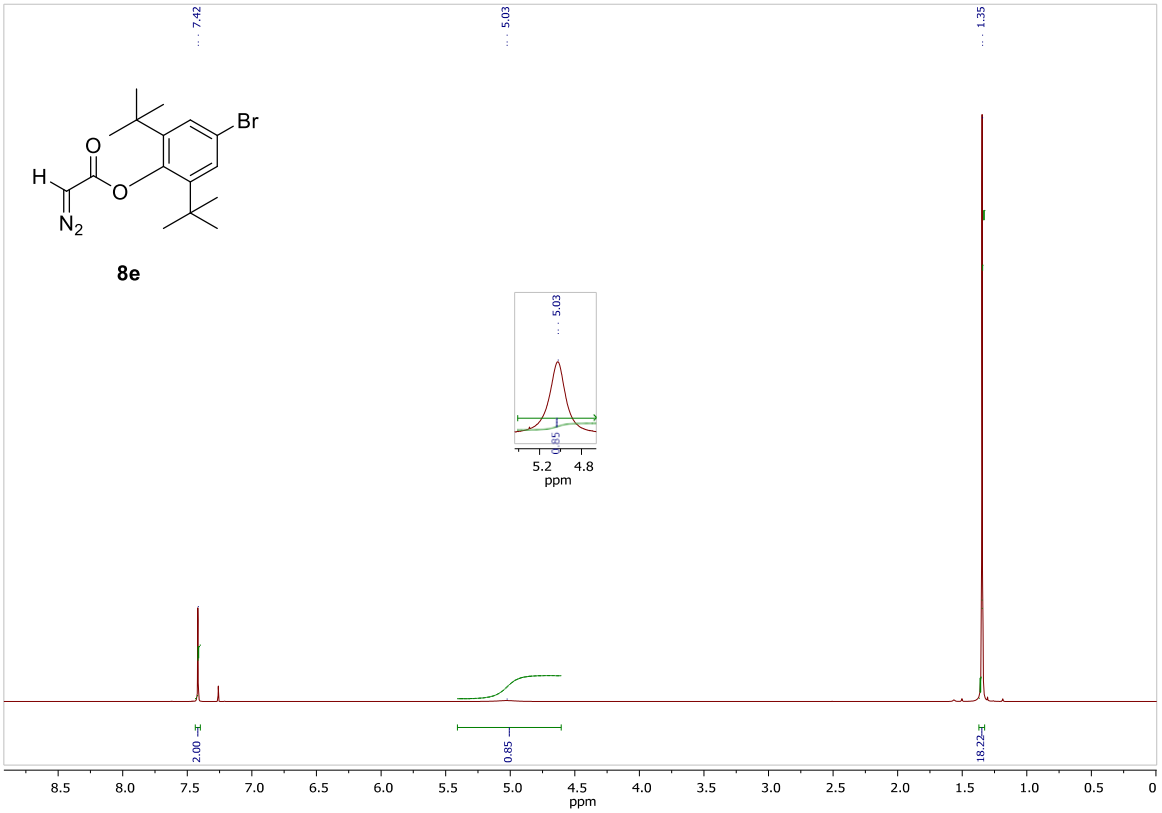
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **34**



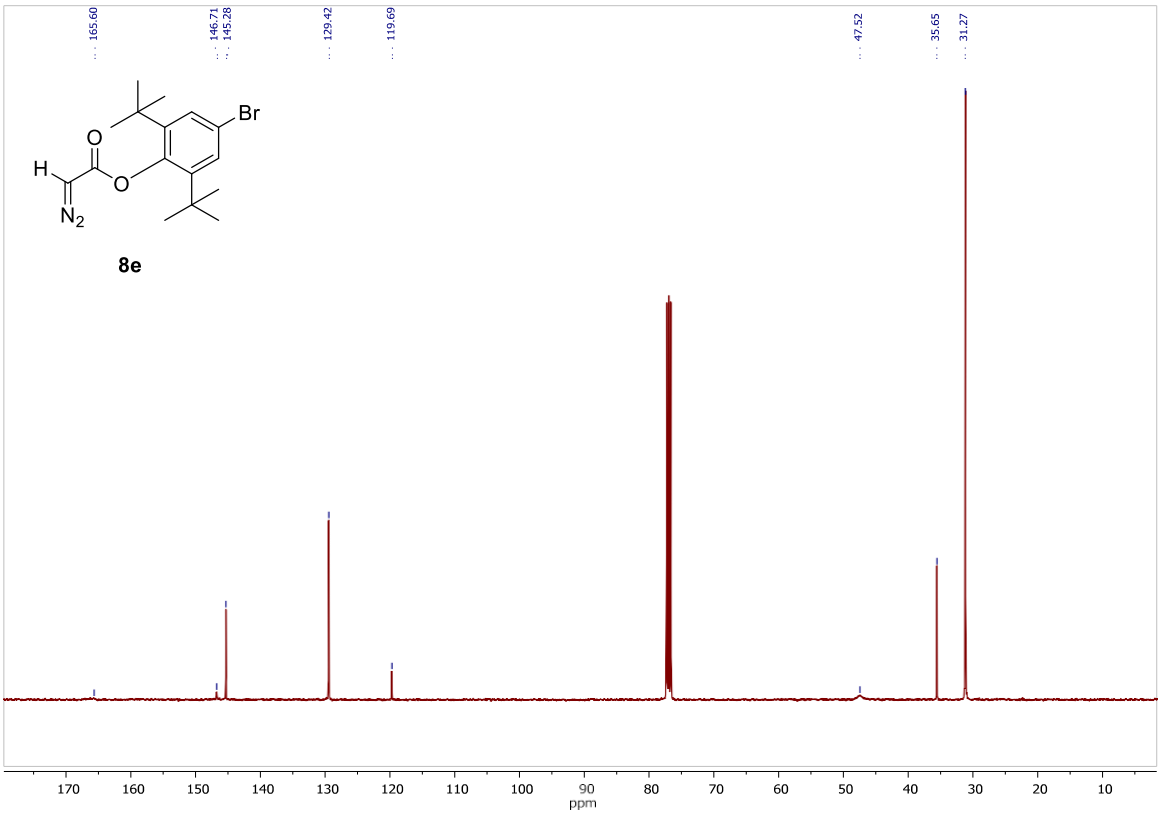
IR of compound **34**



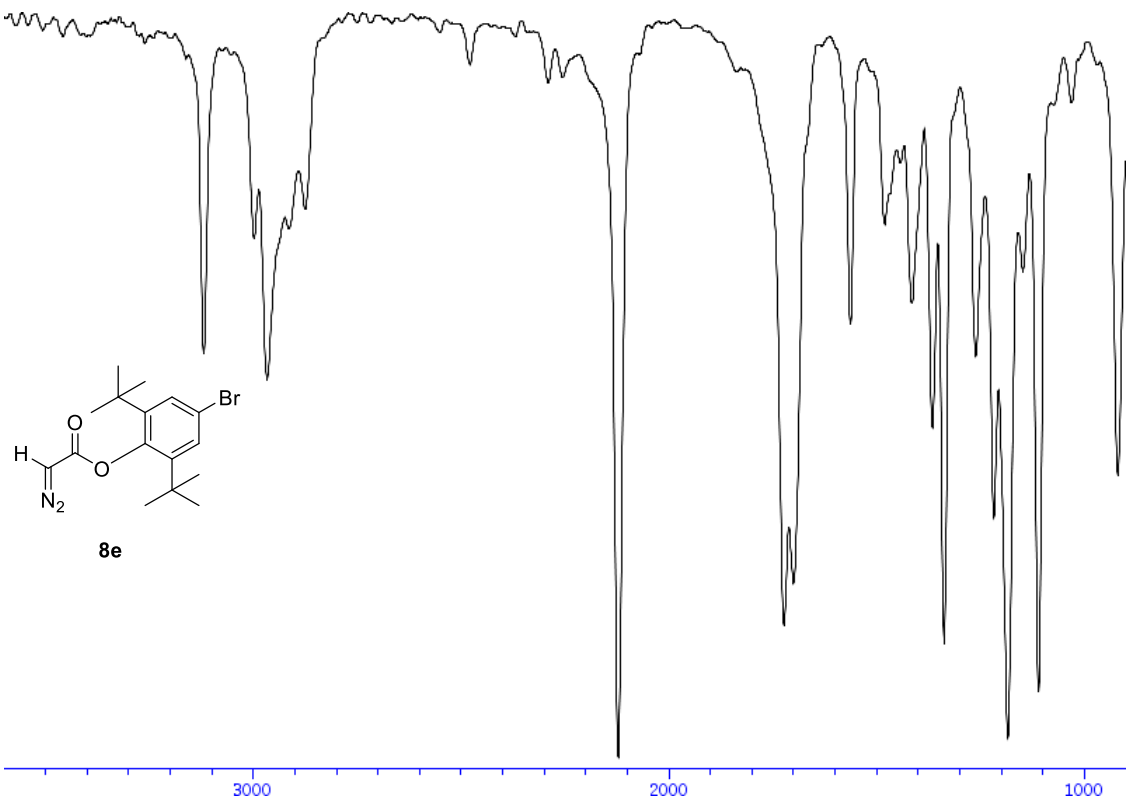
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8e**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8e**

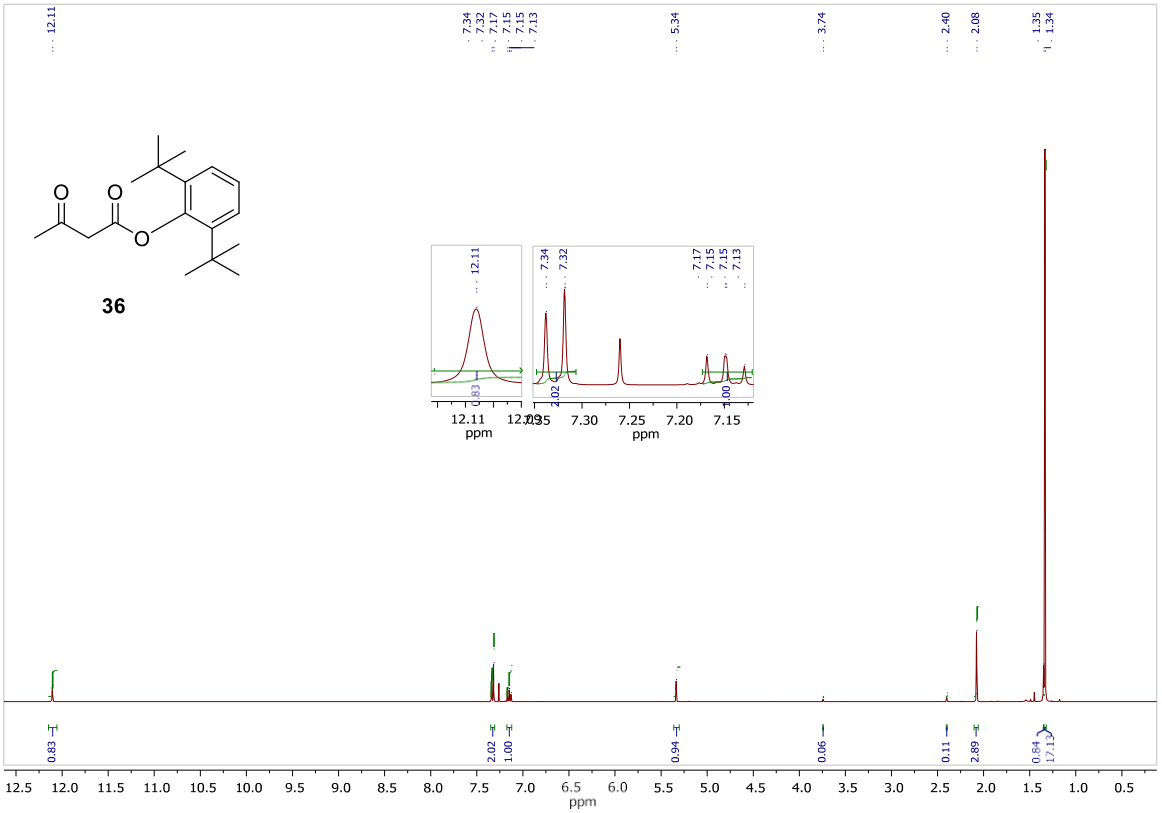


IR of compound **8e**

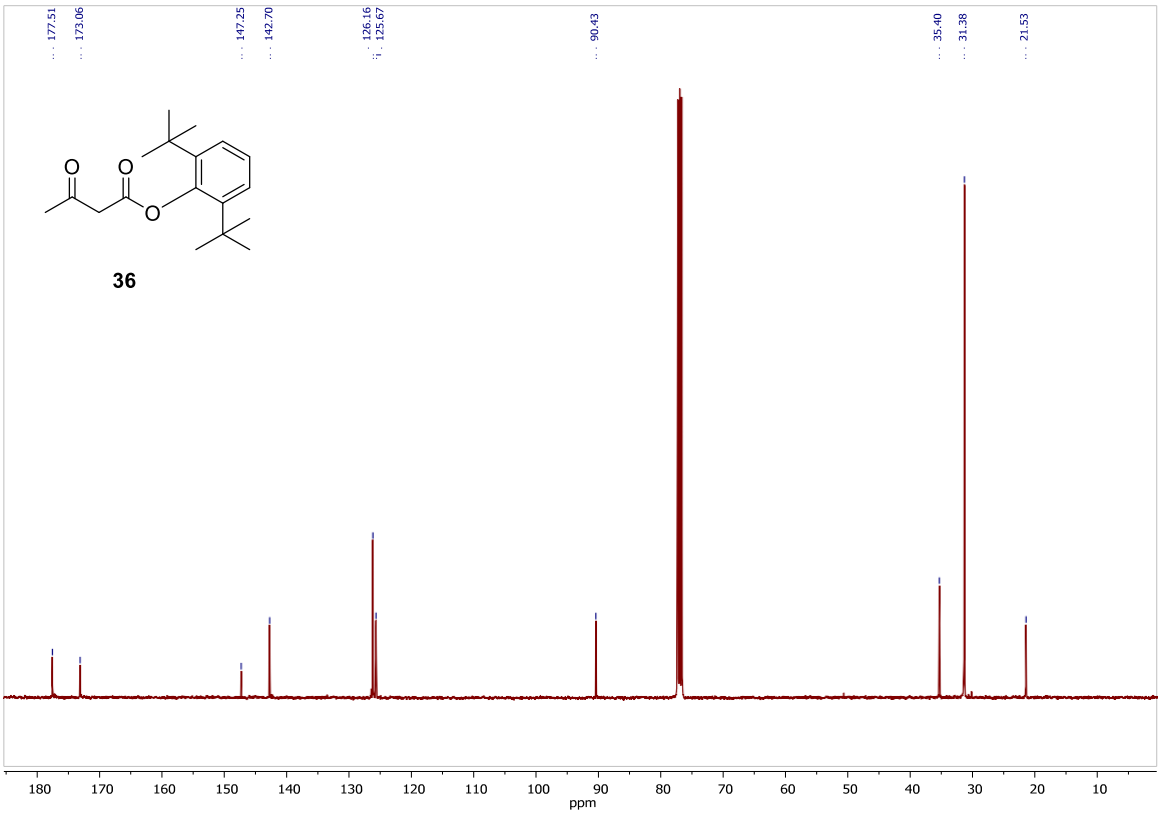


8e

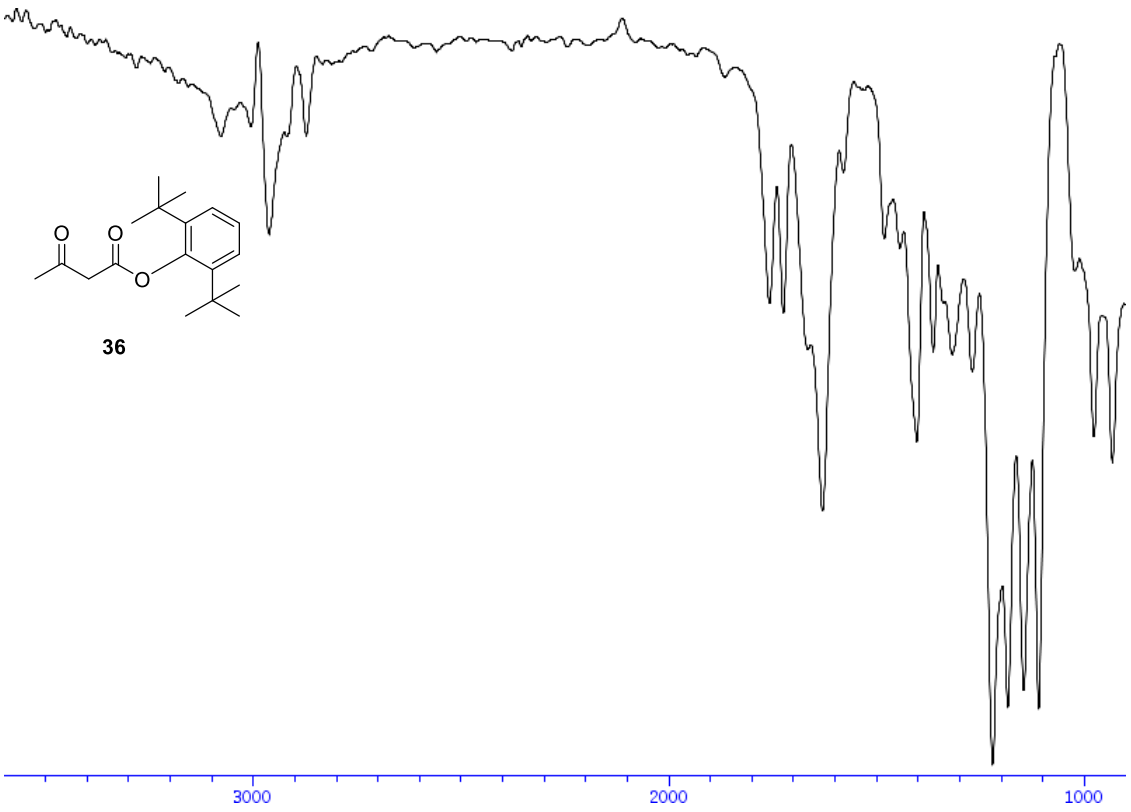
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **36**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **36**

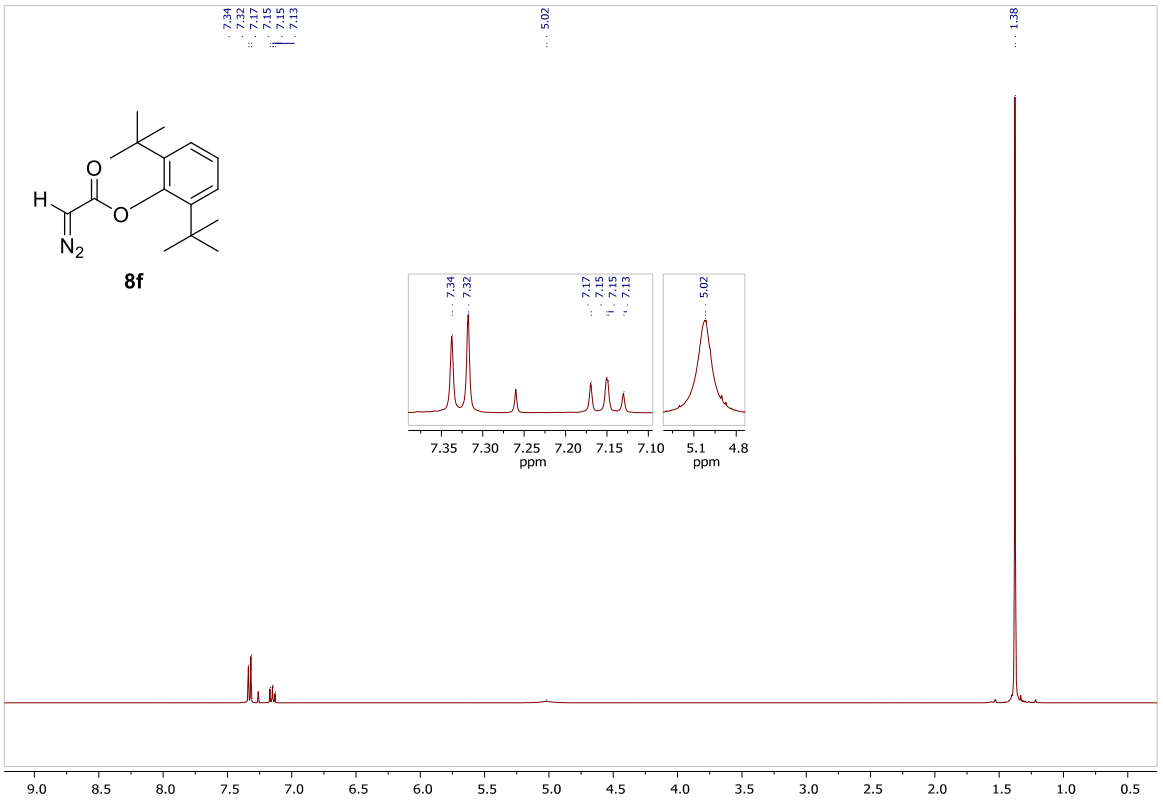


IR of compound **36**

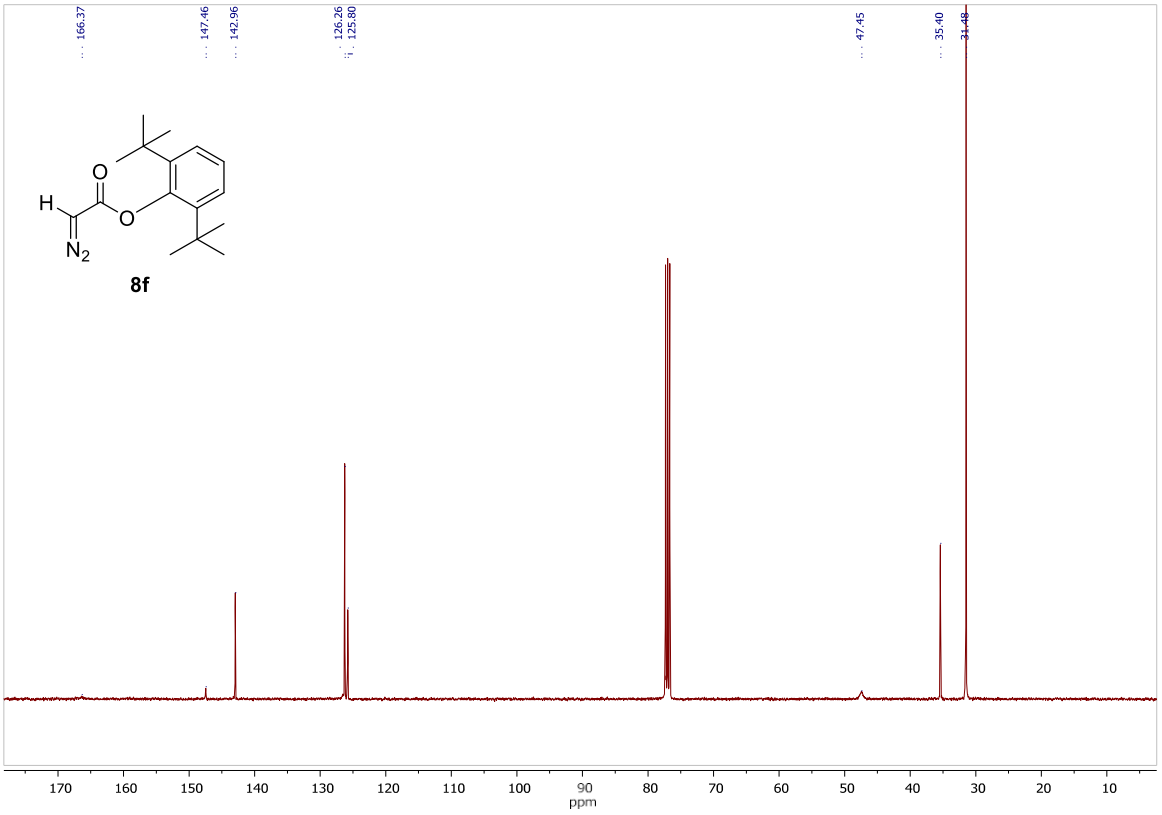


36

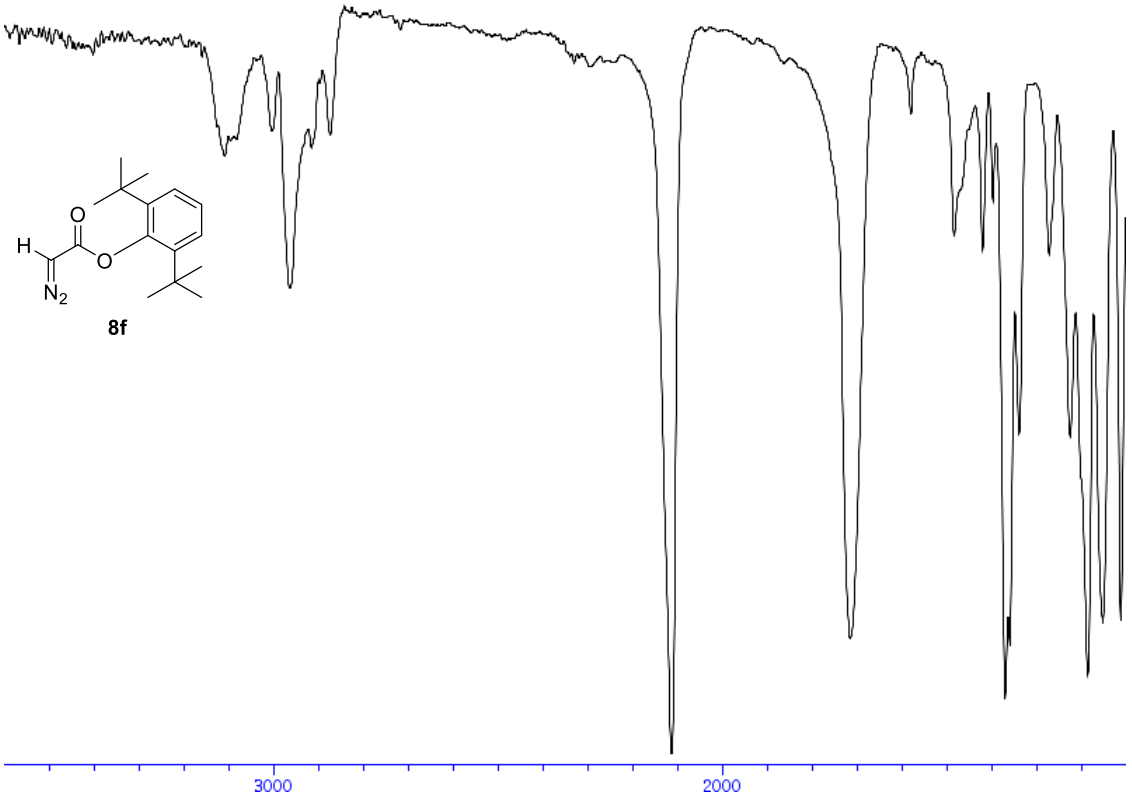
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8f**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8f**

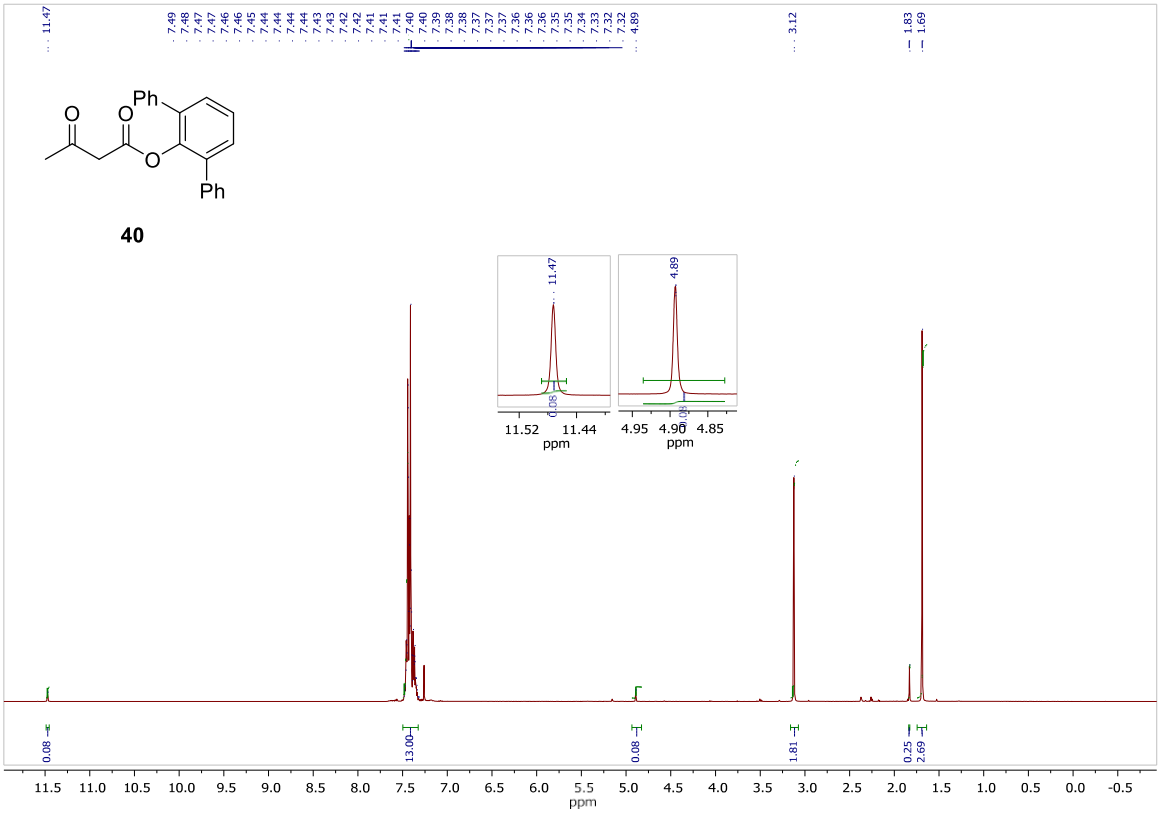


IR of compound **8f**

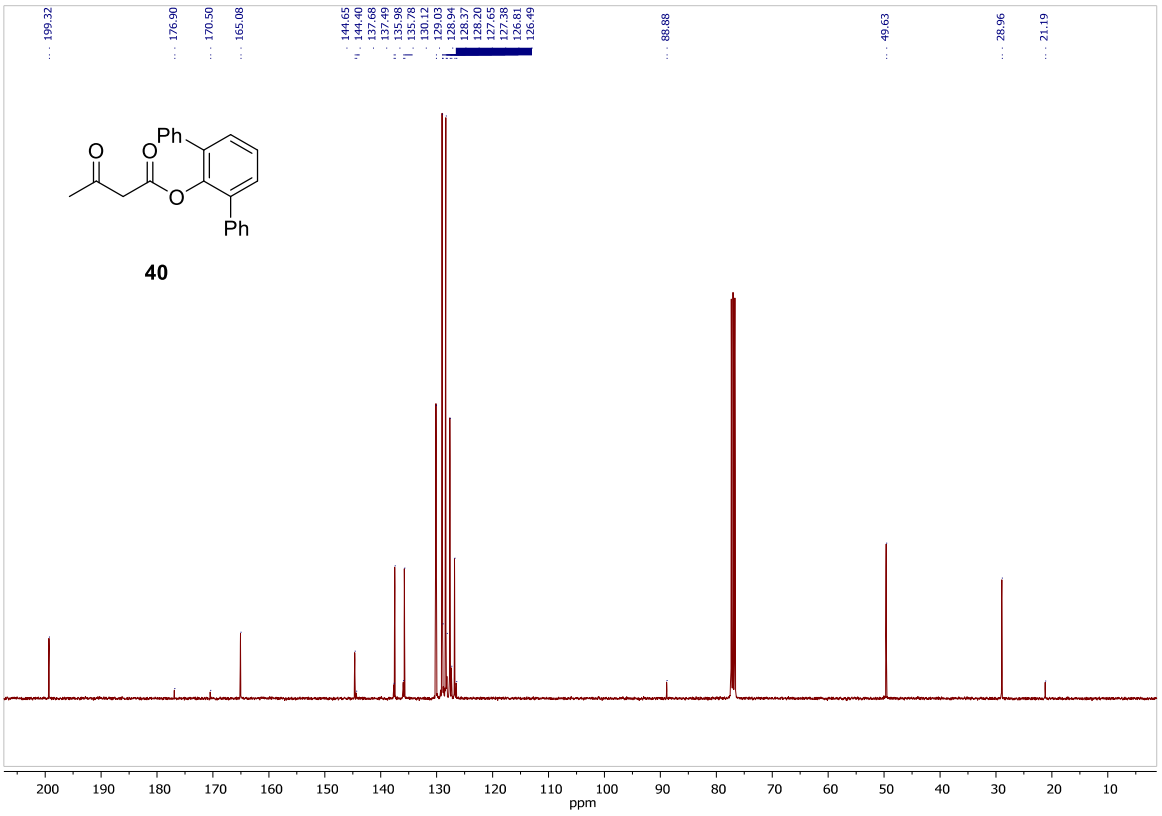


8f

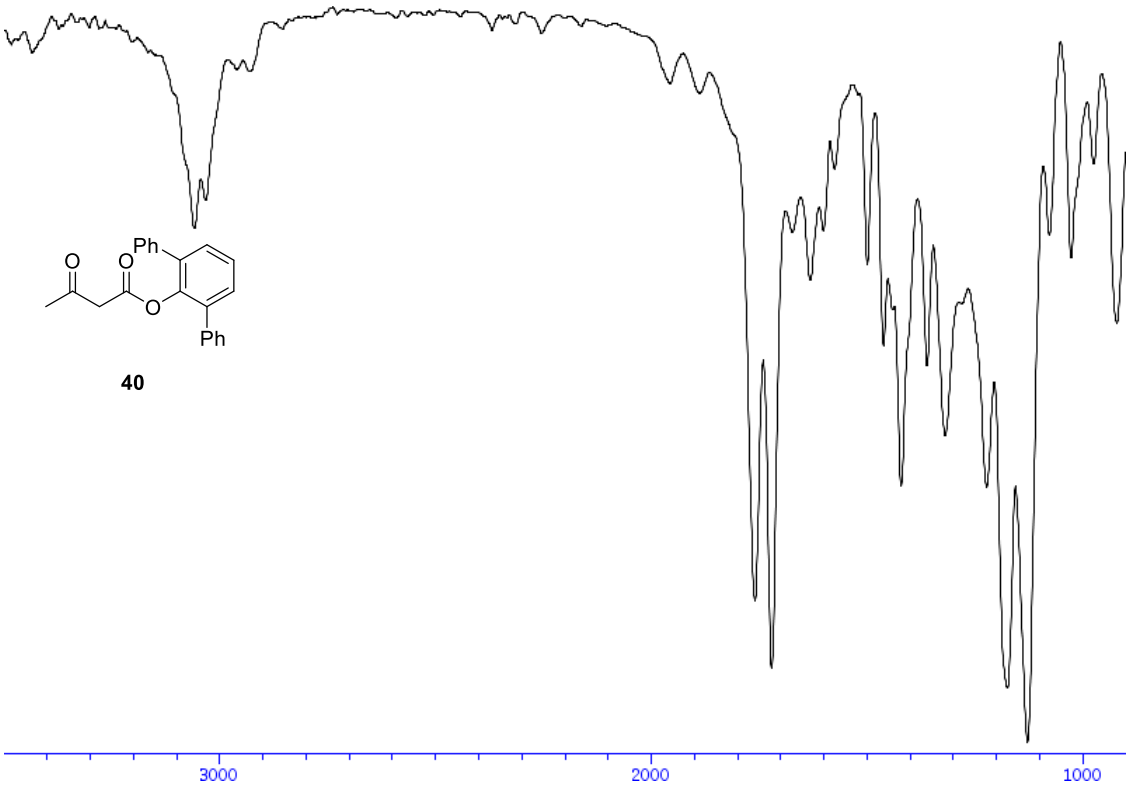
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **40**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **40**

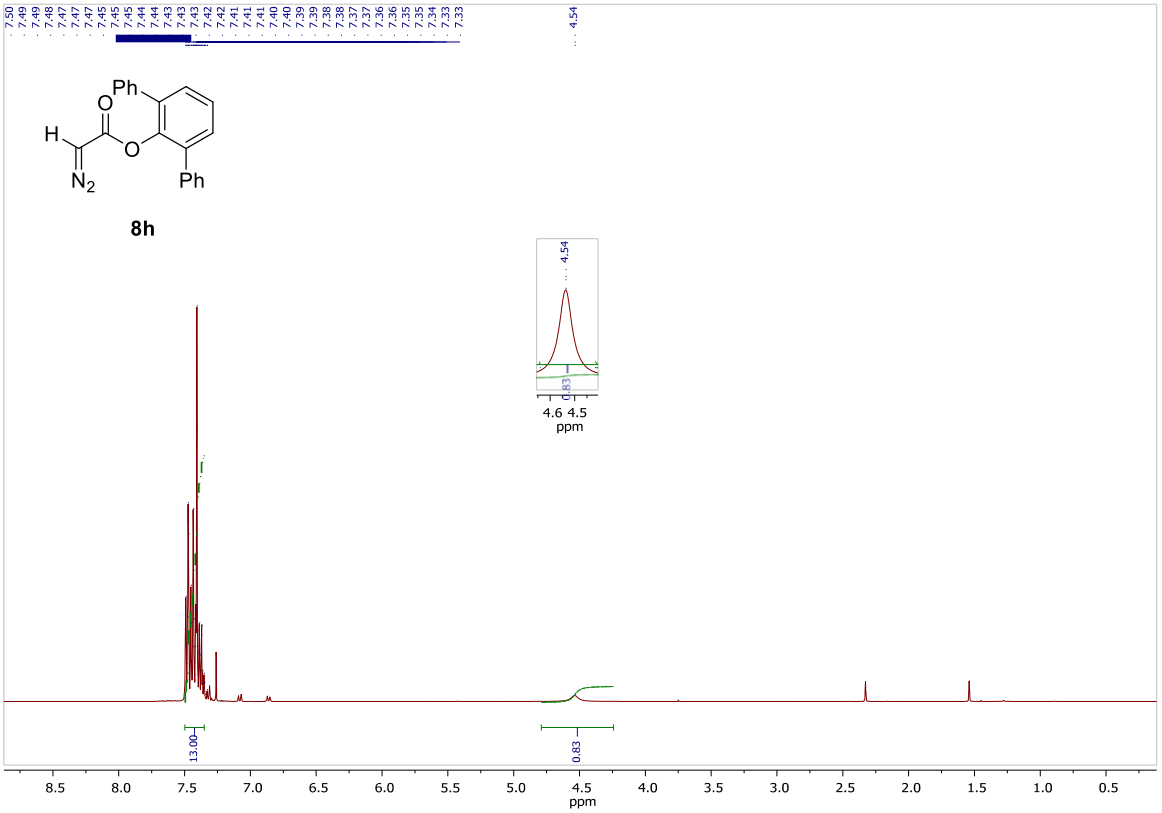


IR of compound **40**

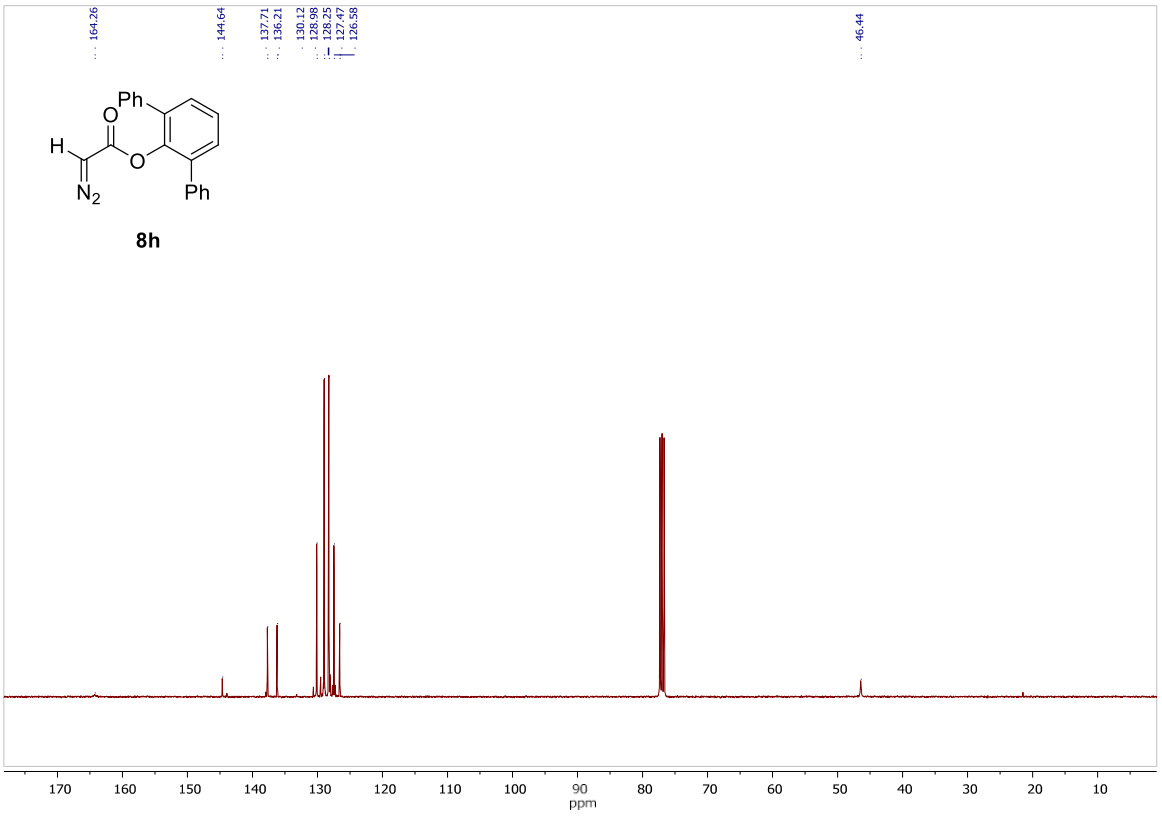


40

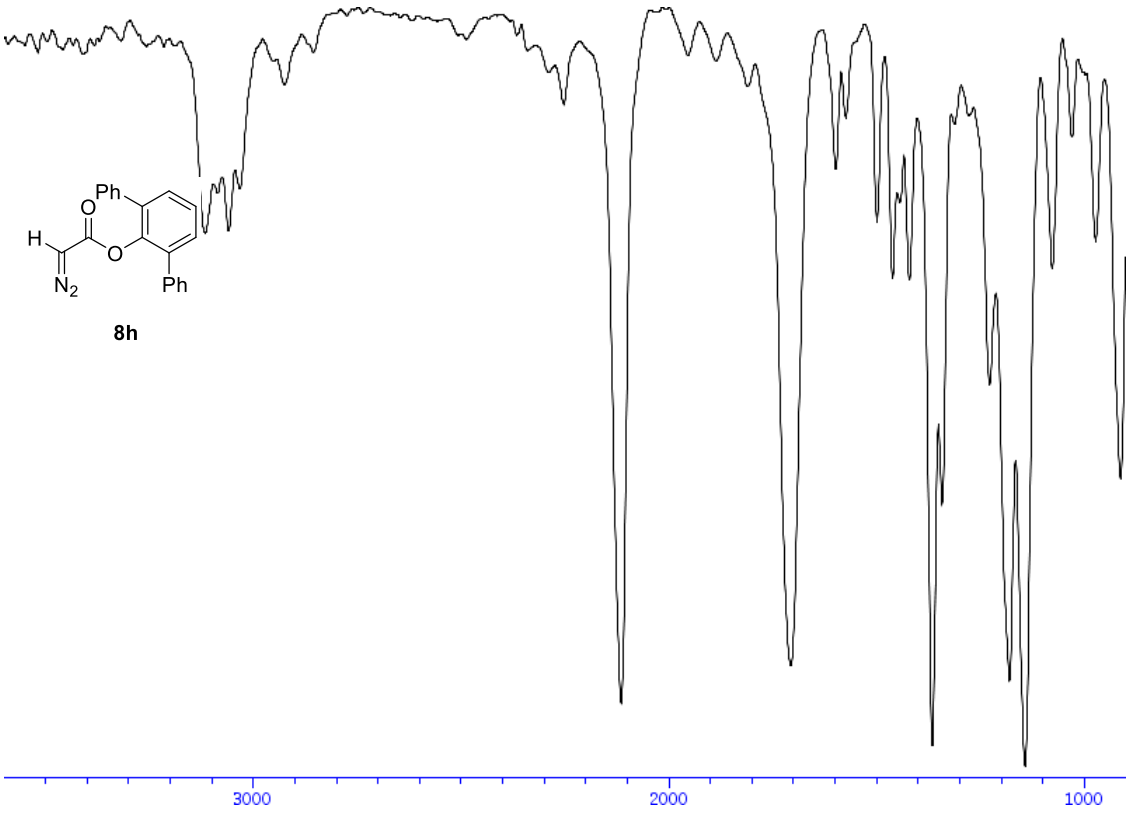
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8h**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8h**

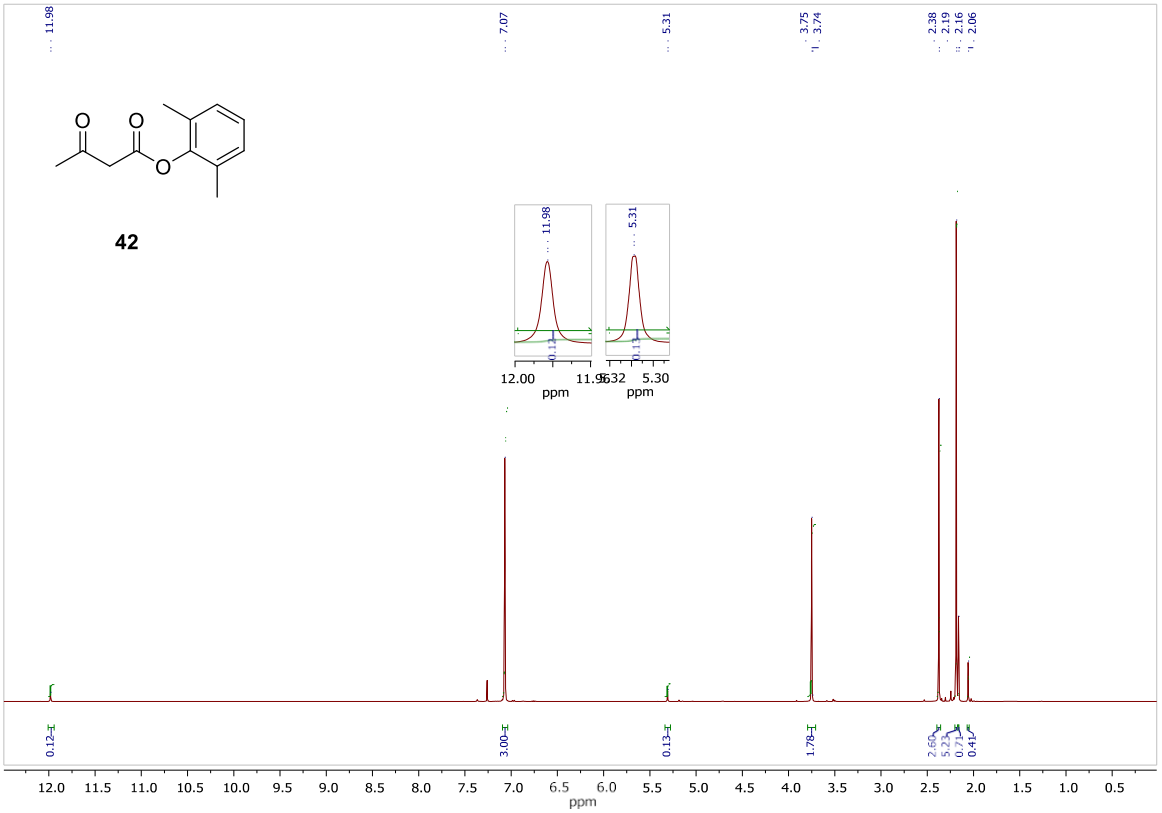


IR of compound **8h**

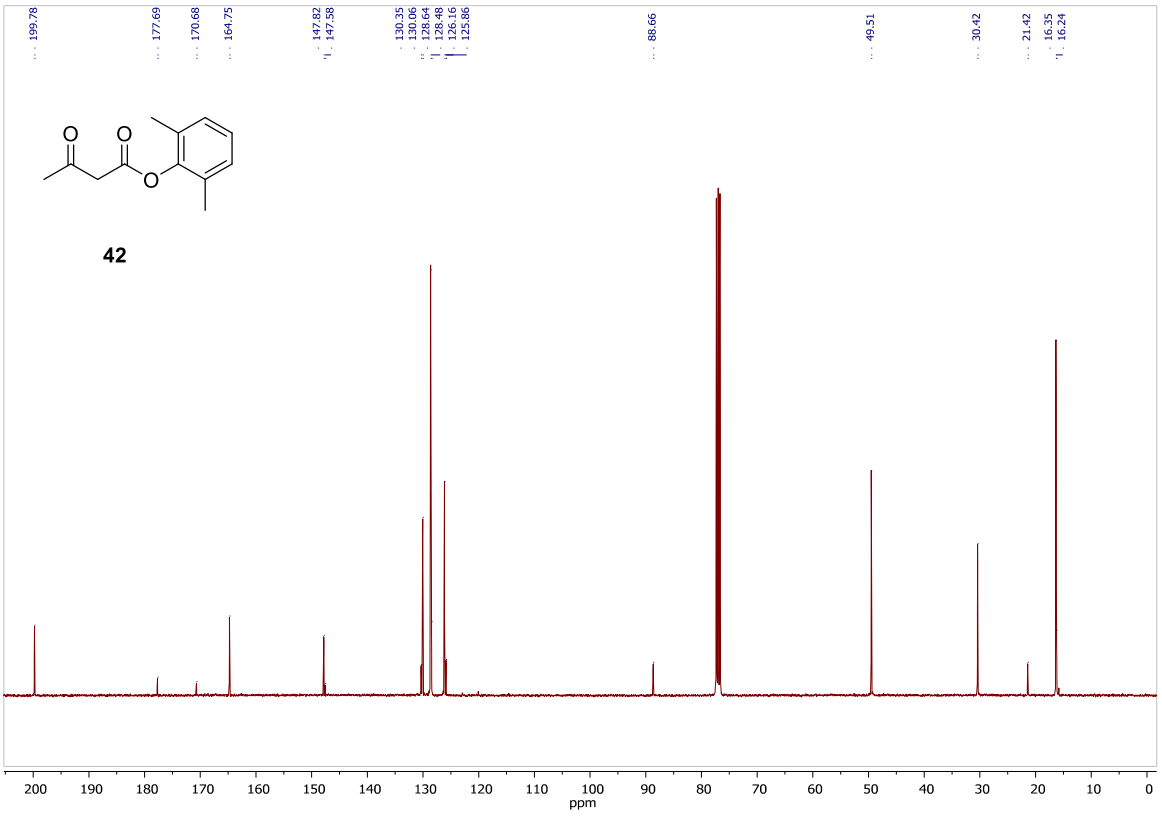


8h

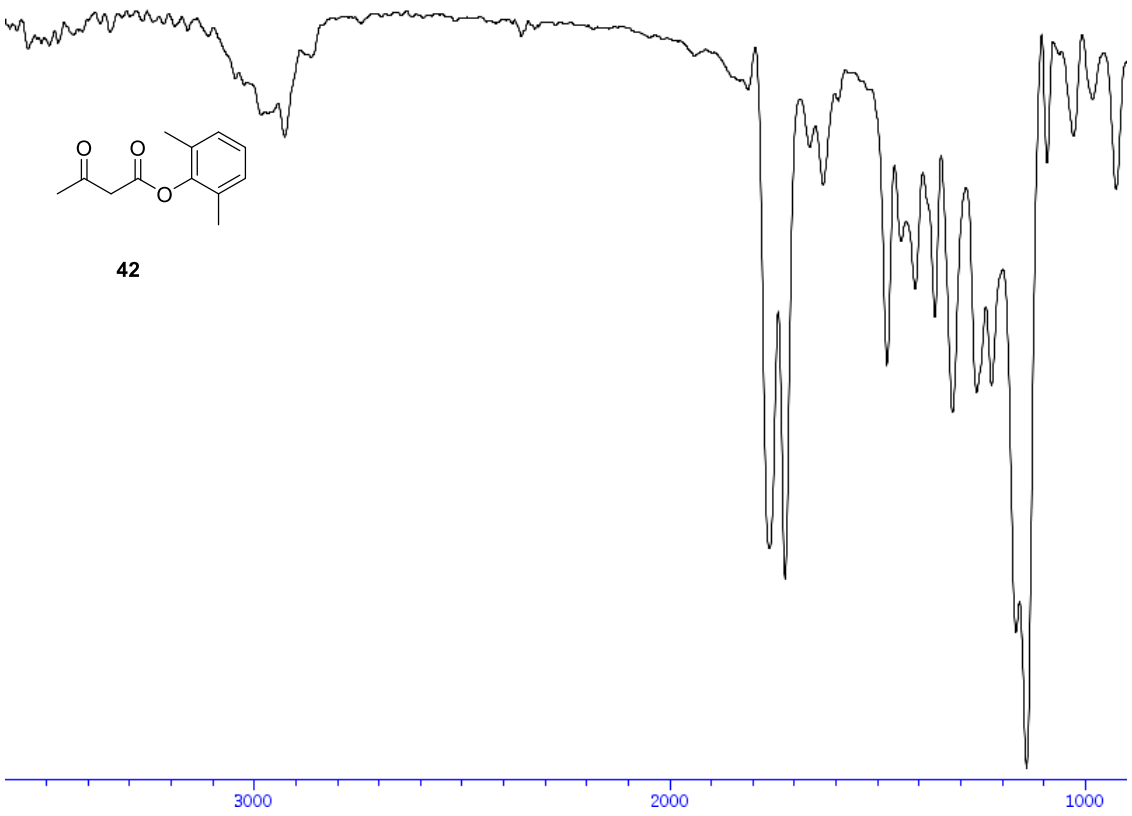
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **42**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **42**

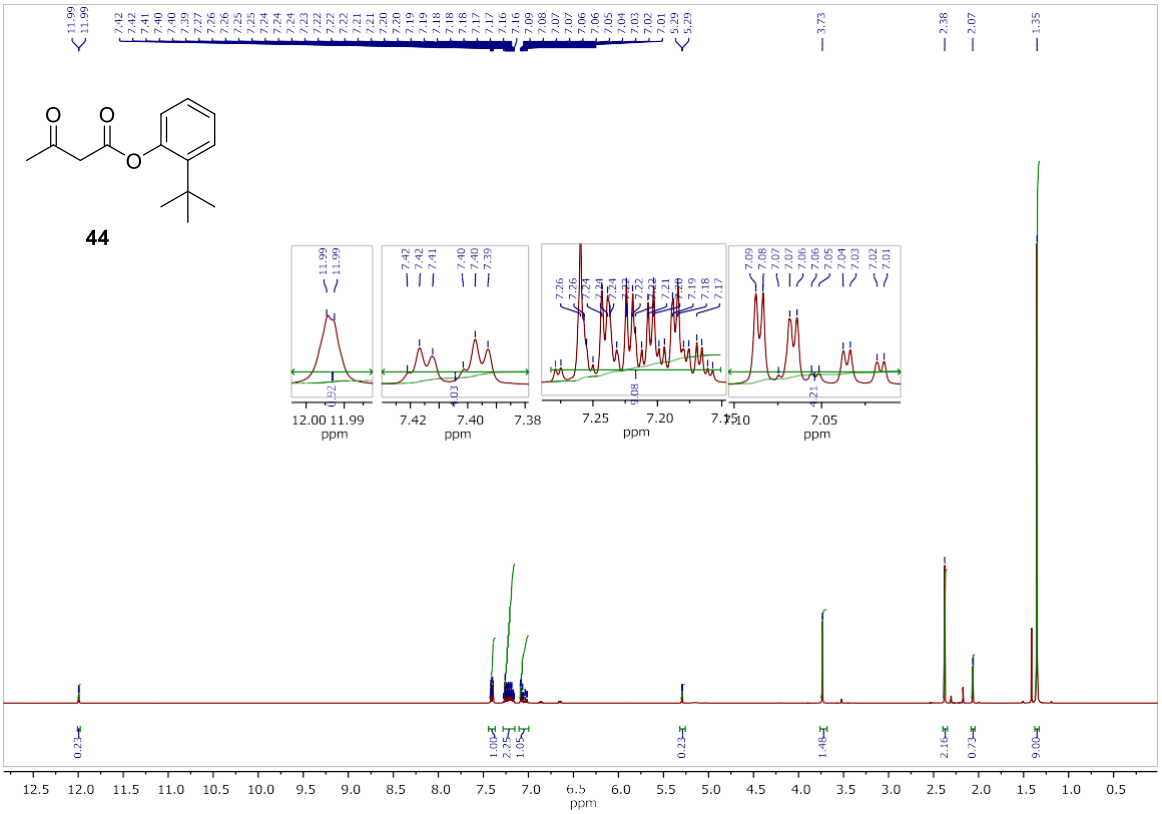


IR of compound **42**

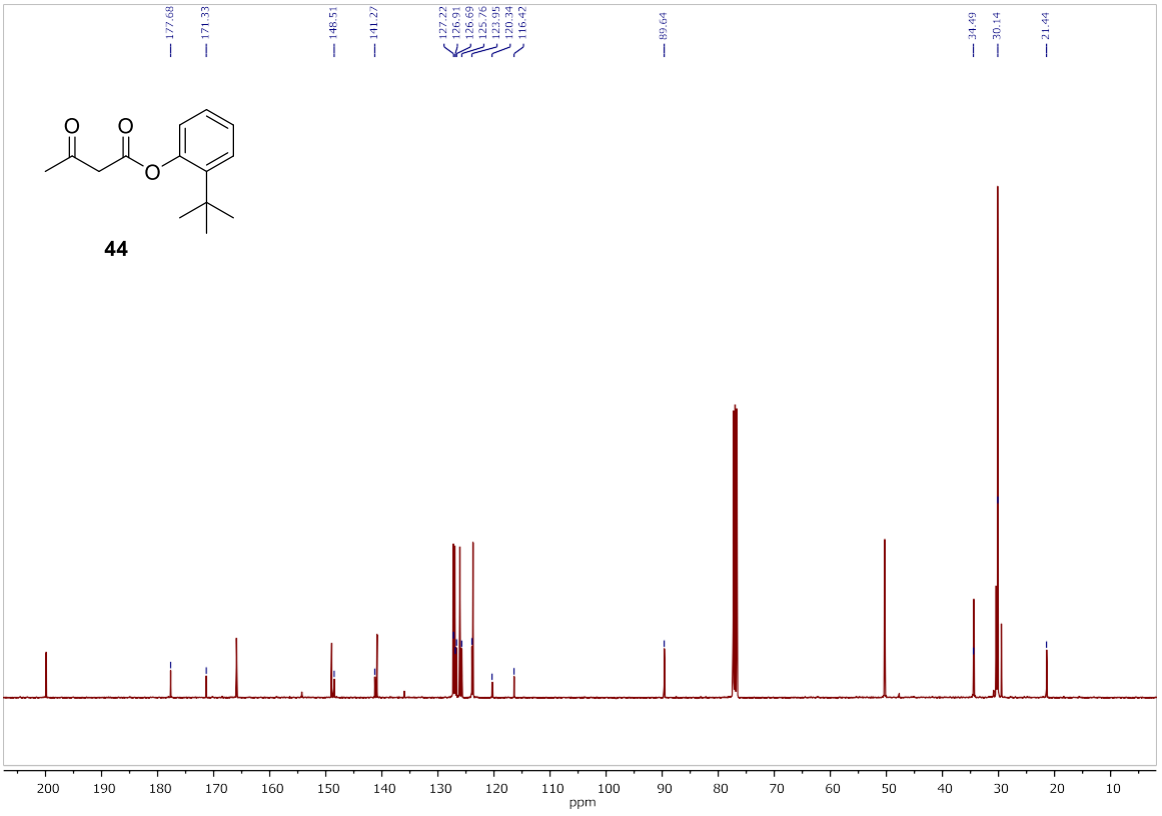


42

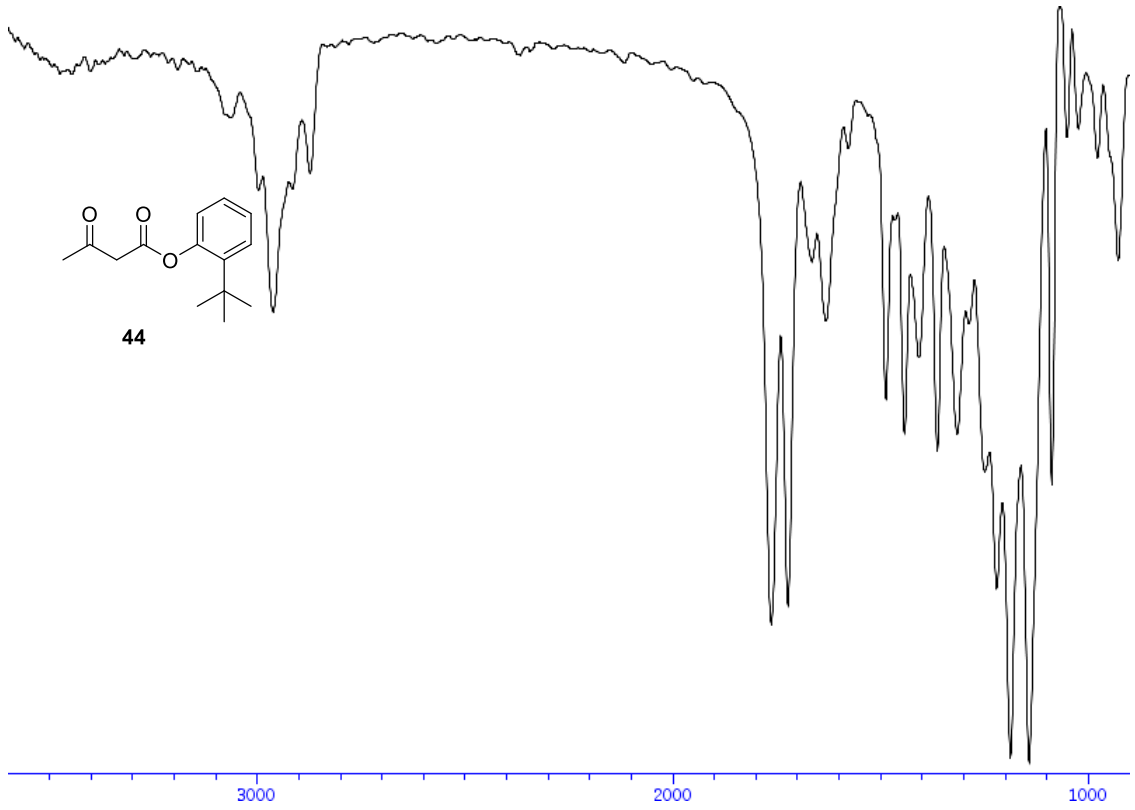
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **44**



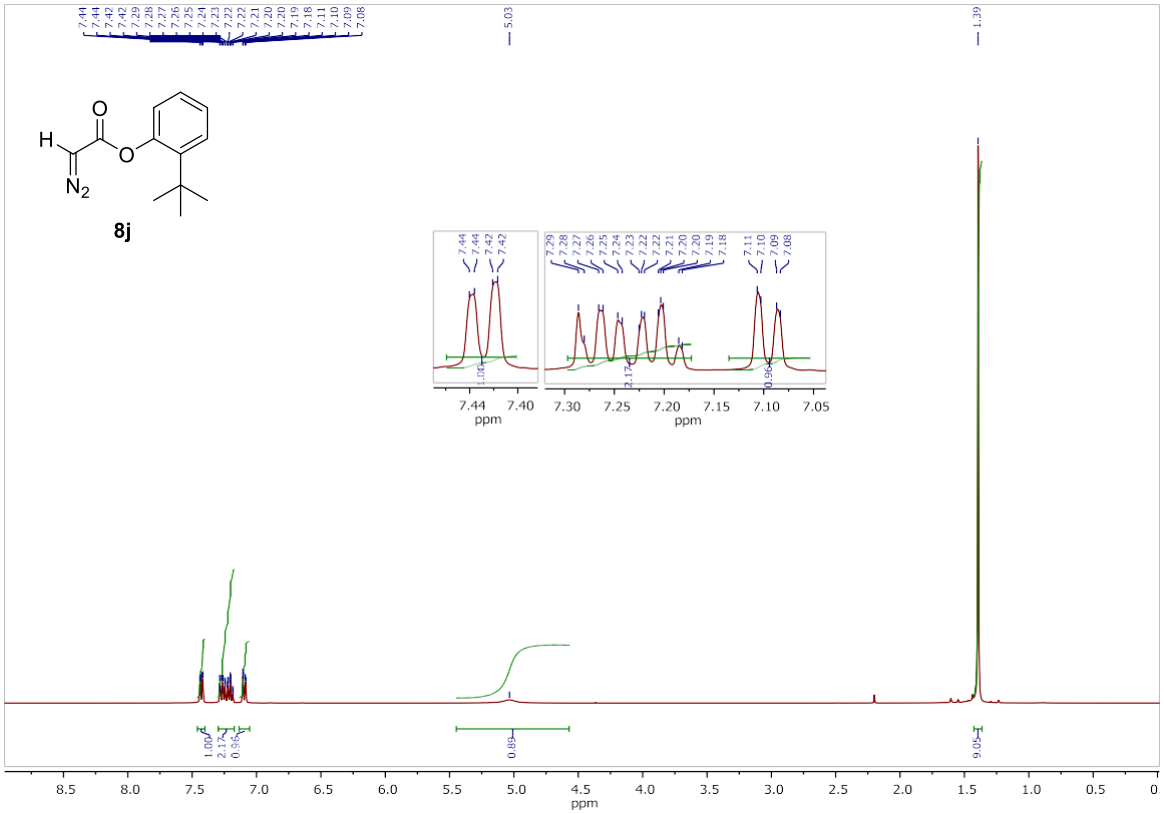
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **44**



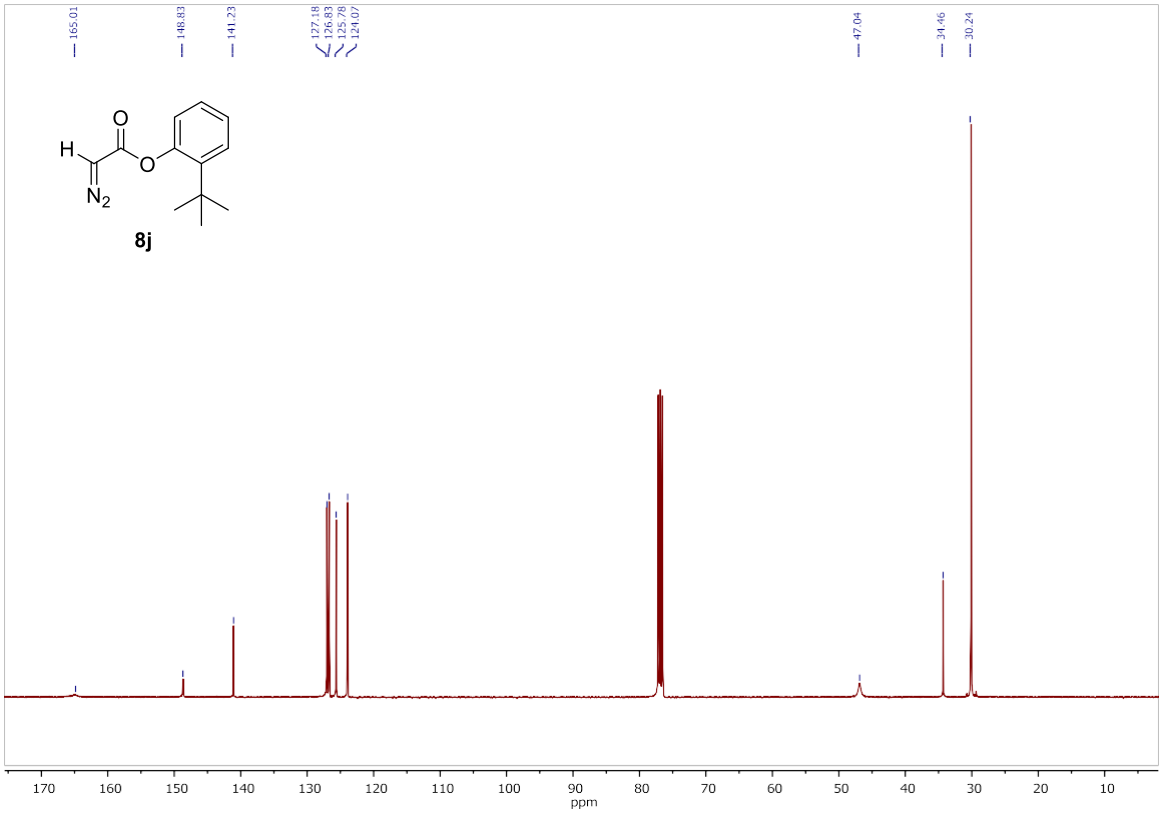
IR of compound **44**



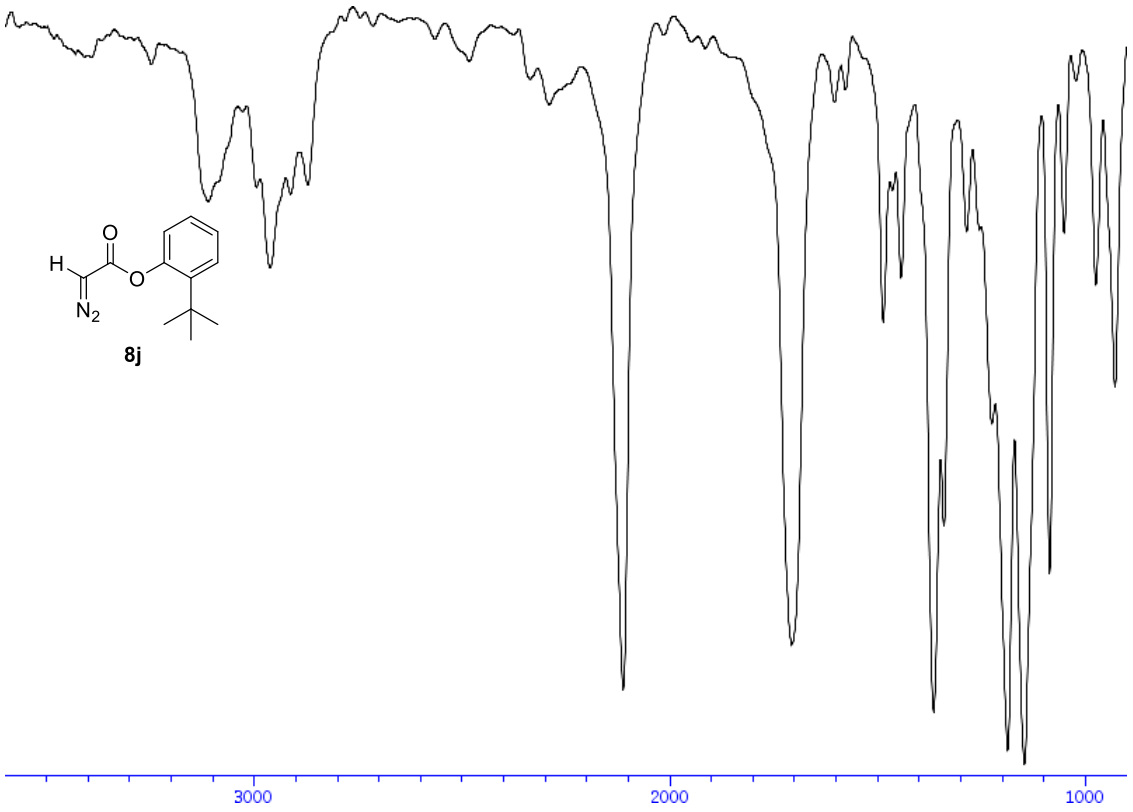
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8j**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8j**

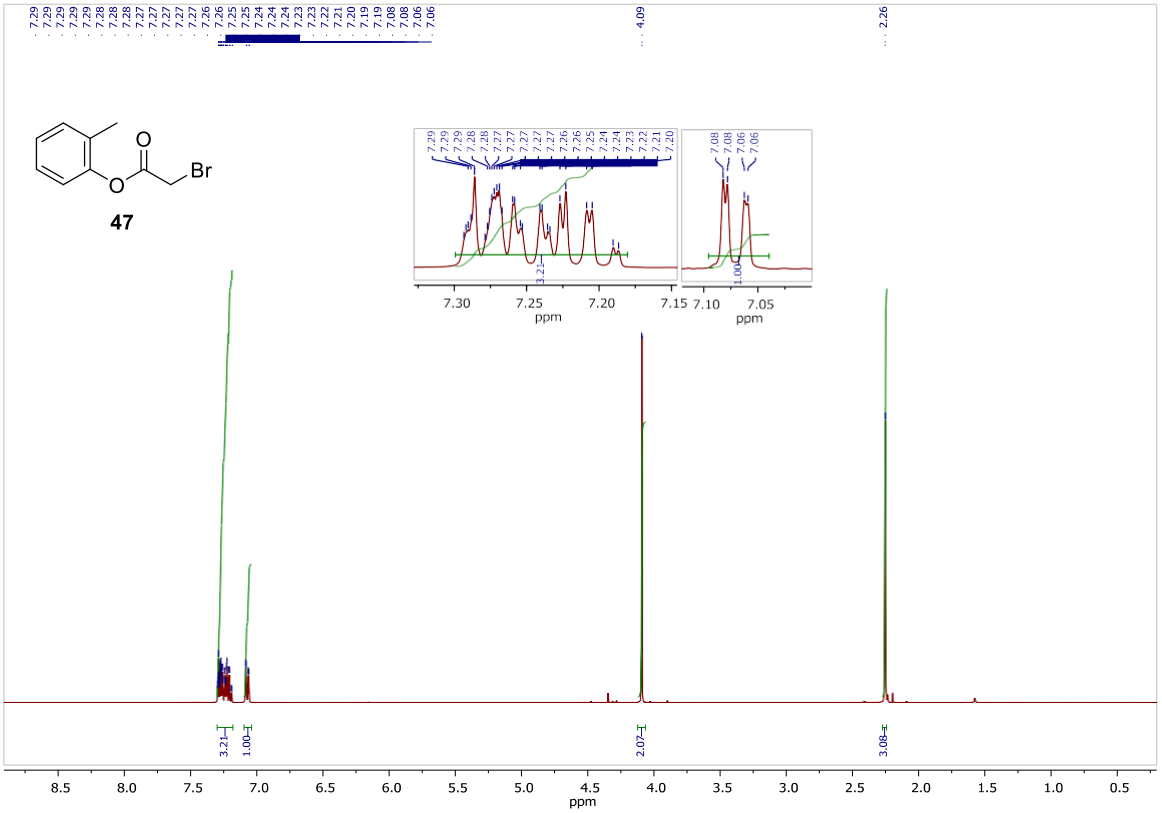


IR of compound **8j**

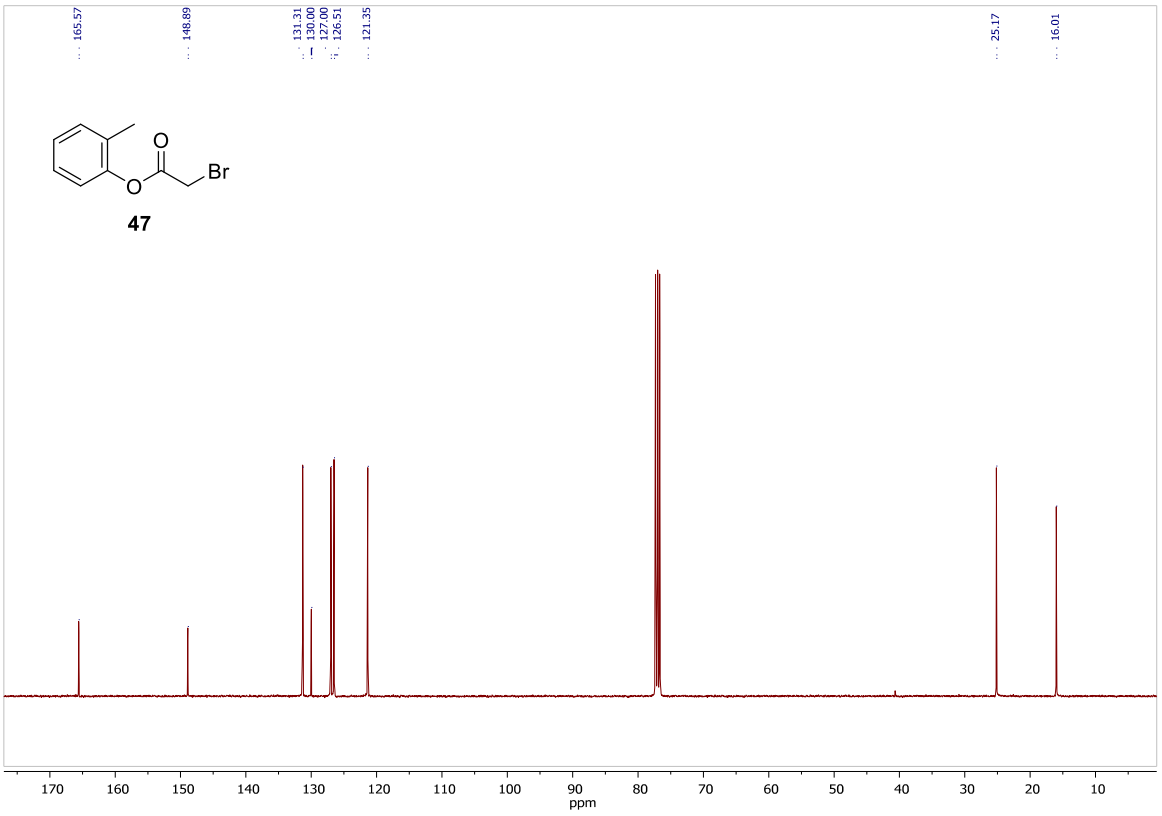


8j

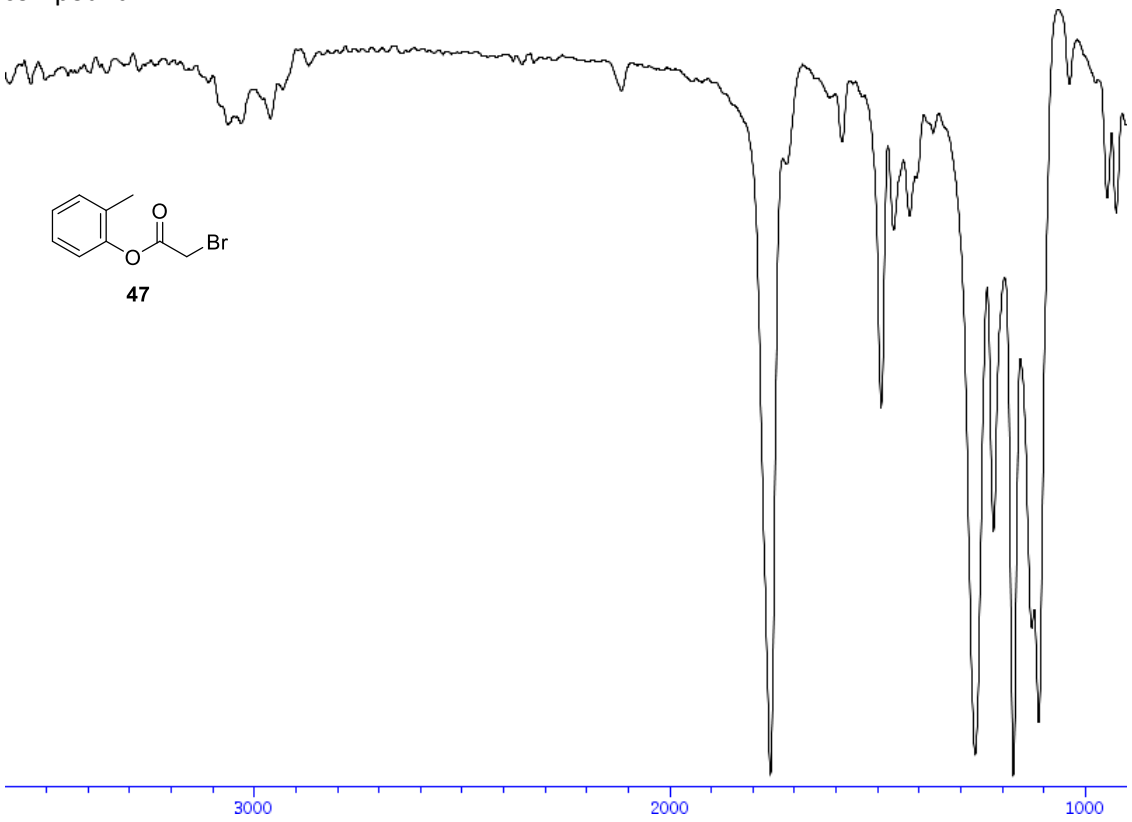
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **47**



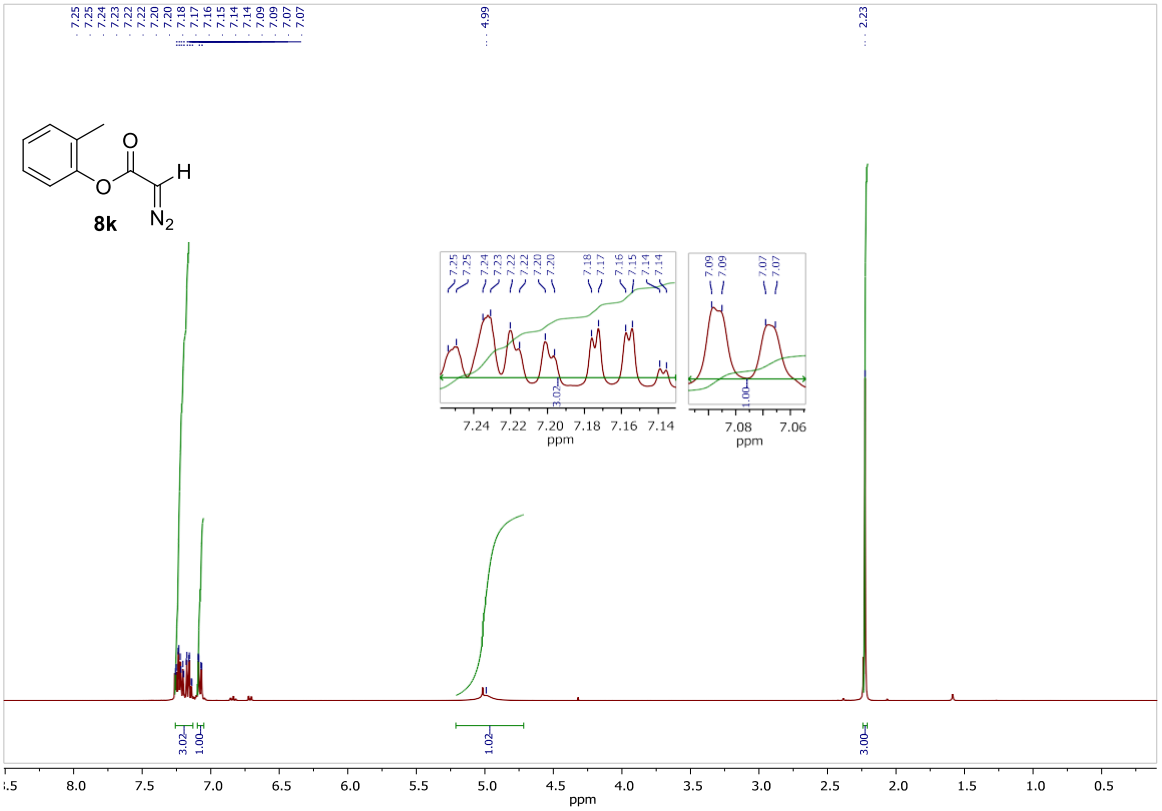
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **47**



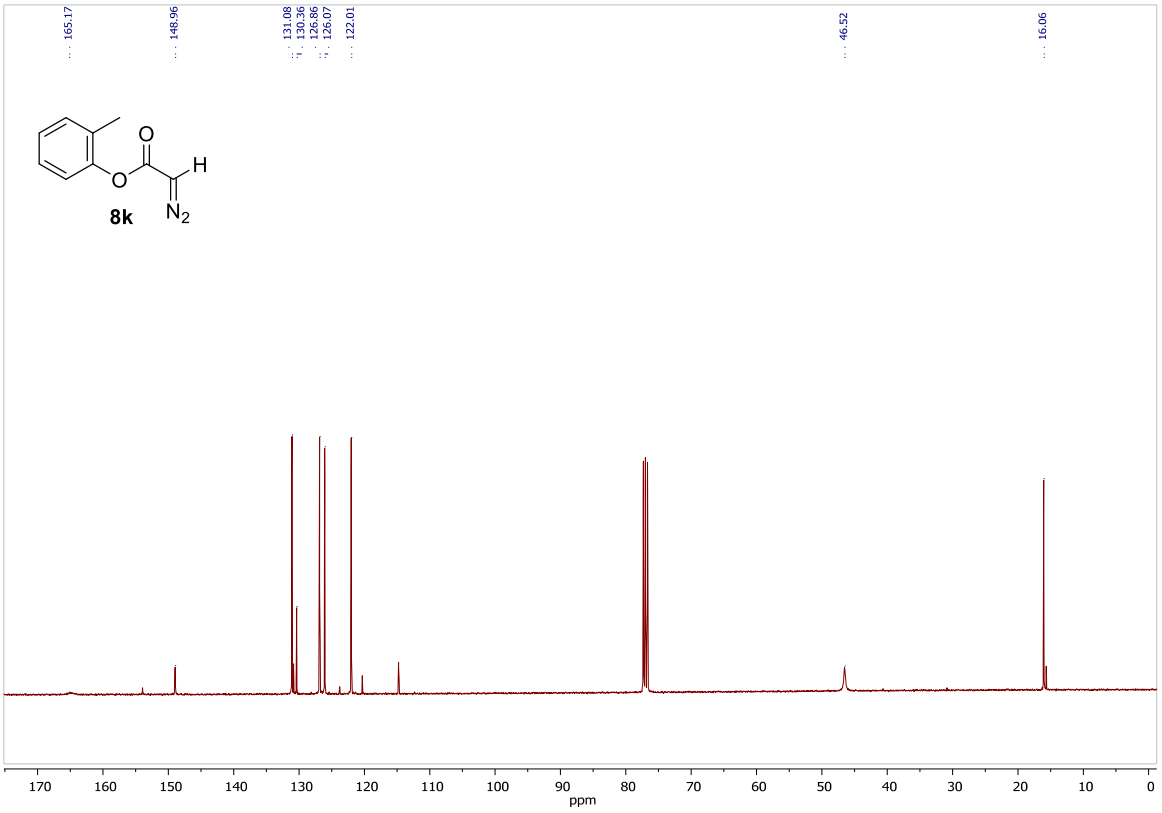
IR of compound **47**



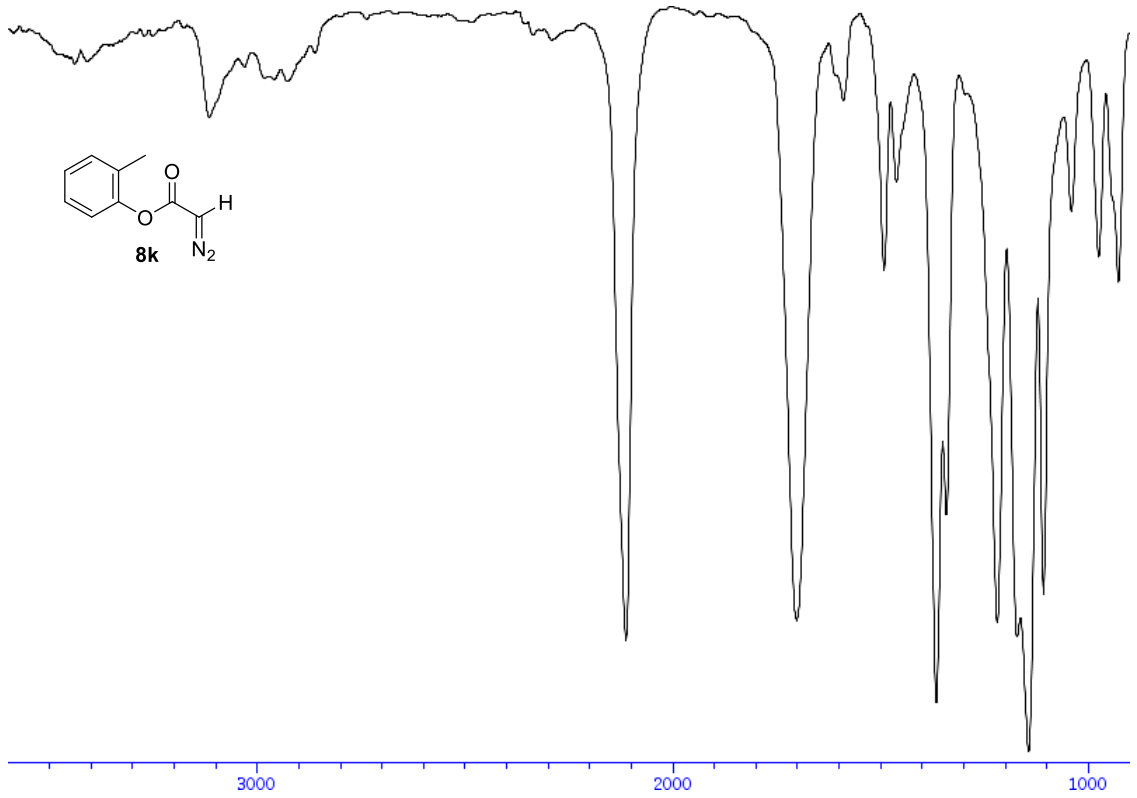
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8k**



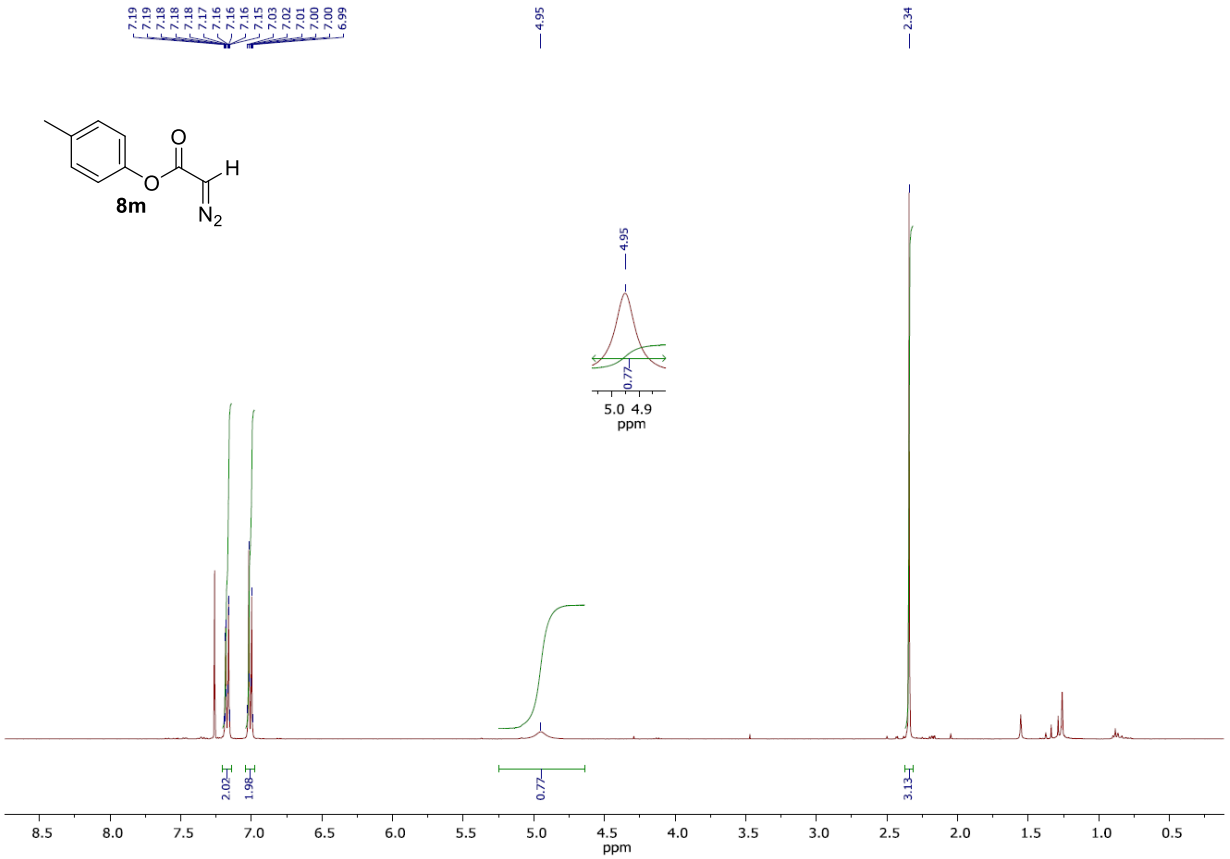
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8k**



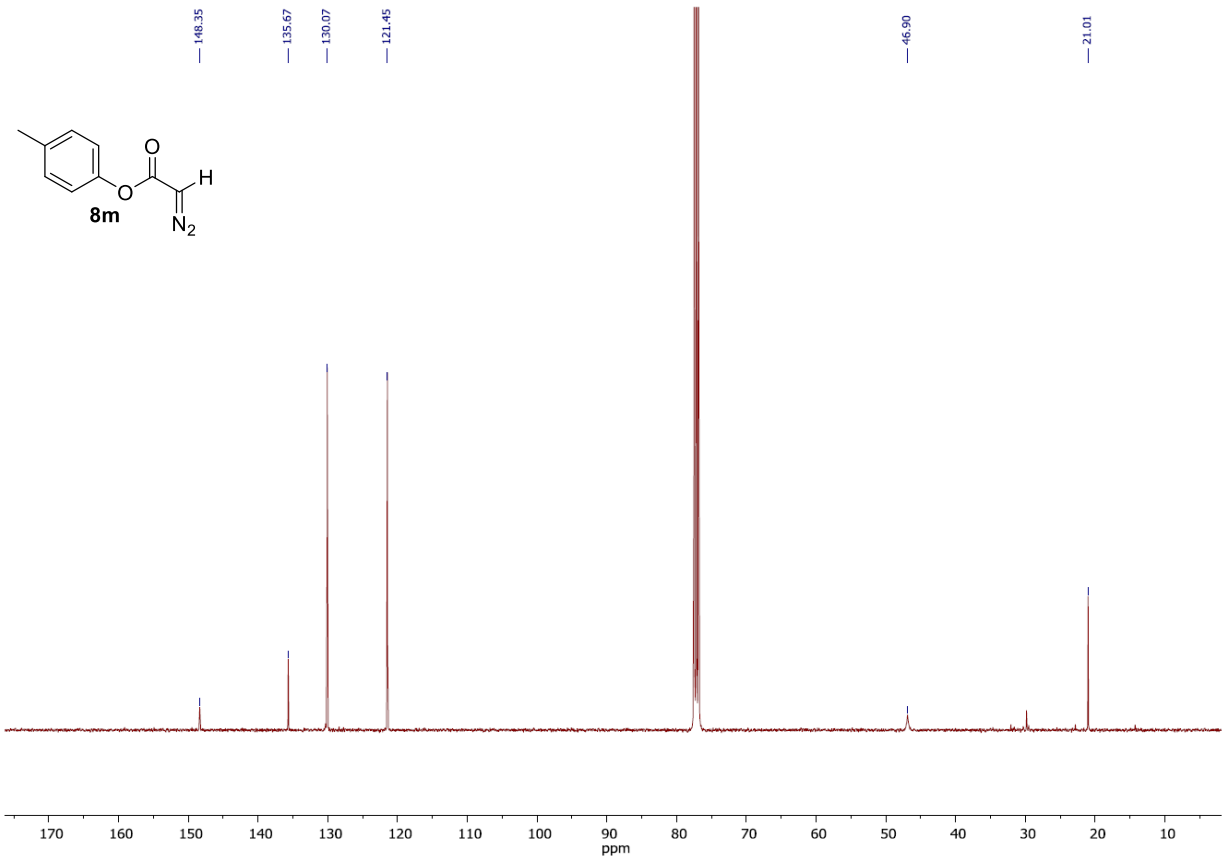
IR of compound **8k**



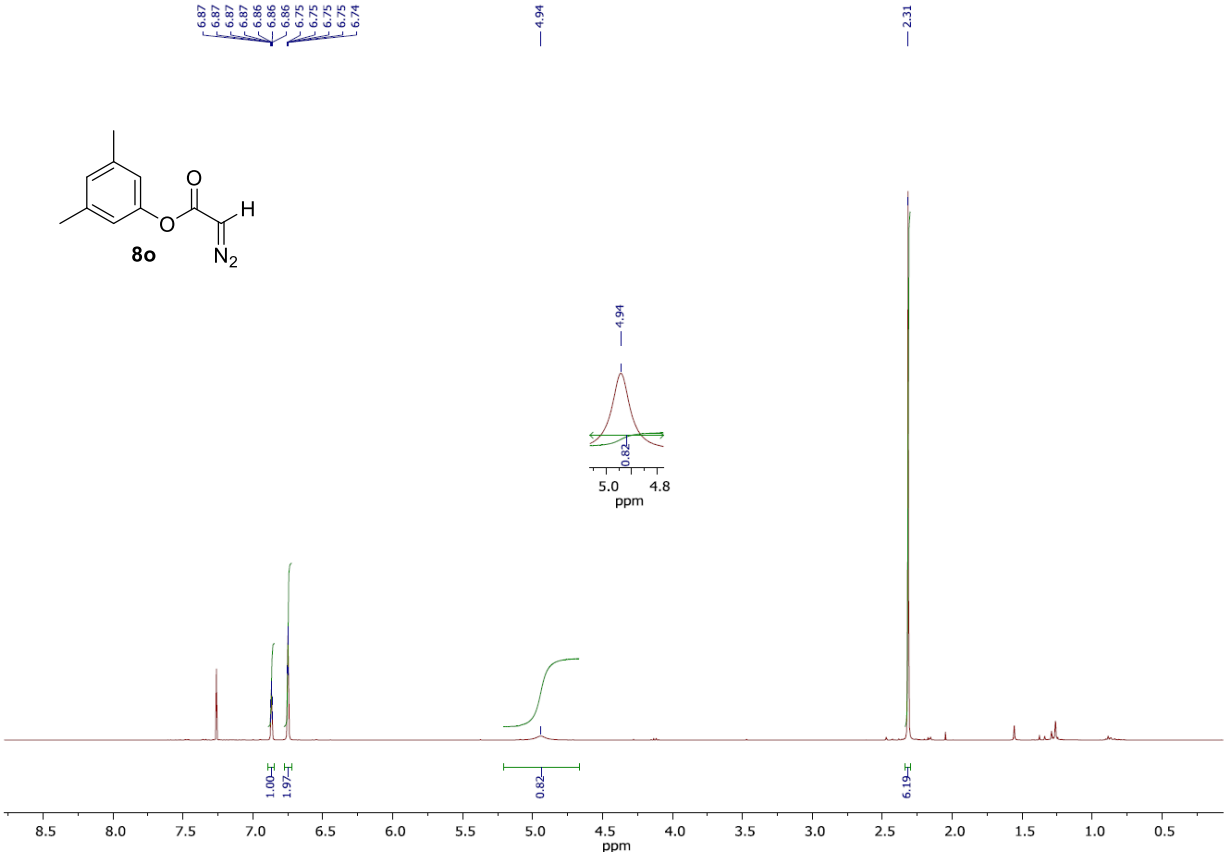
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8m**



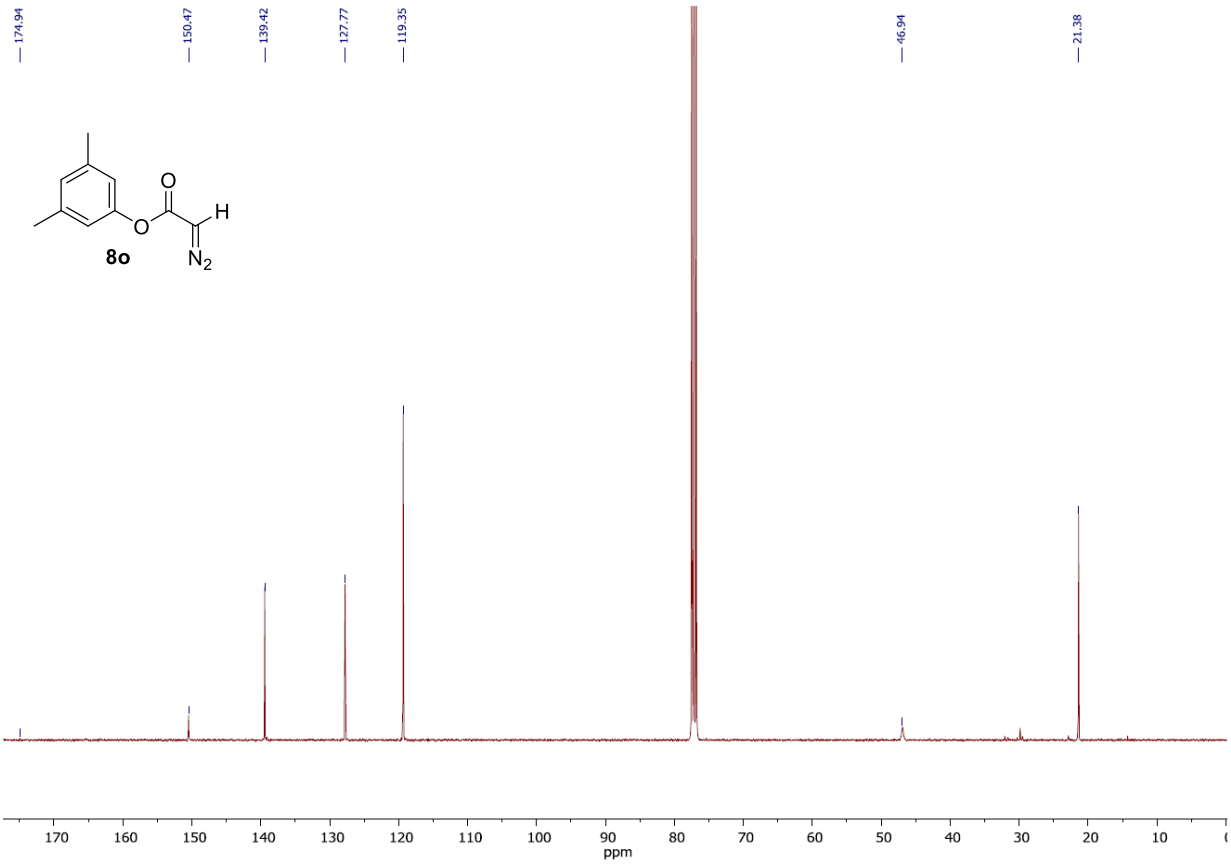
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8m**



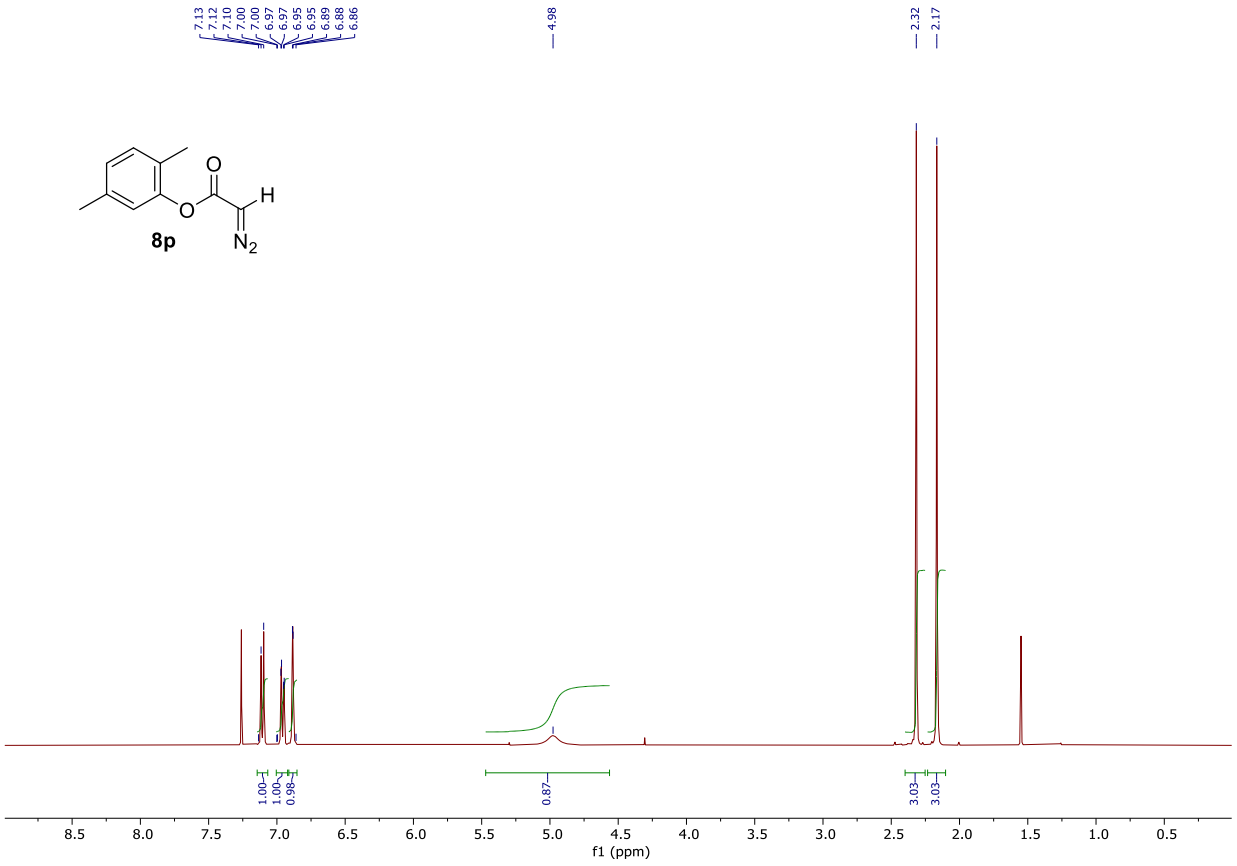
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8o**



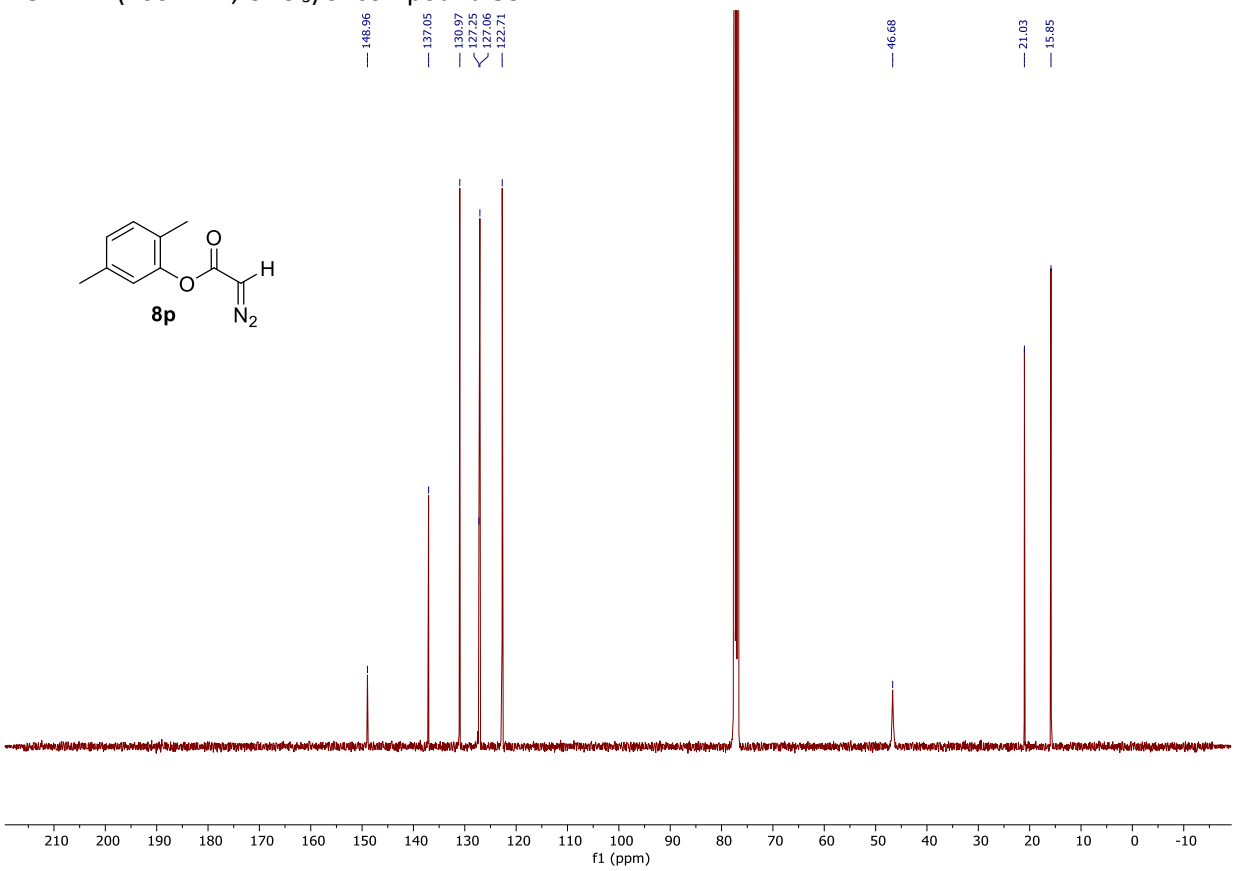
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8o**



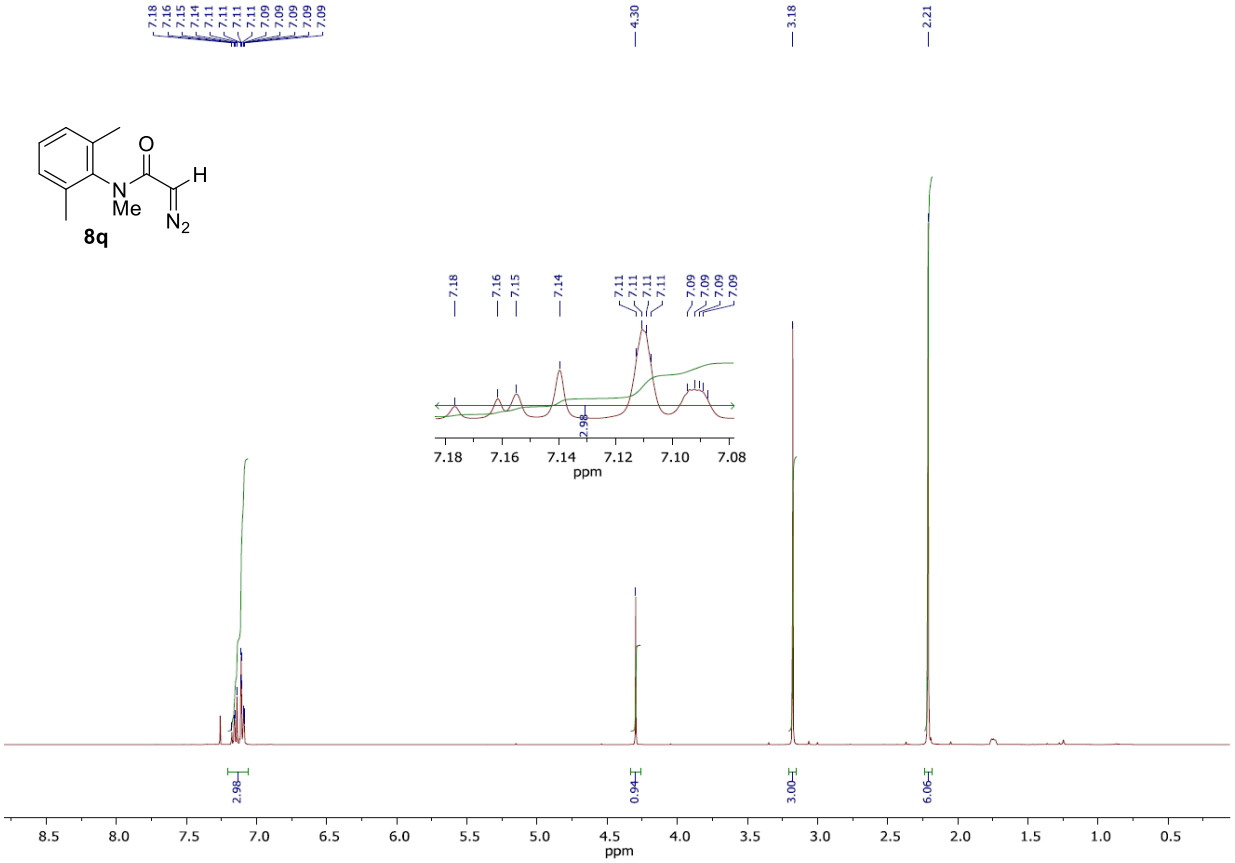
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8p**



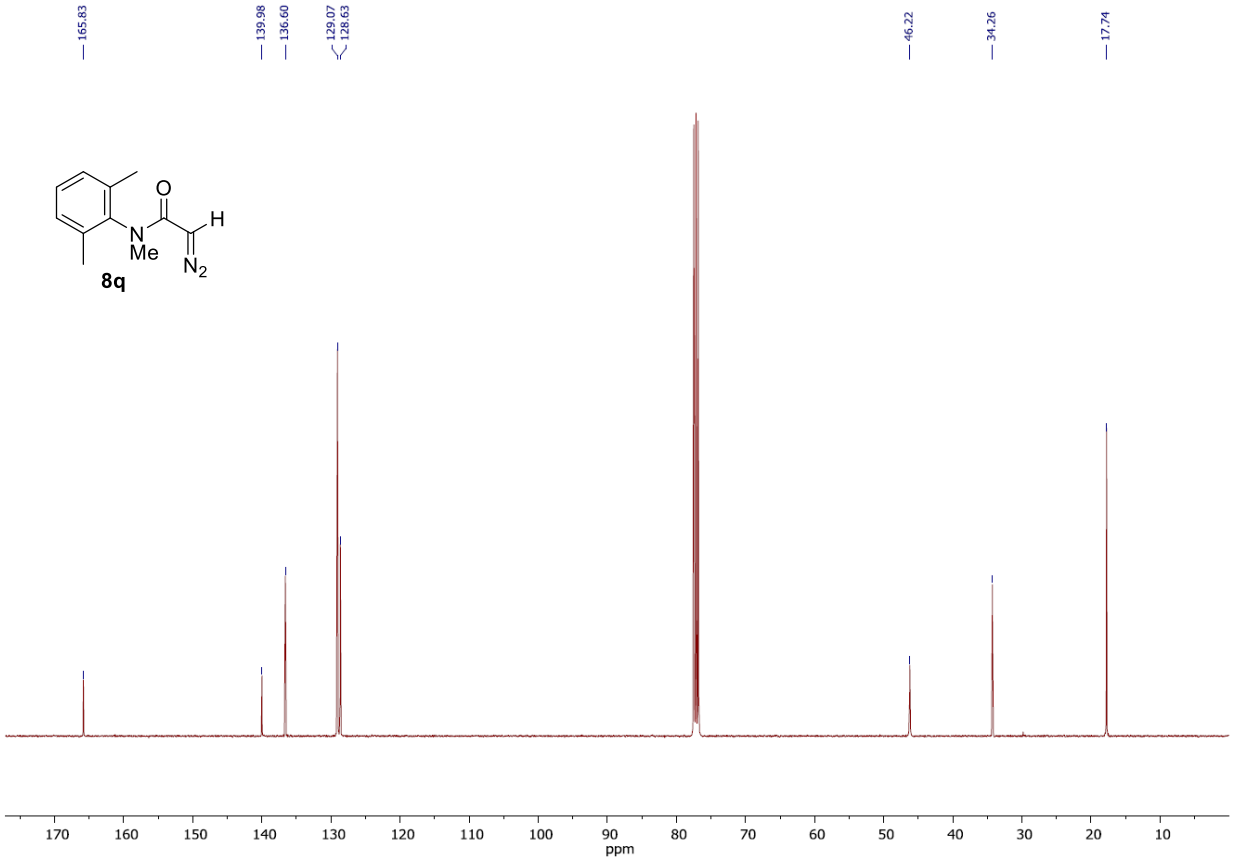
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8o**



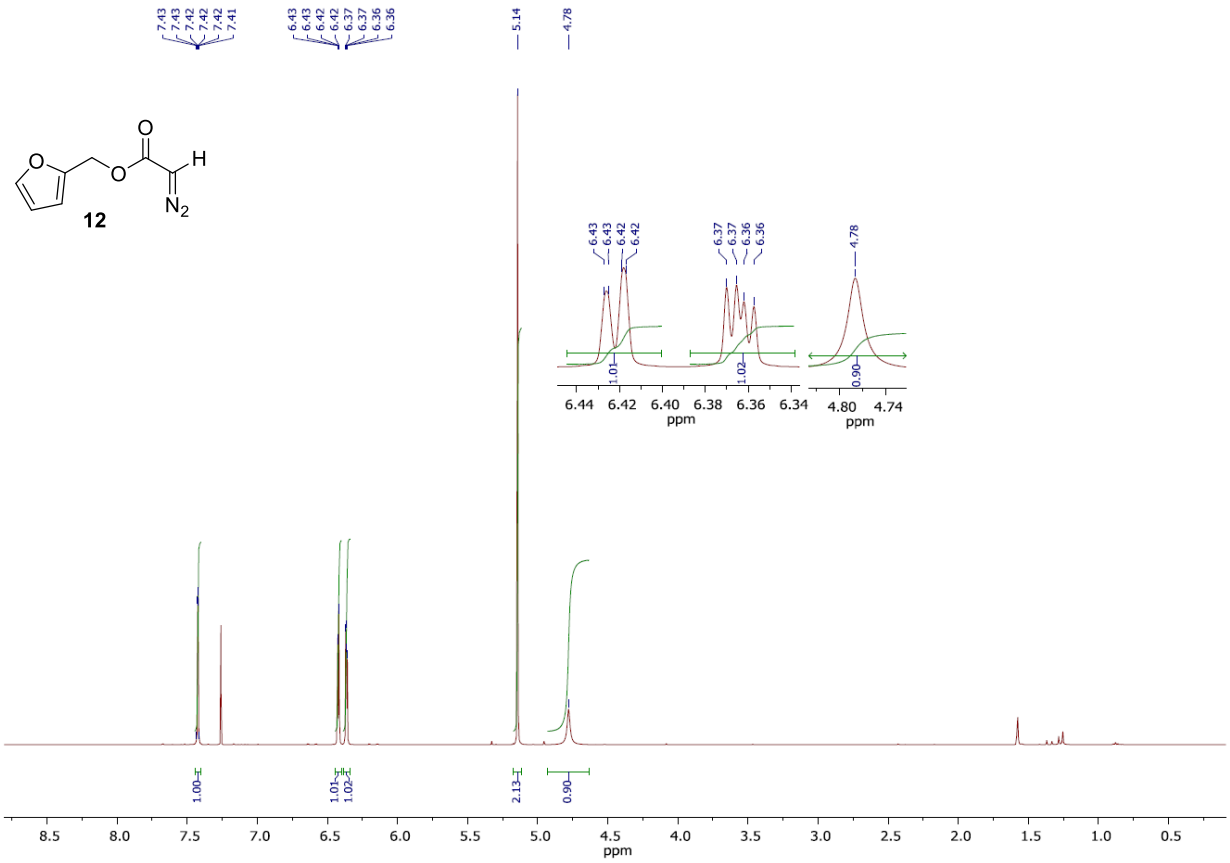
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **8q**



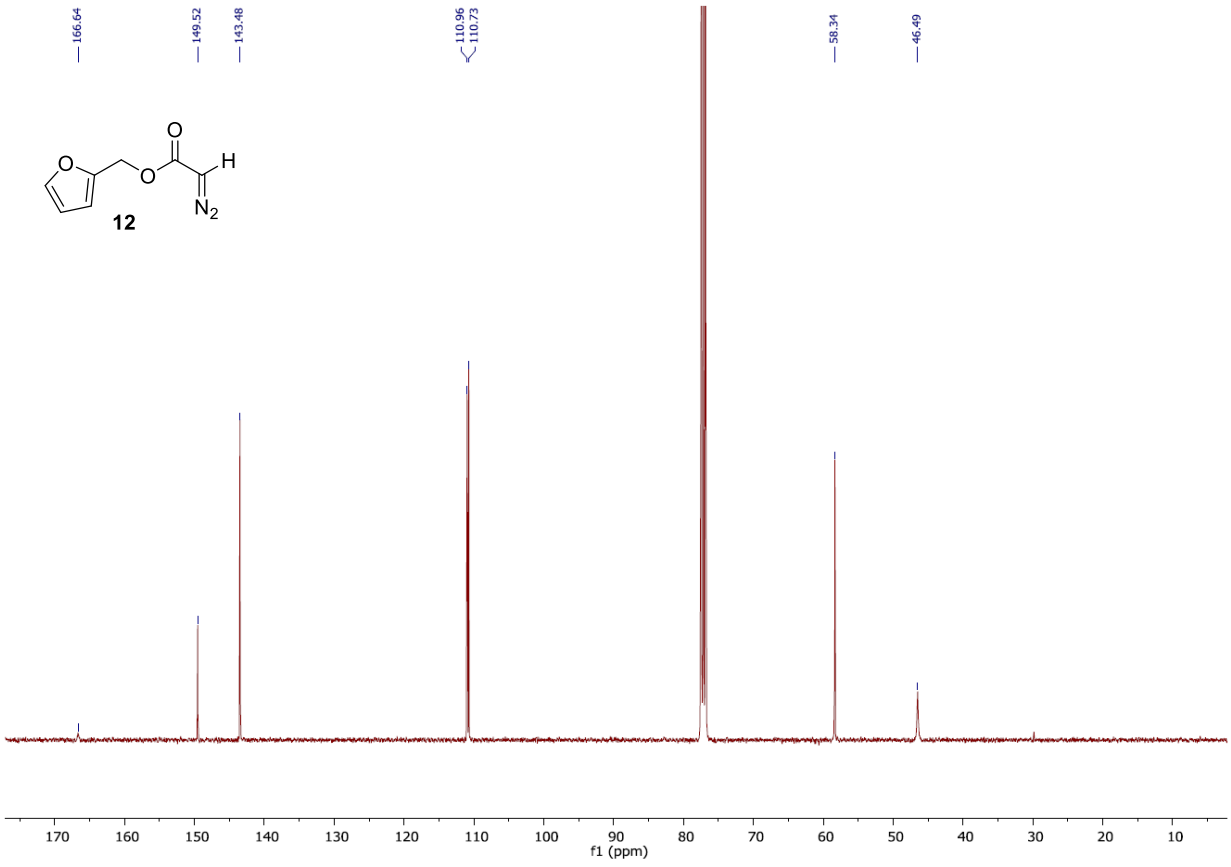
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **8q**



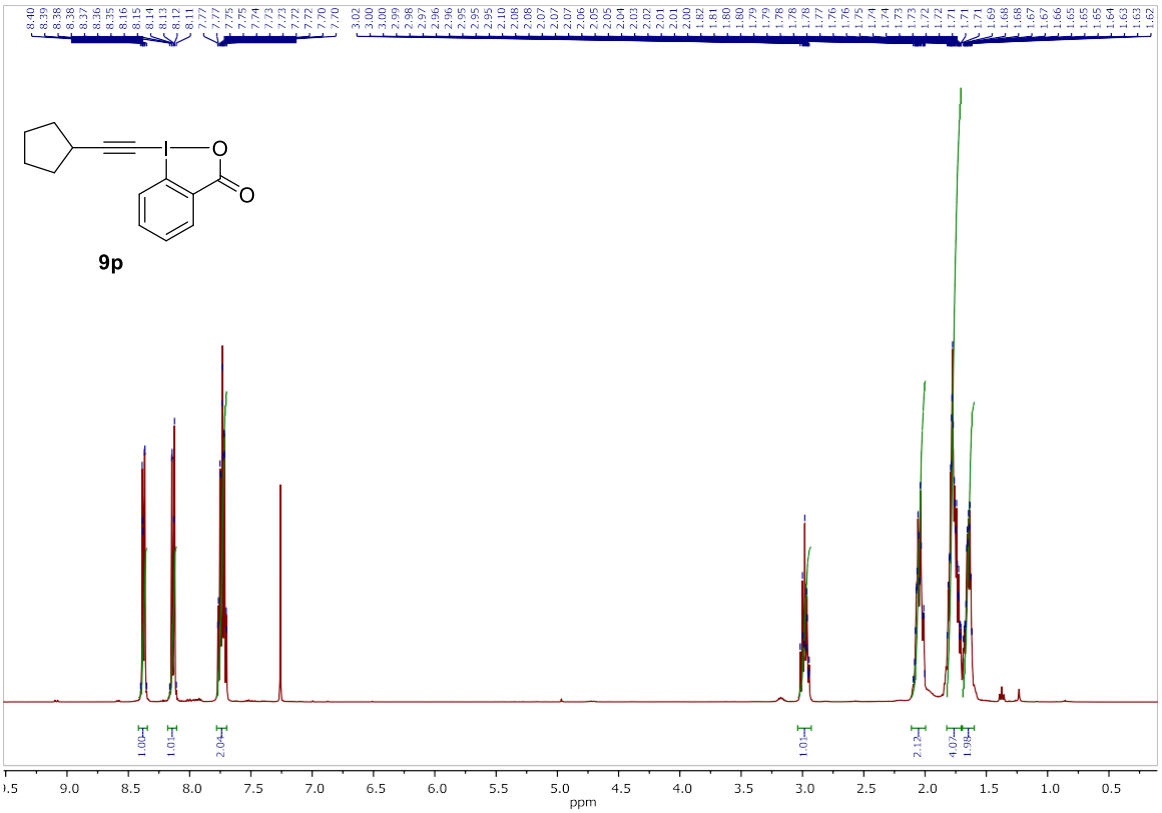
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **12**



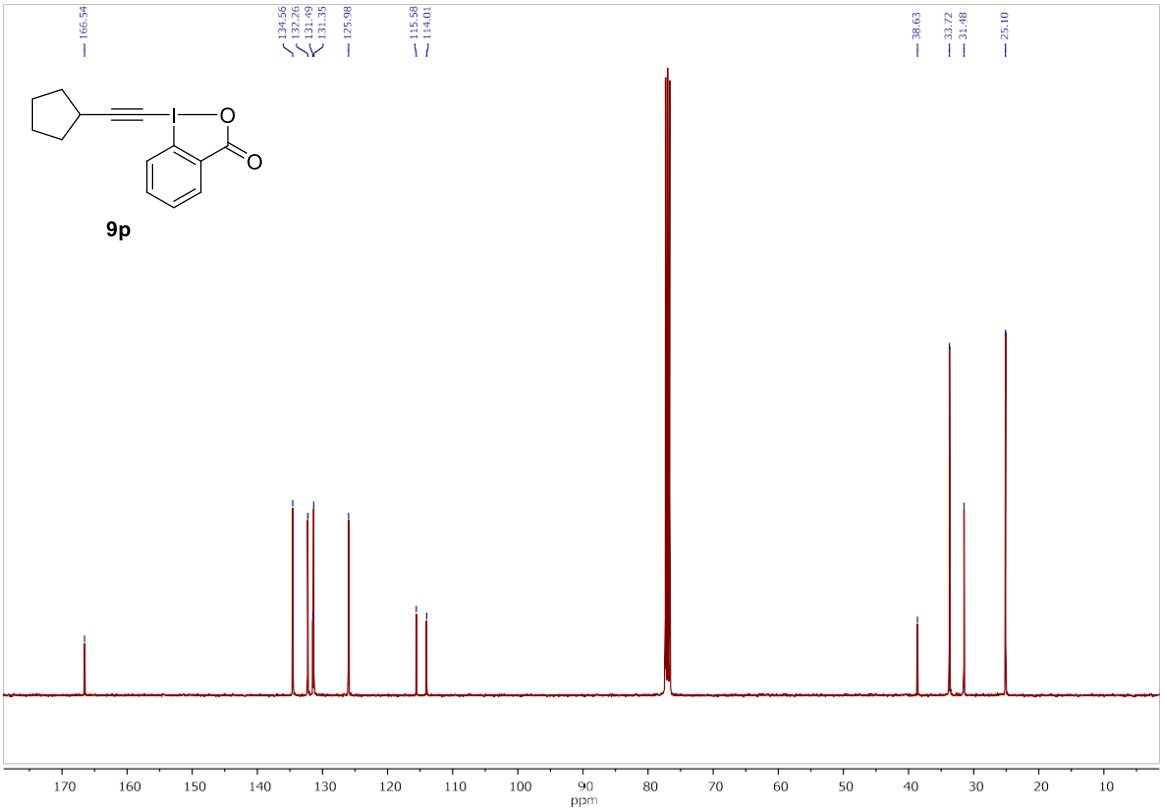
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **12**



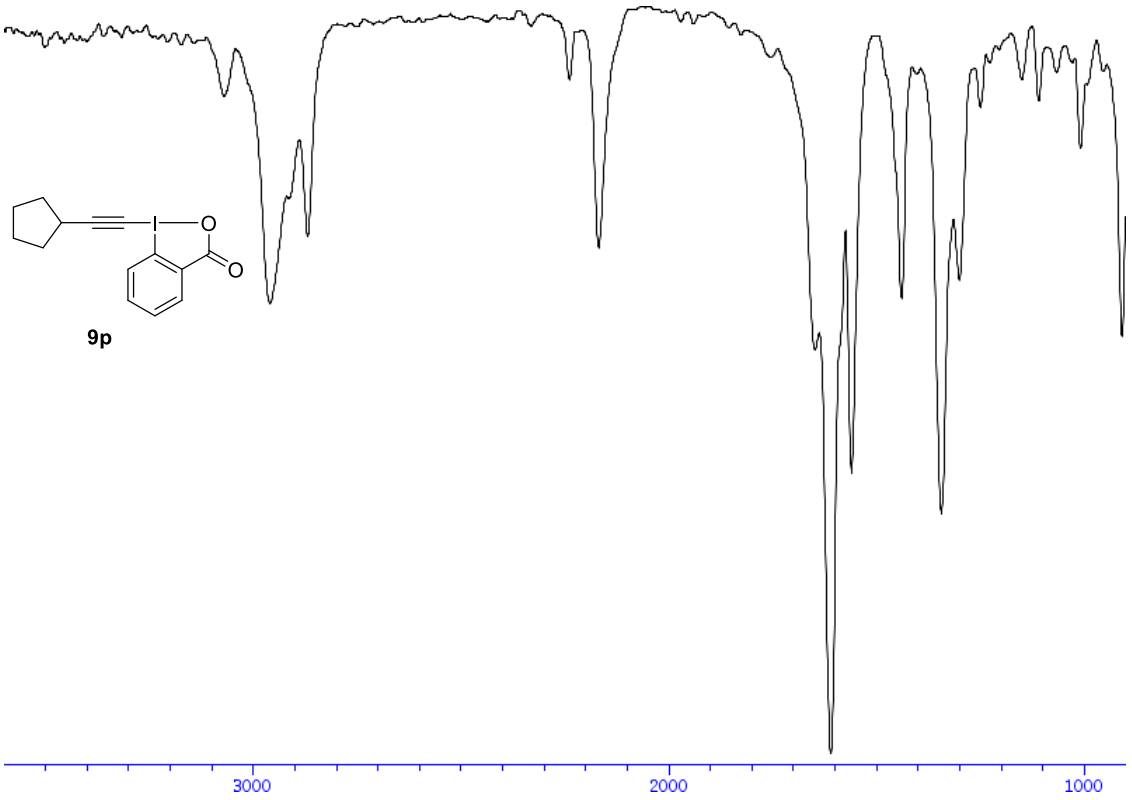
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **9p**



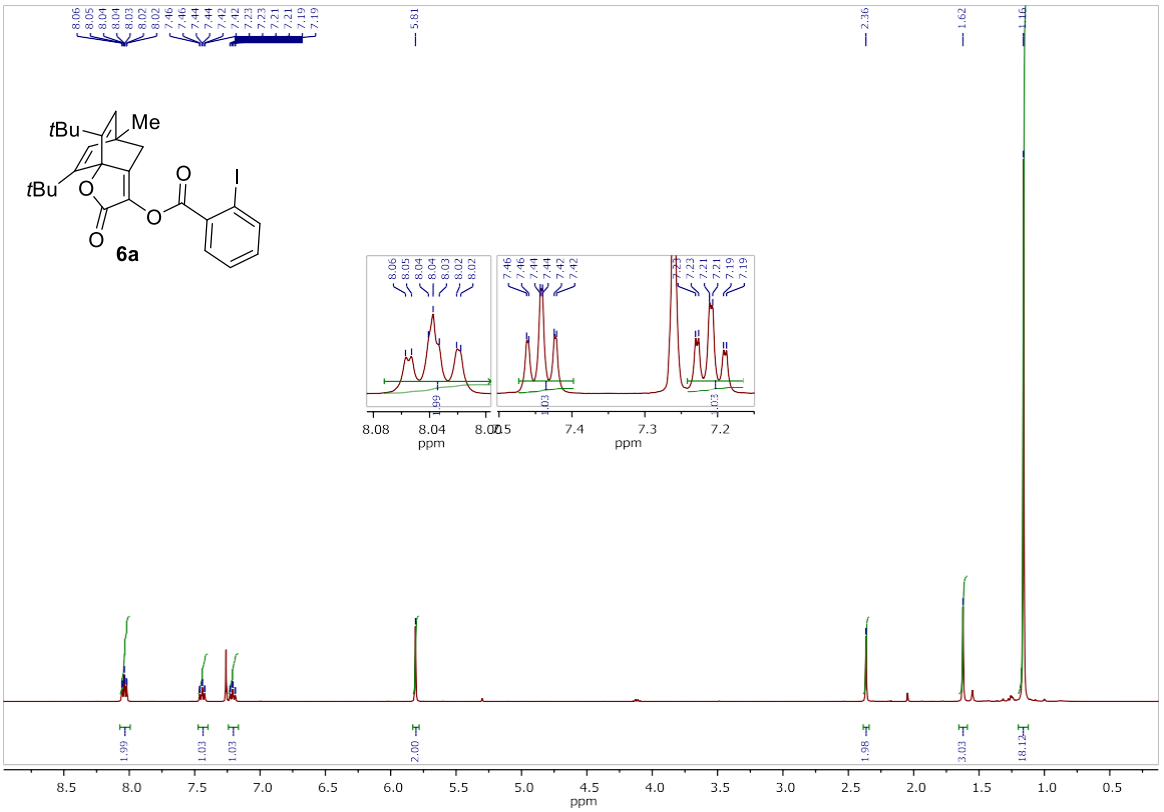
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **9p**



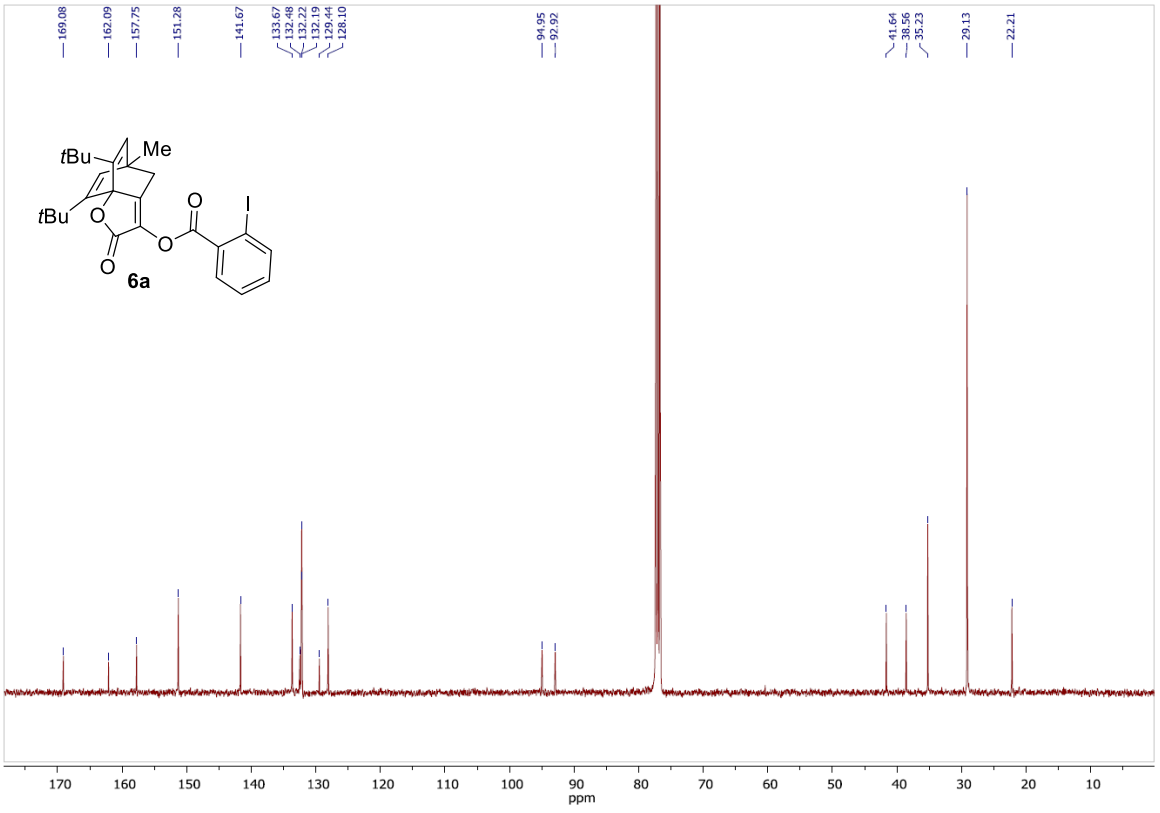
IR of compound **9p**



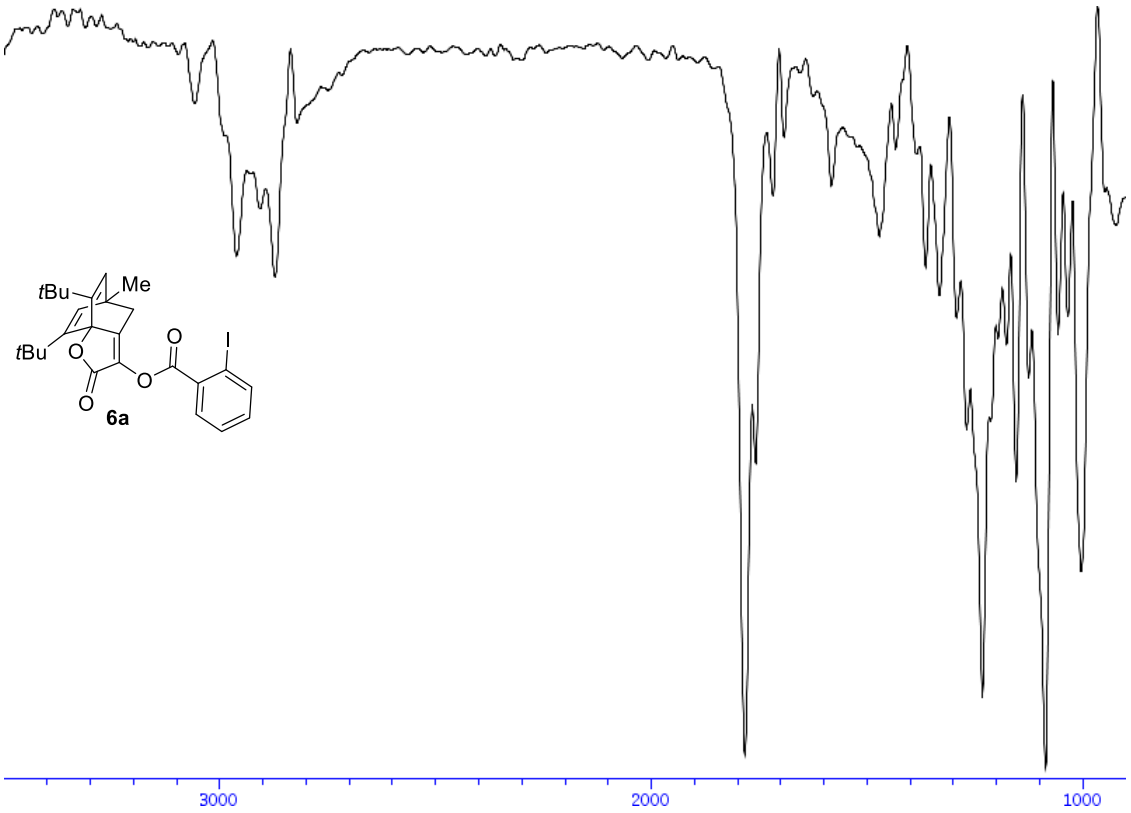
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6a**



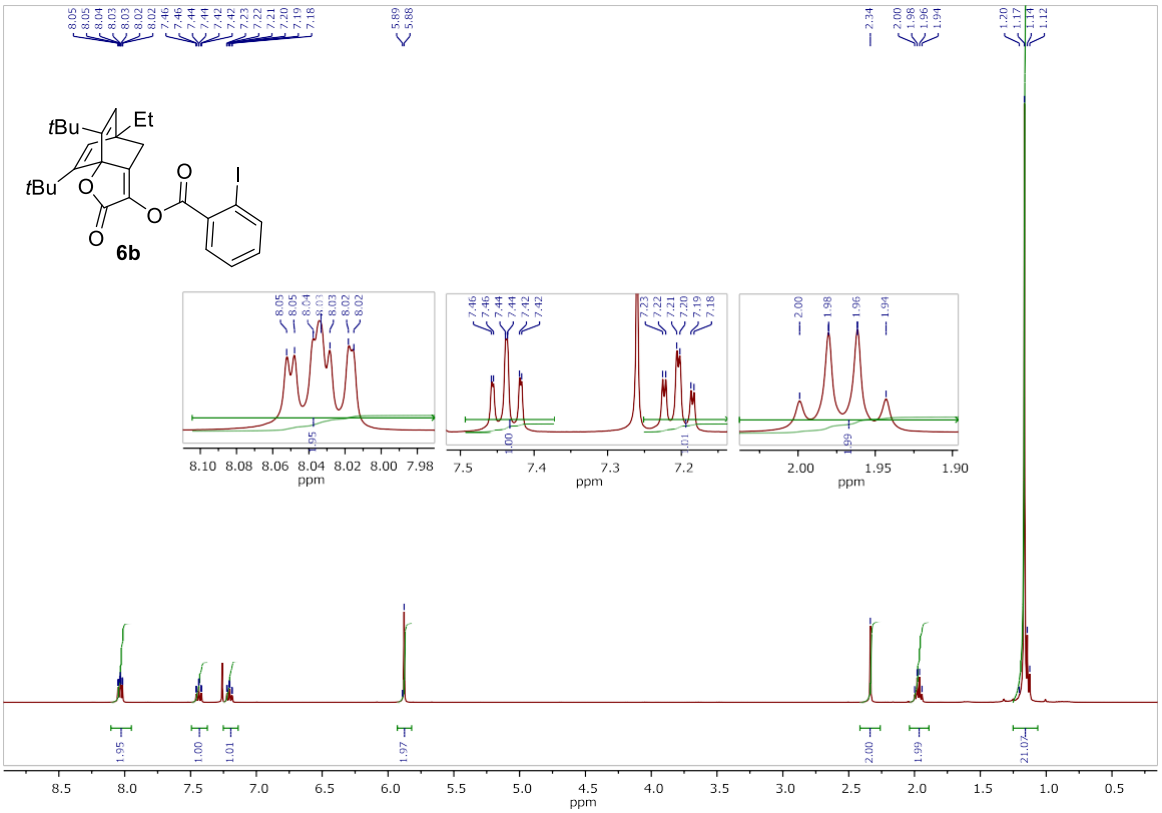
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6a**



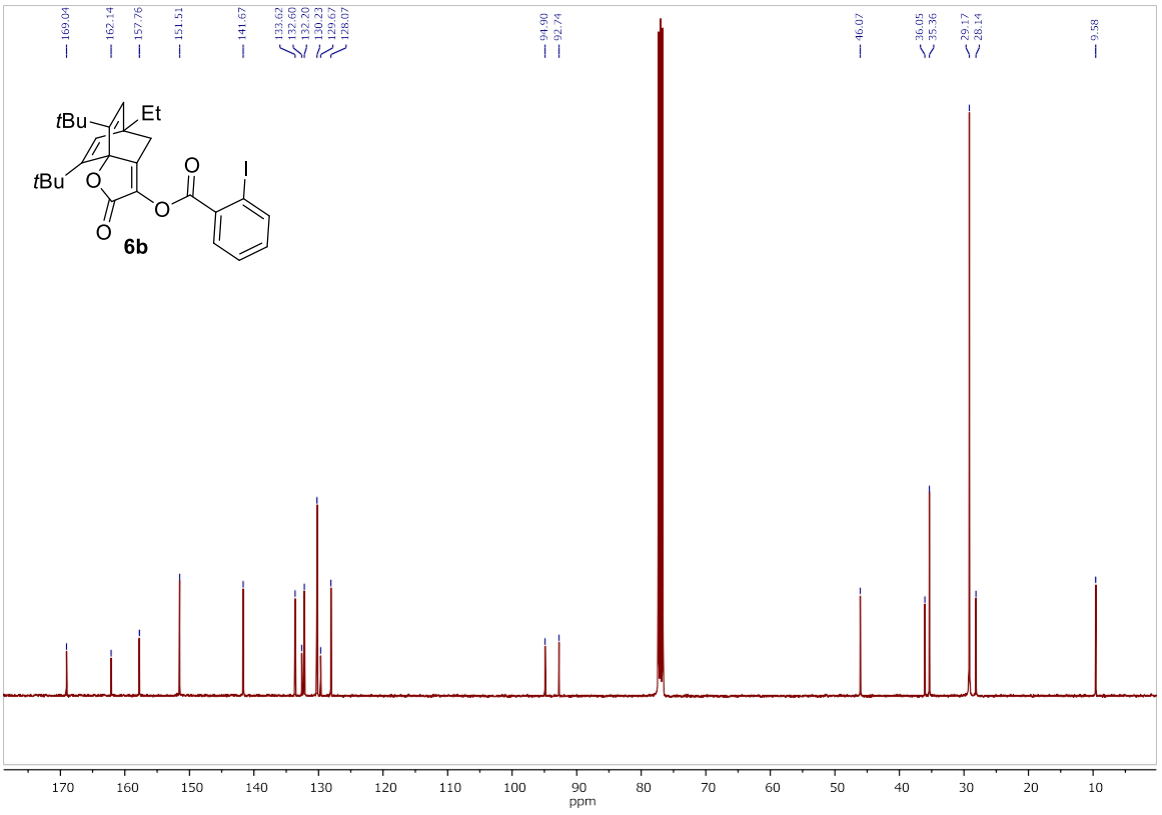
IR of compound **6a**



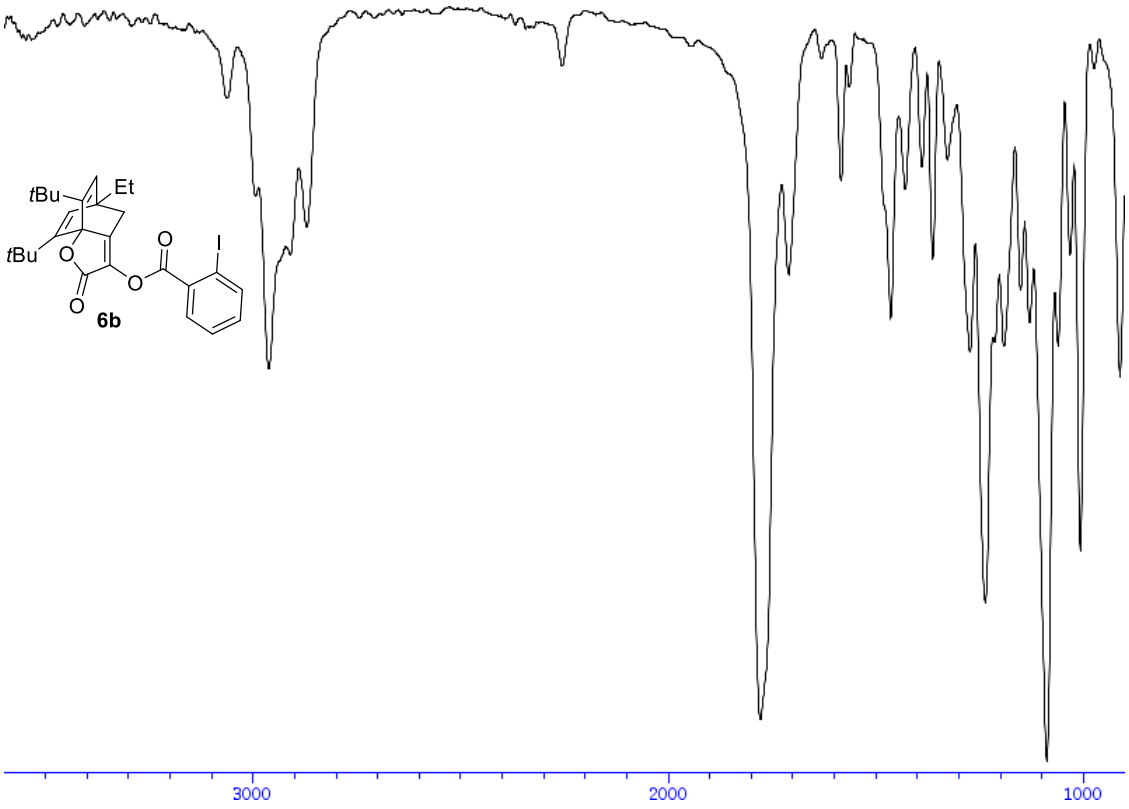
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6b**



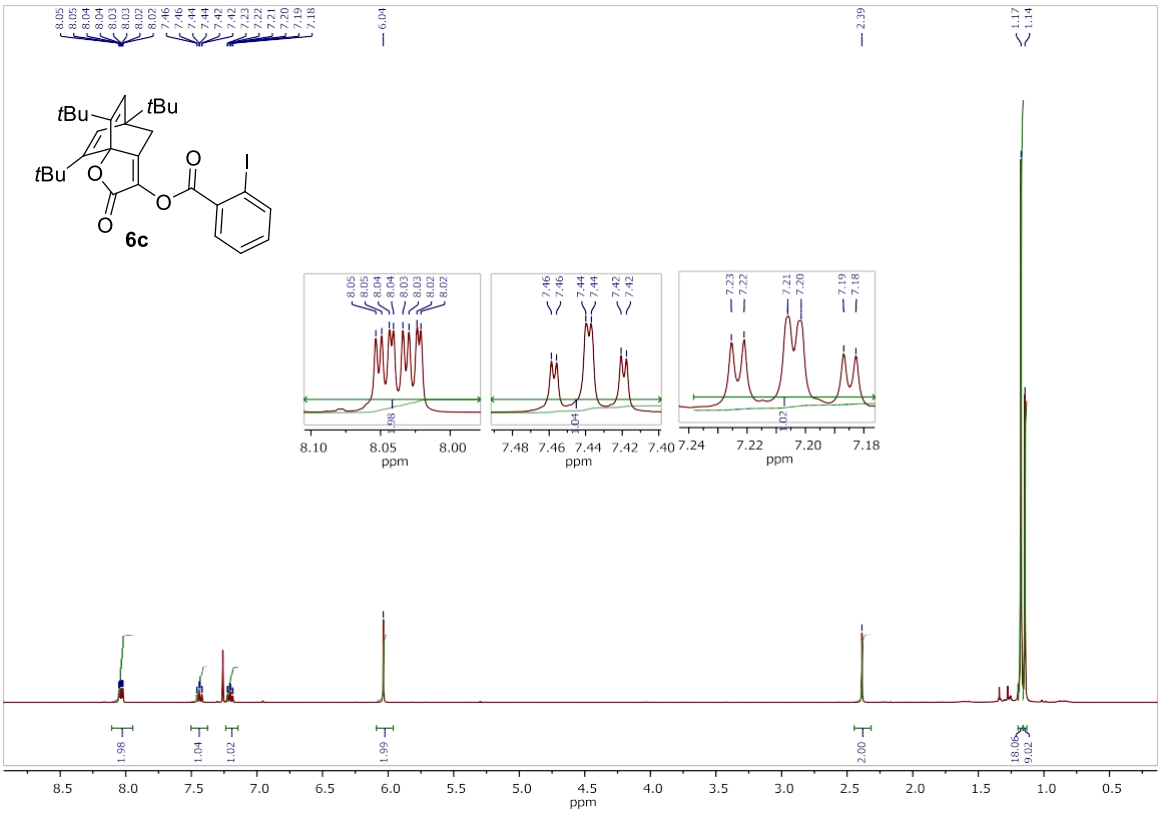
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6b**



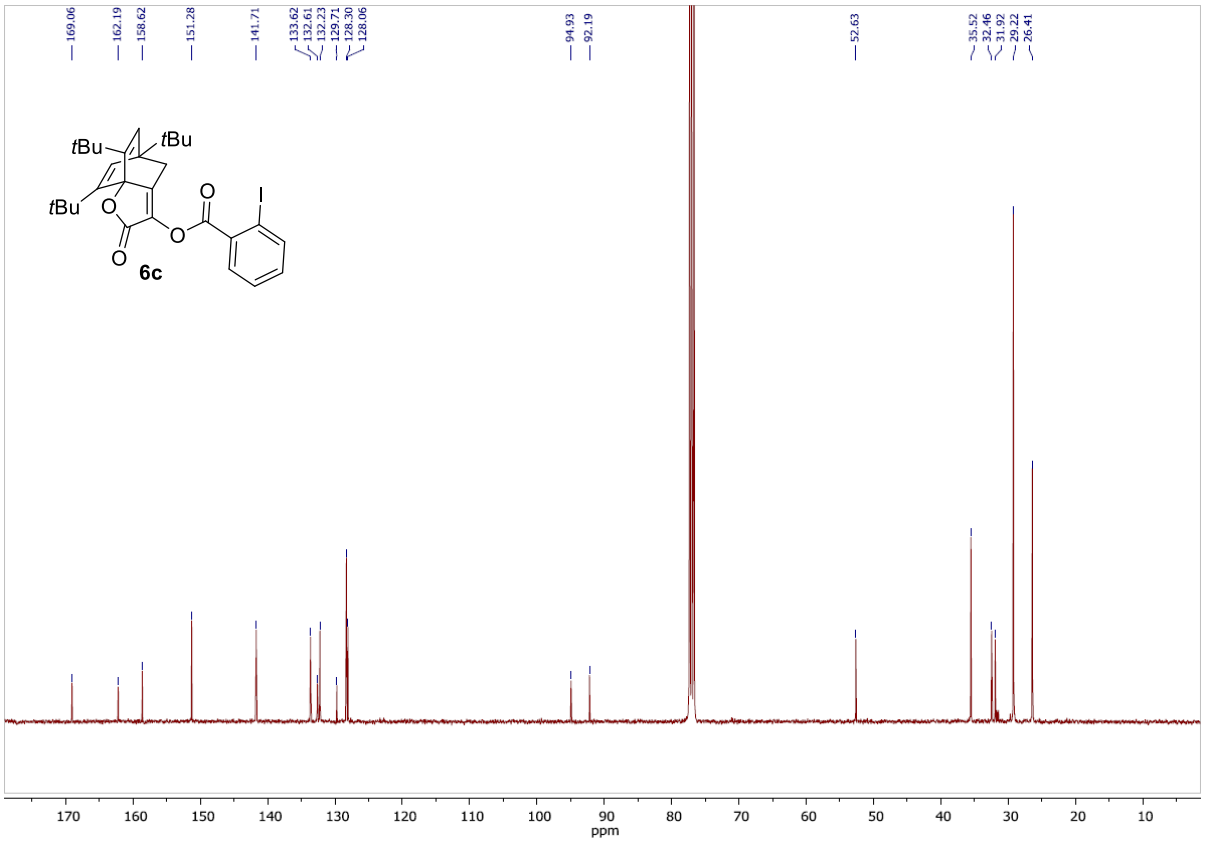
IR of compound **6b**



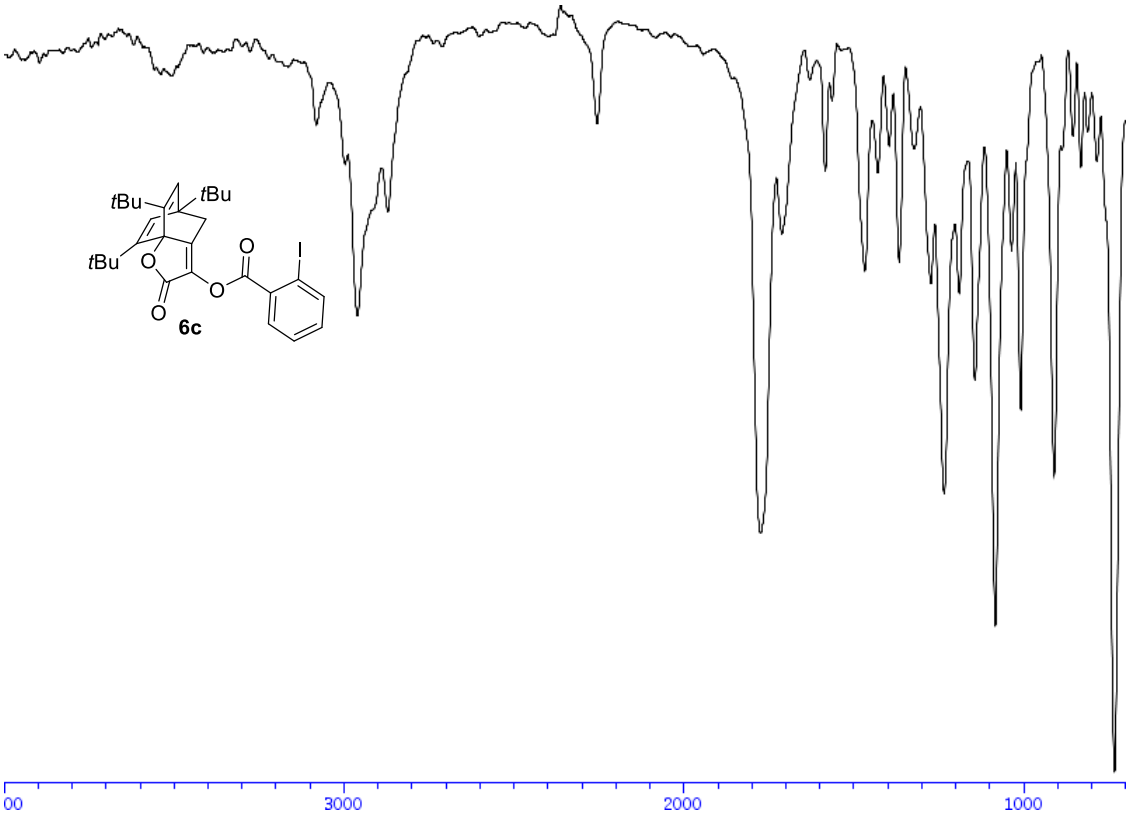
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6c**



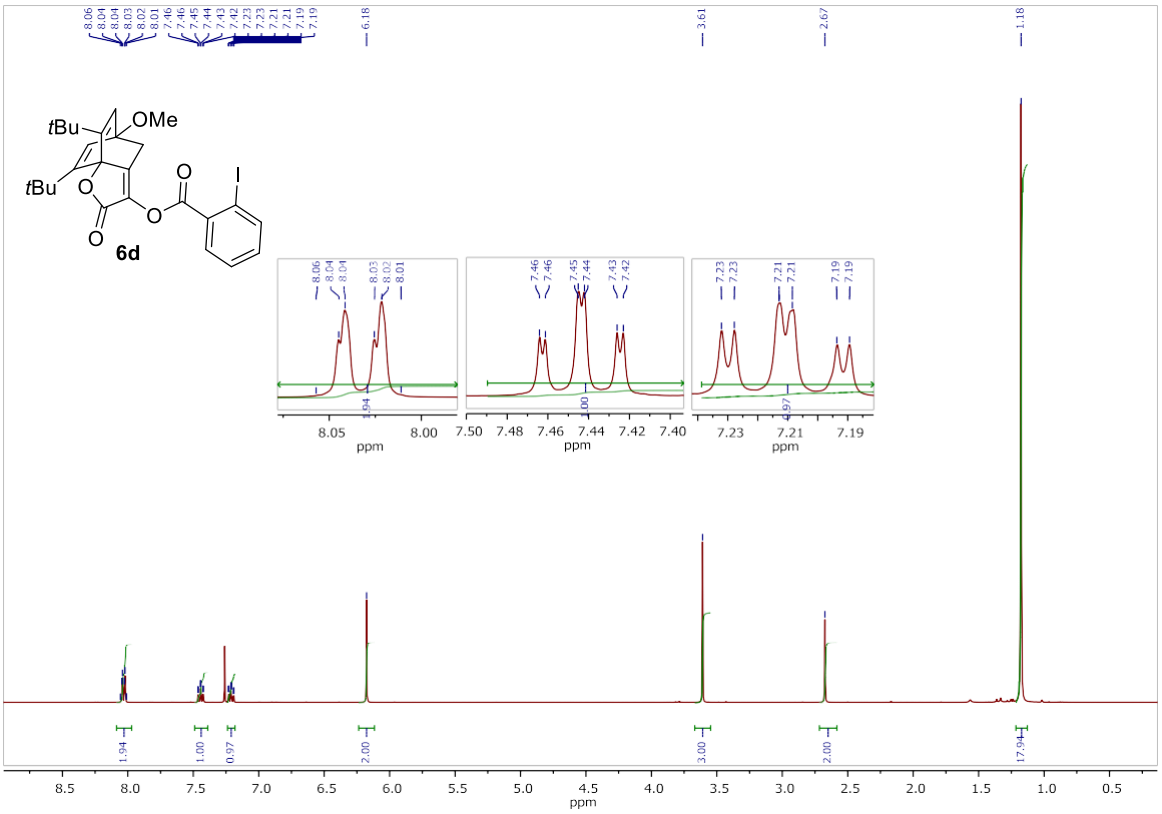
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6c**



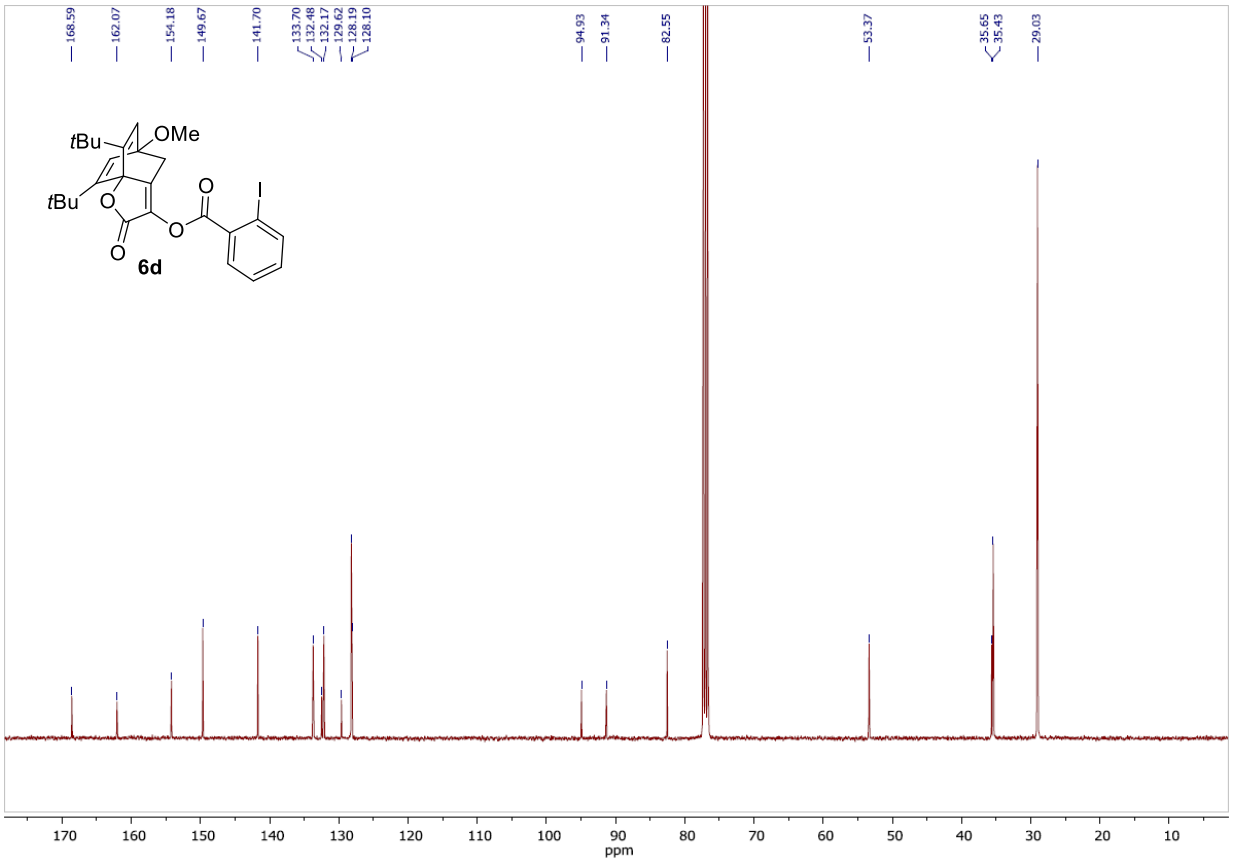
IR of compound **6c**



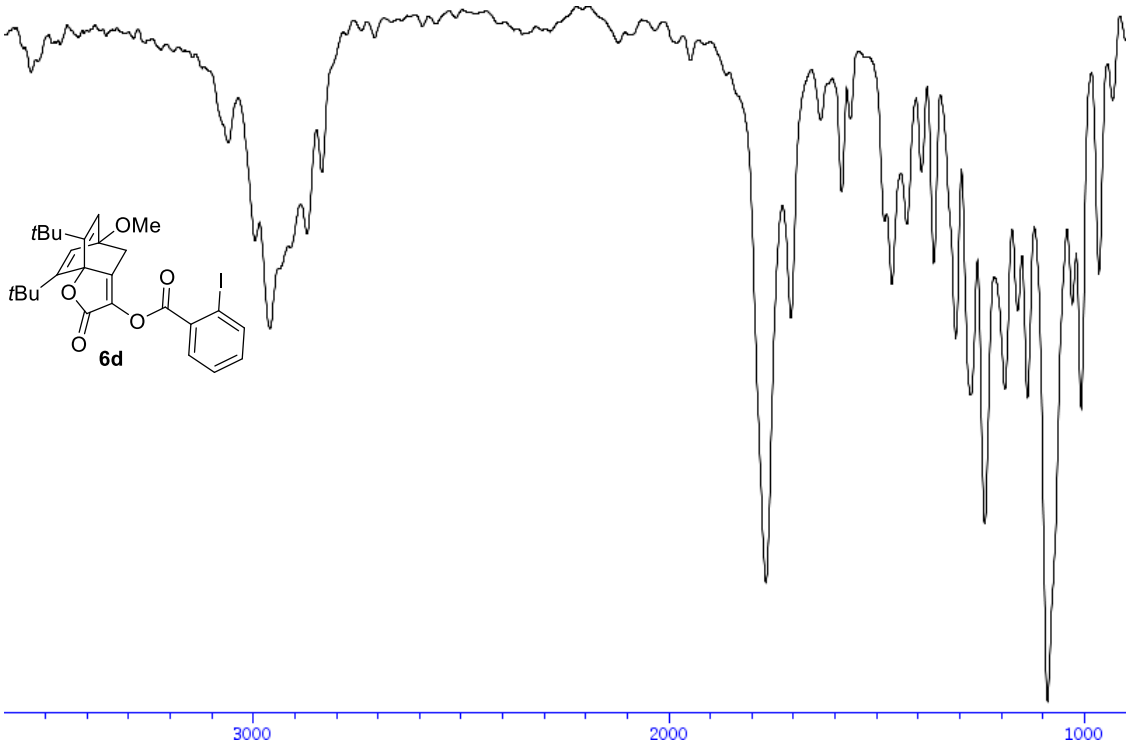
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6d**



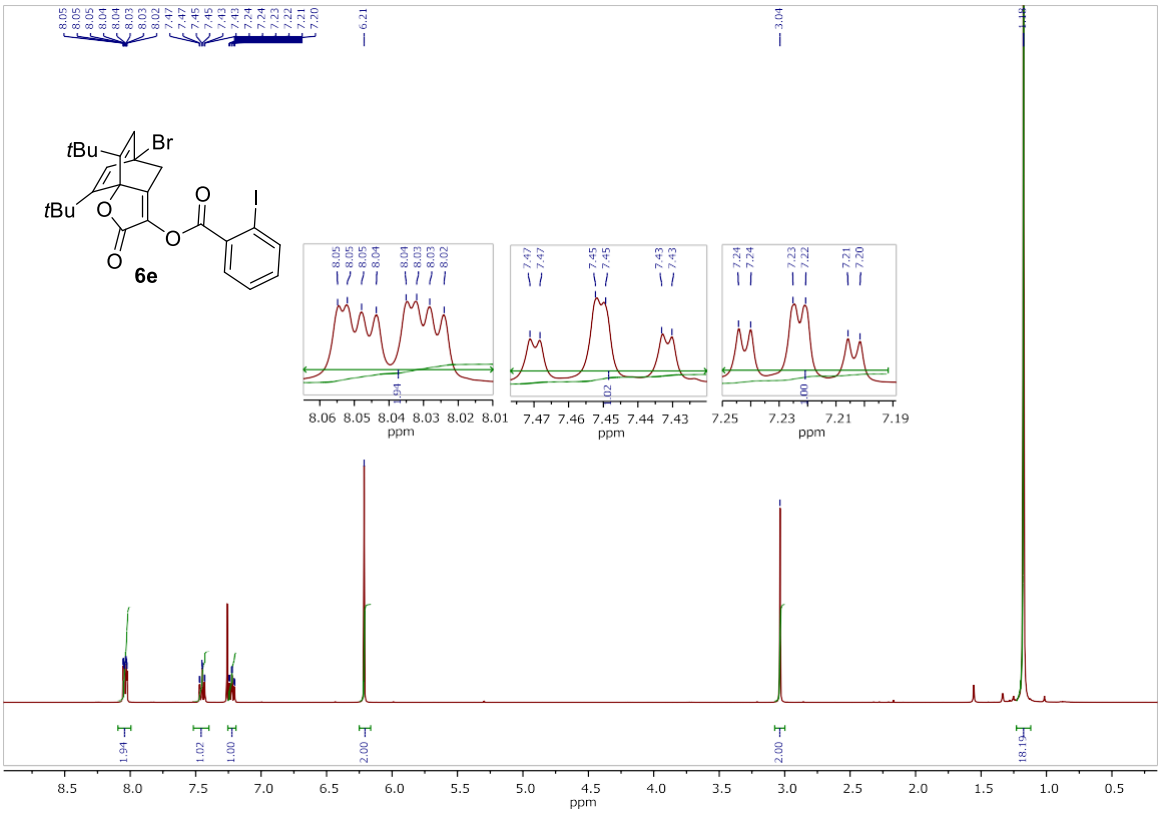
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6d**



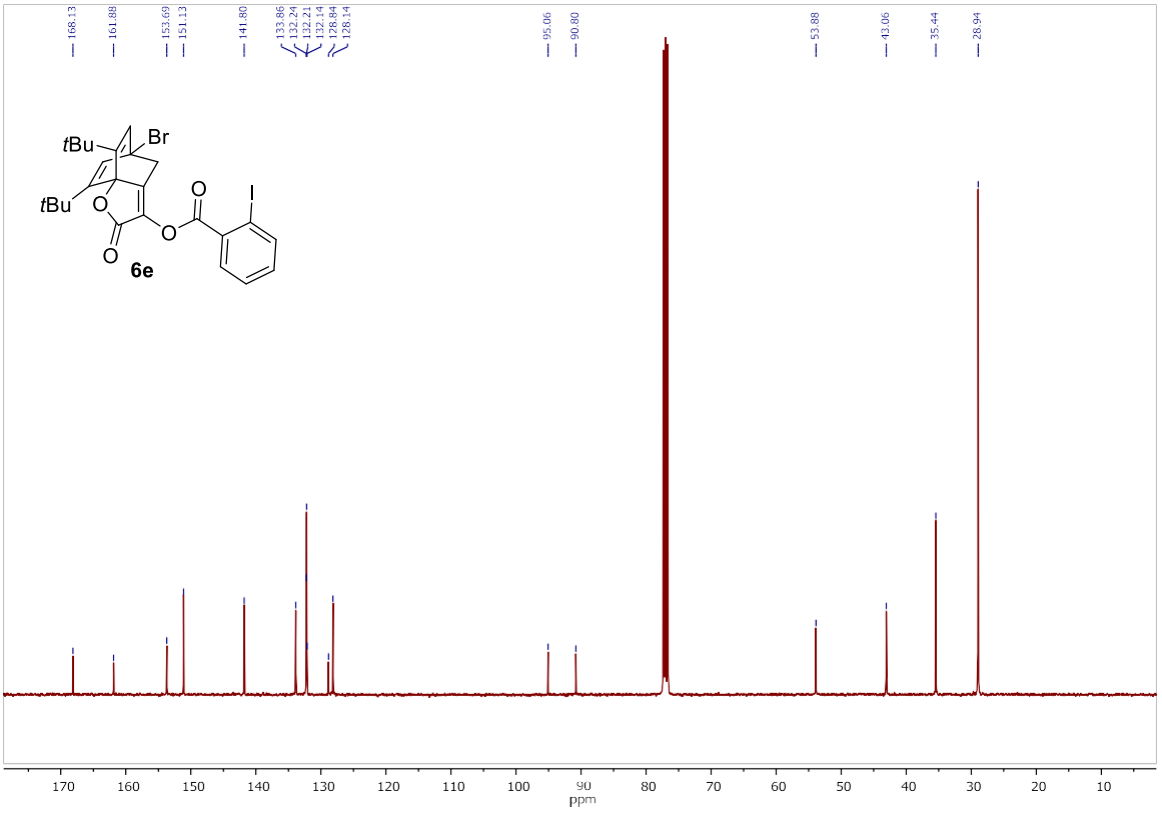
IR of compound **6d**



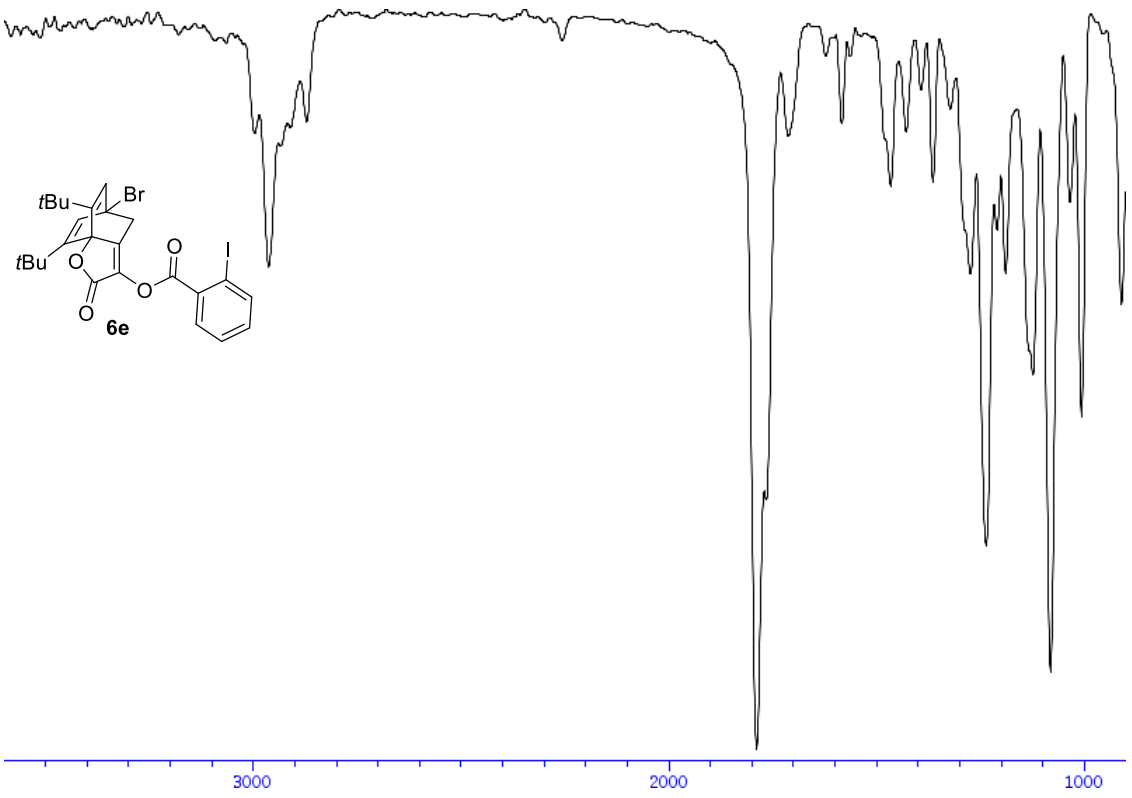
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6e**



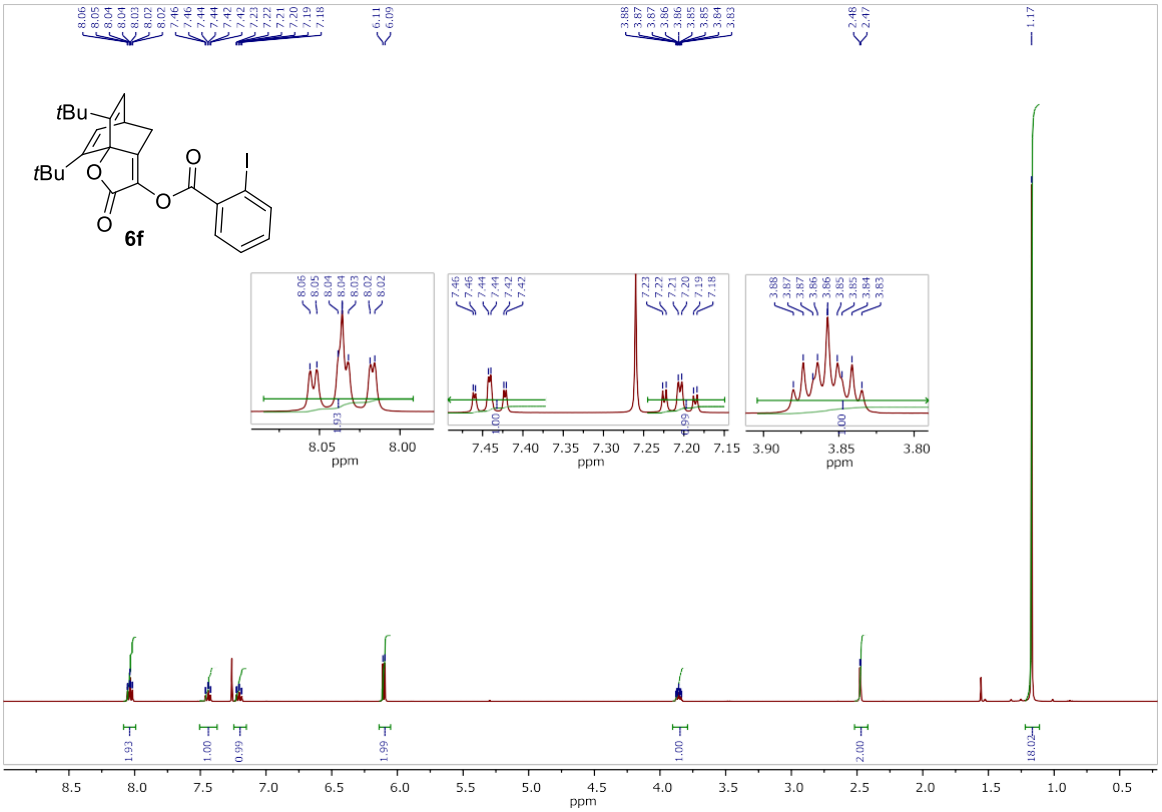
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6e**



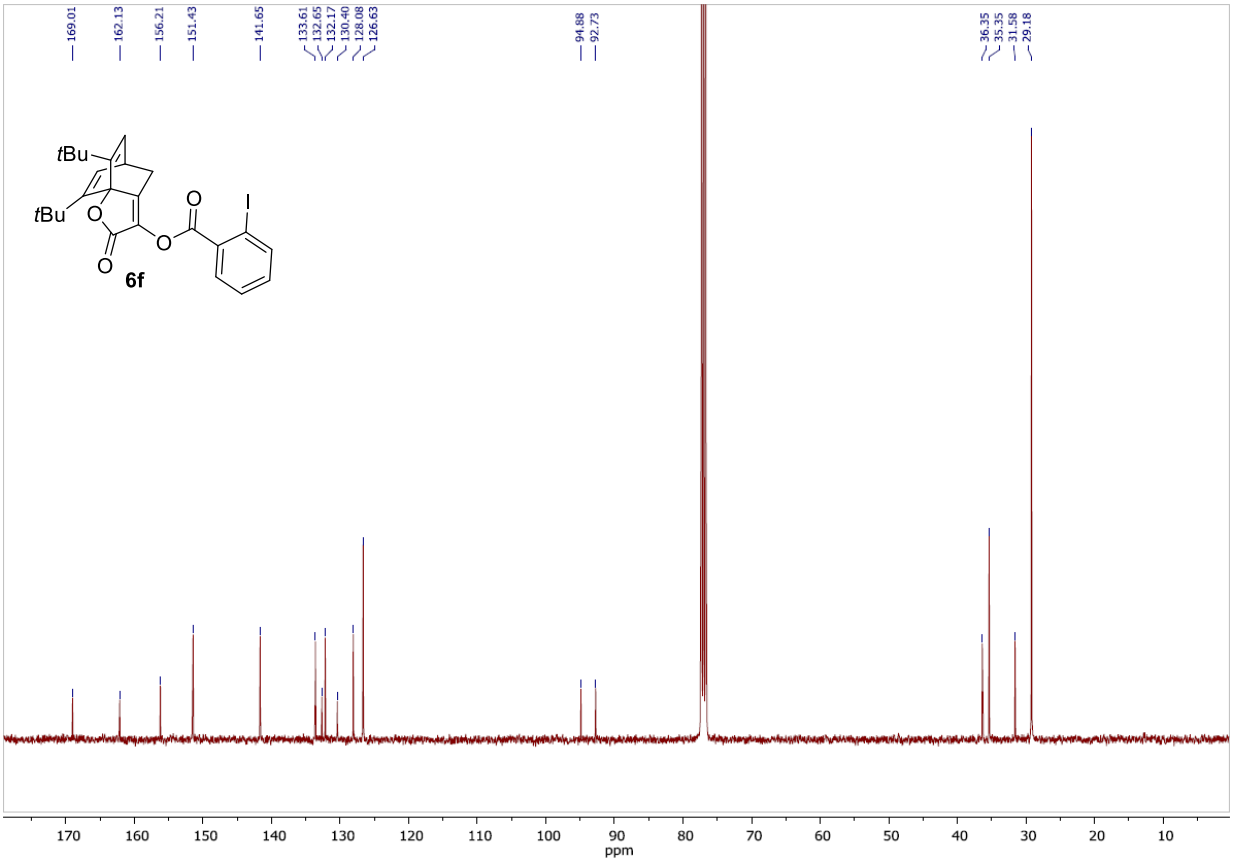
IR of compound **6e**



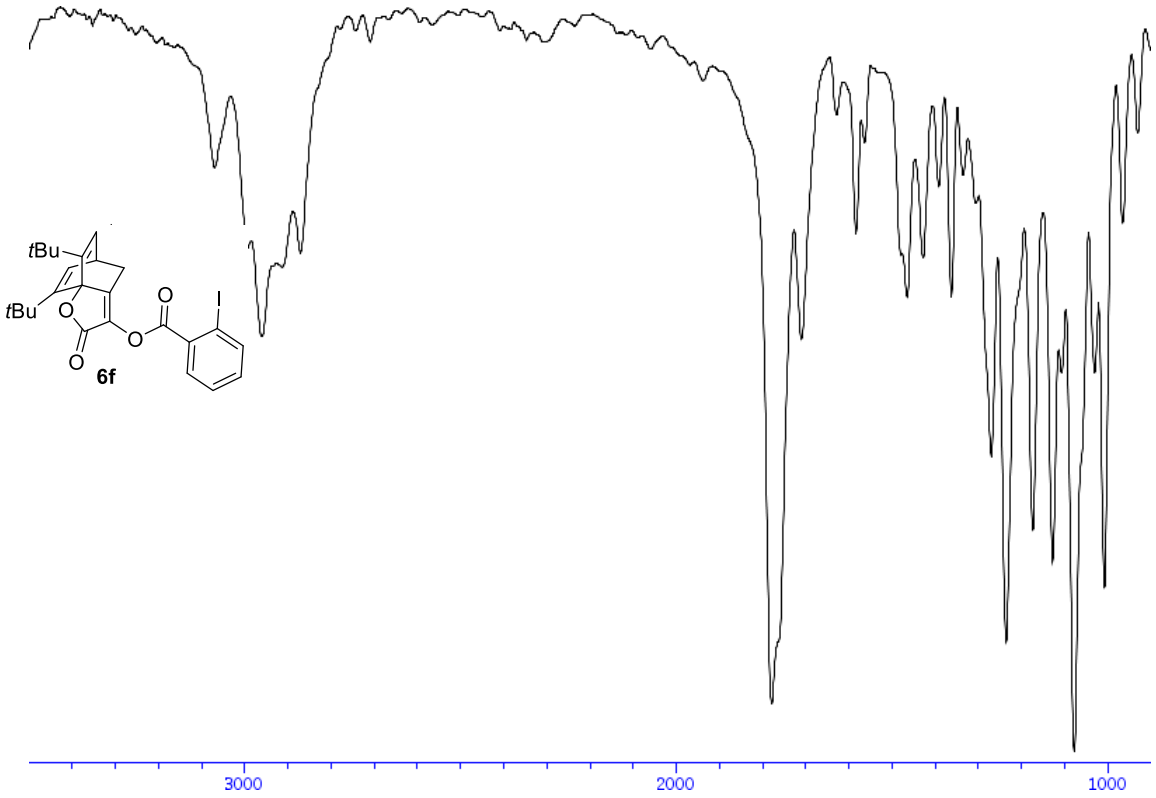
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6f**



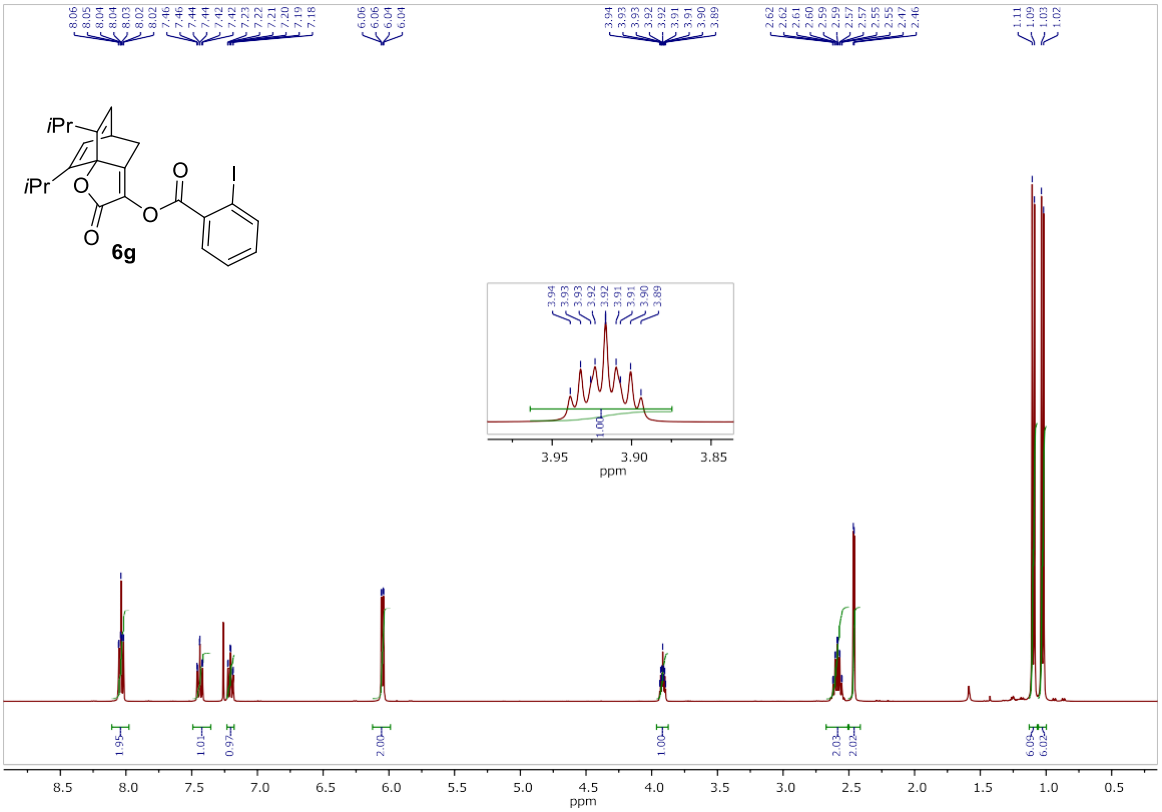
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6f**



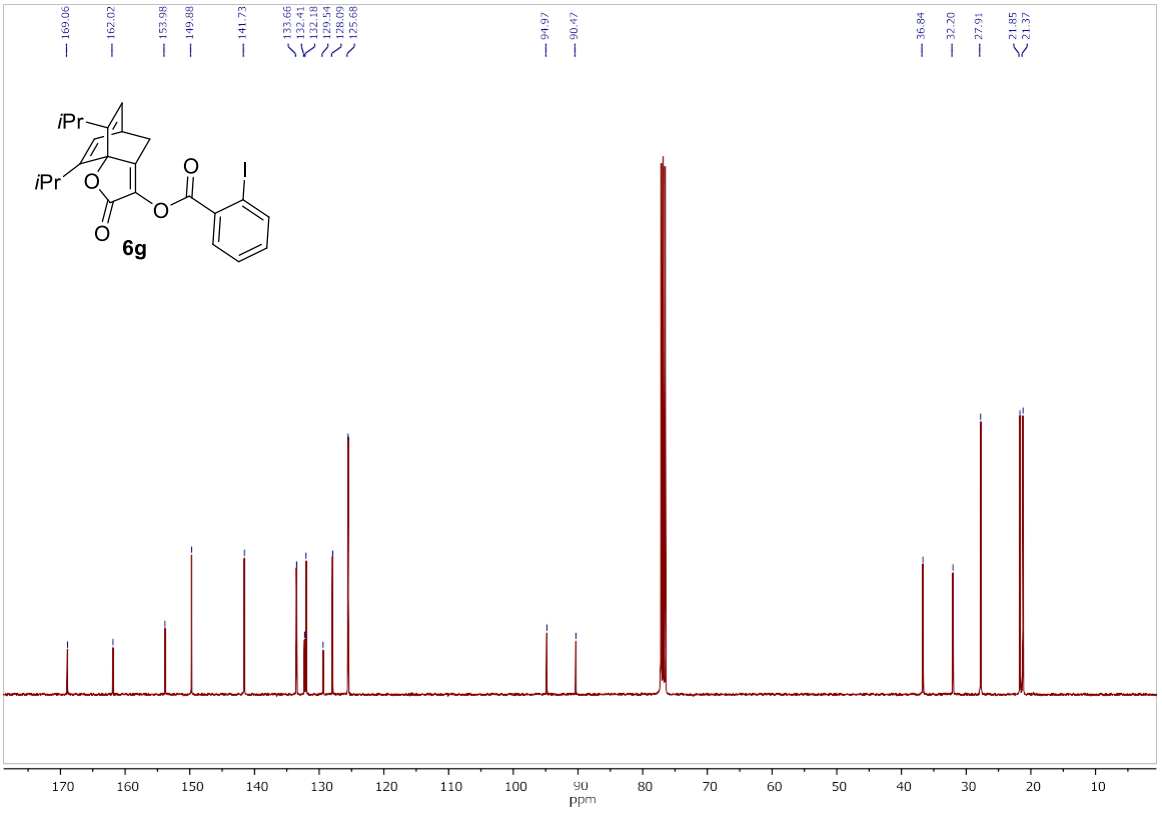
IR of compound **6f**



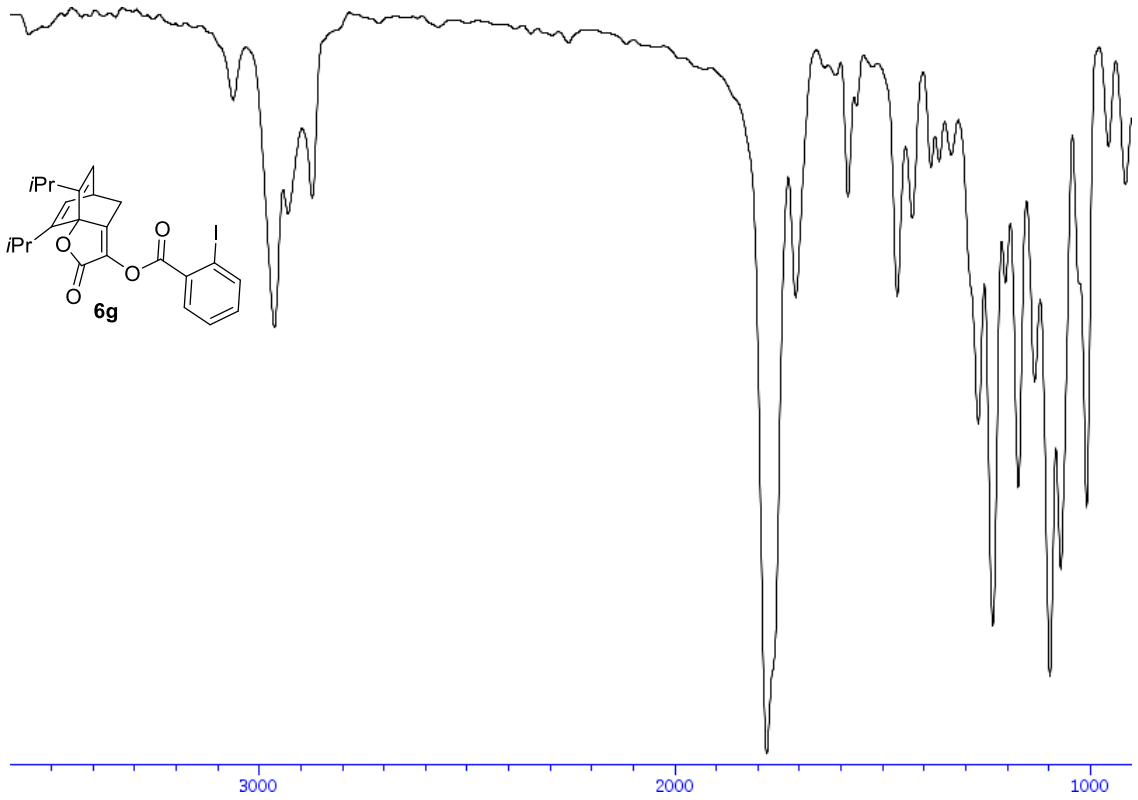
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6g**



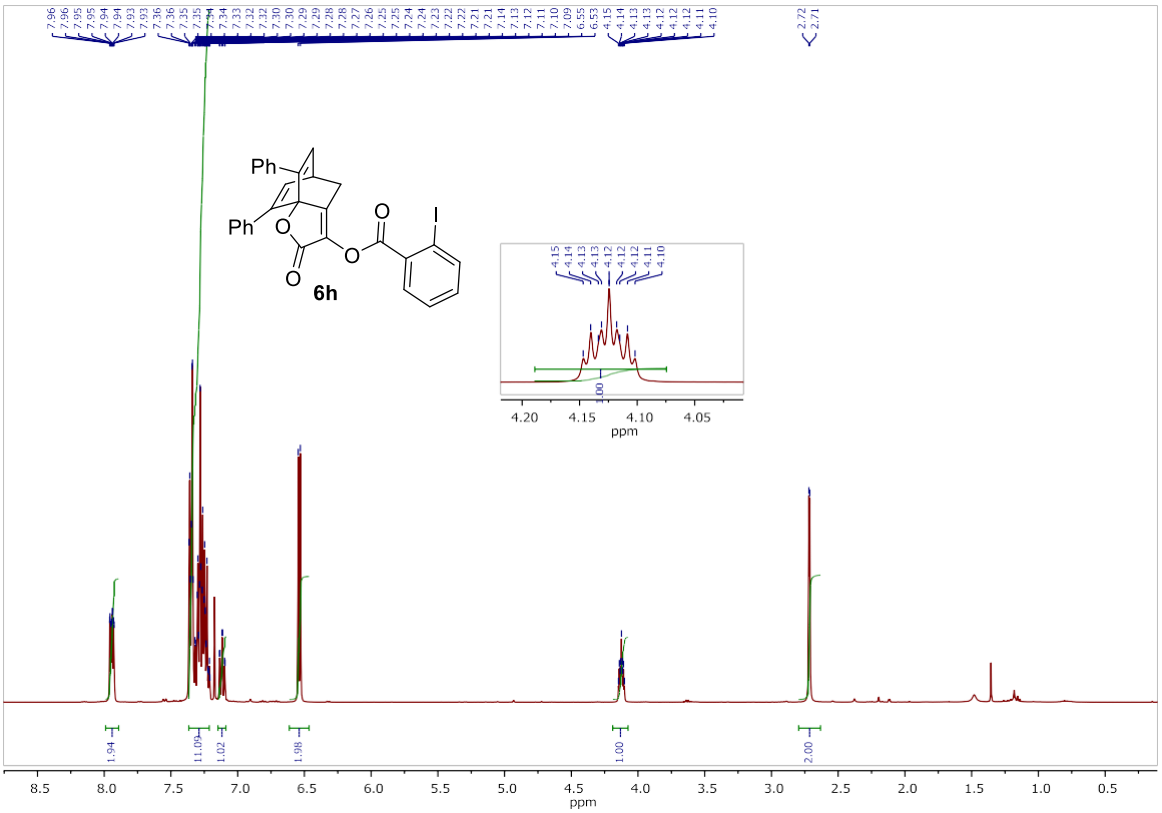
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6g**



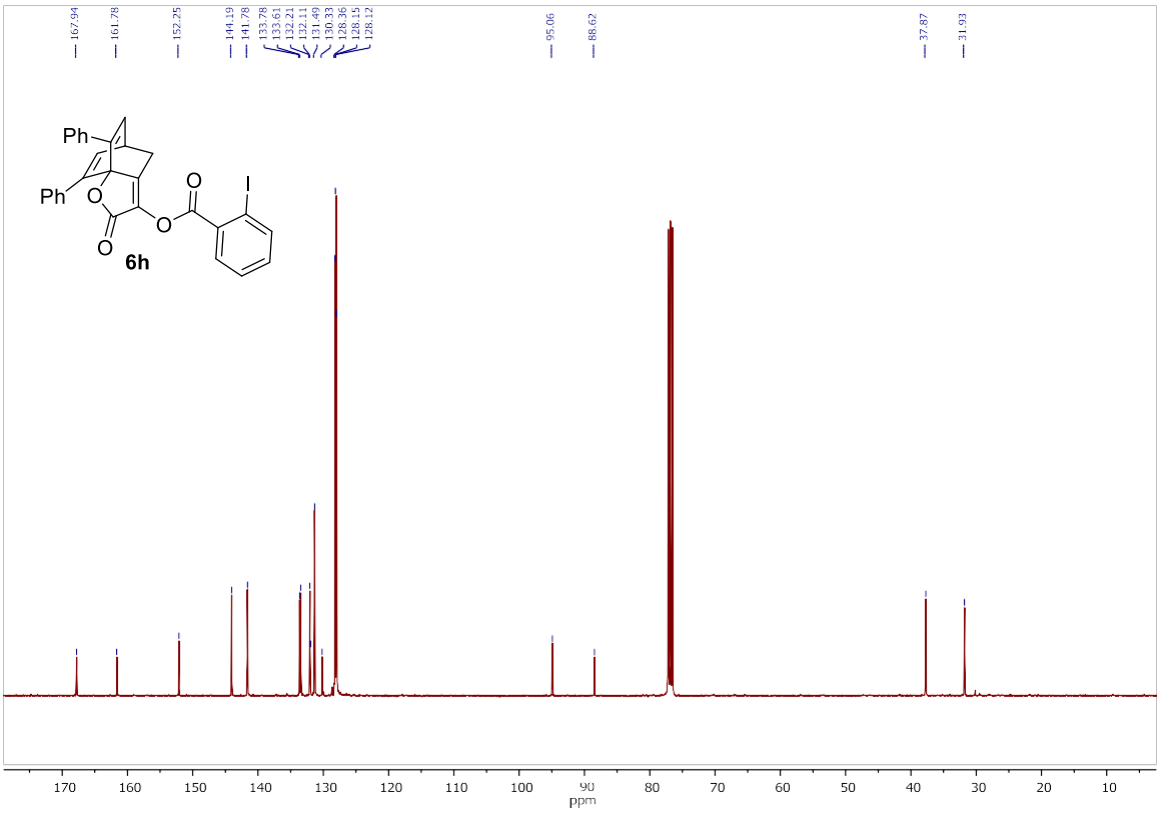
IR of compound **6g**



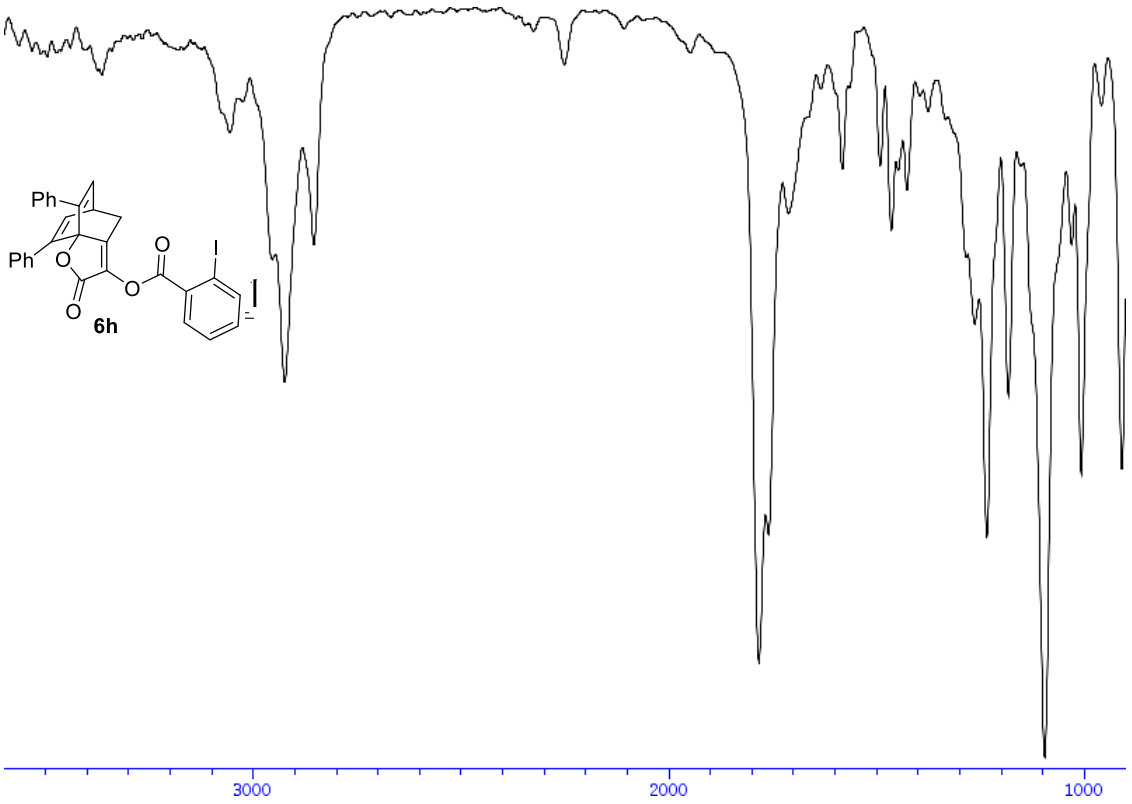
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6h**



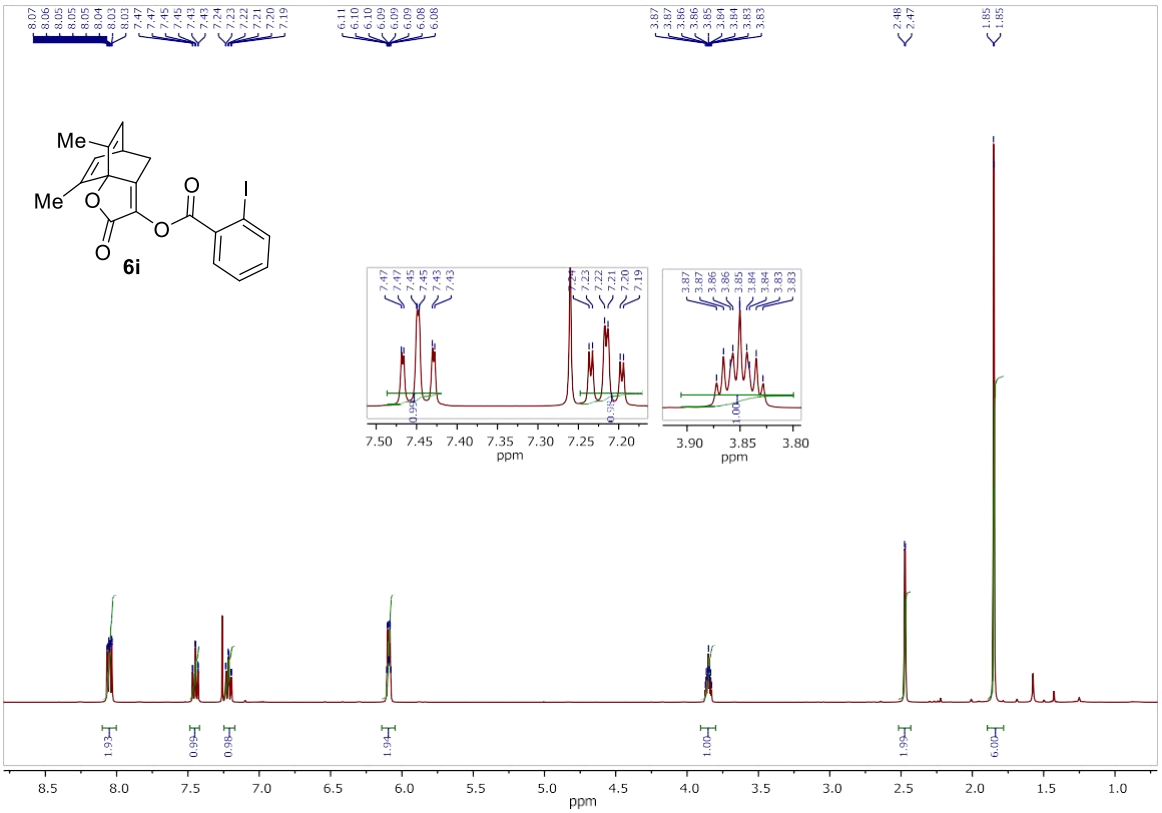
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6h**



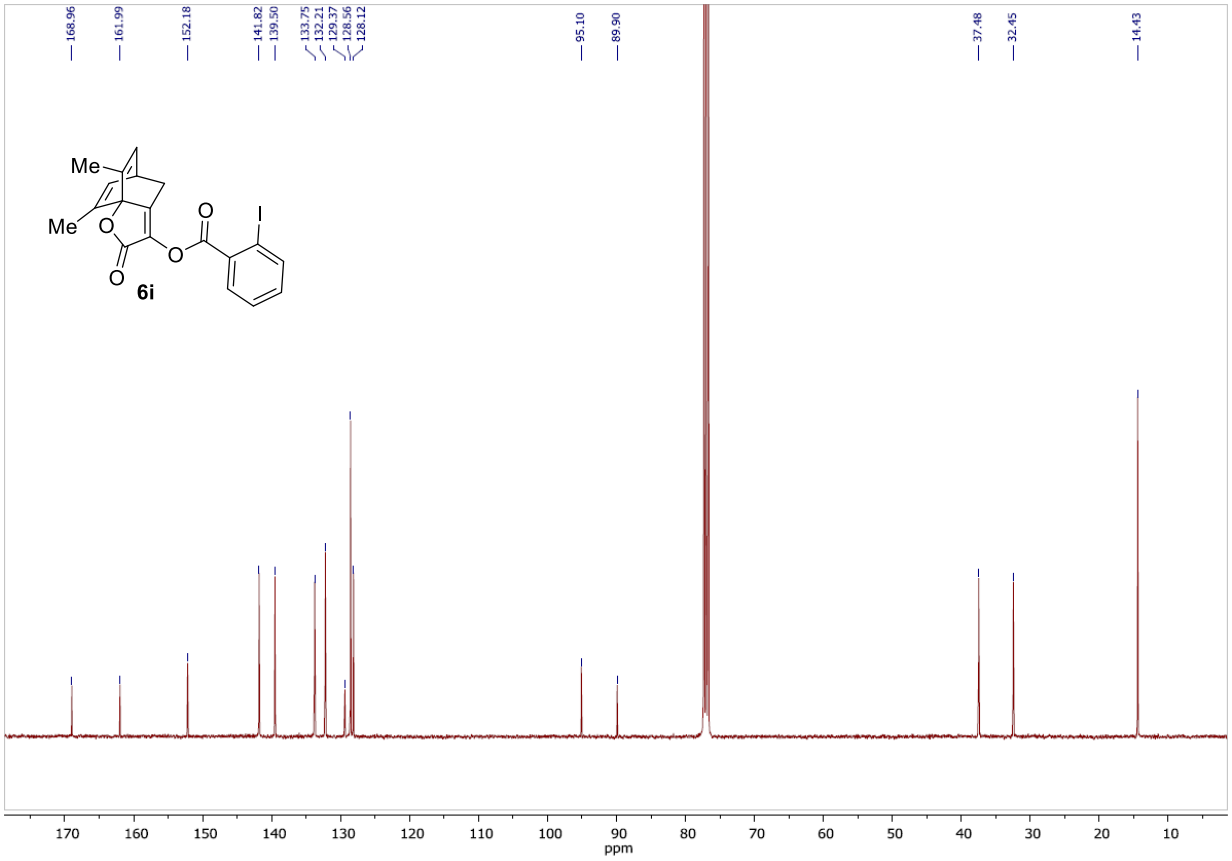
IR of compound **6h**



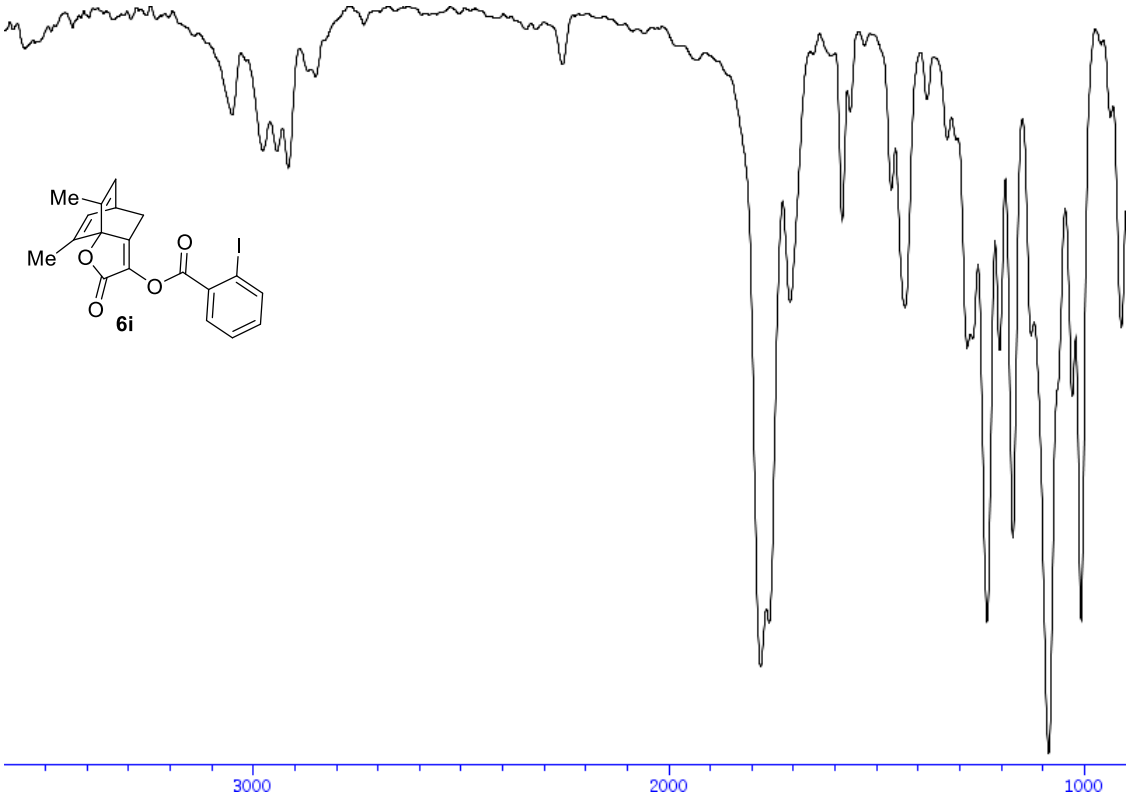
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6i**



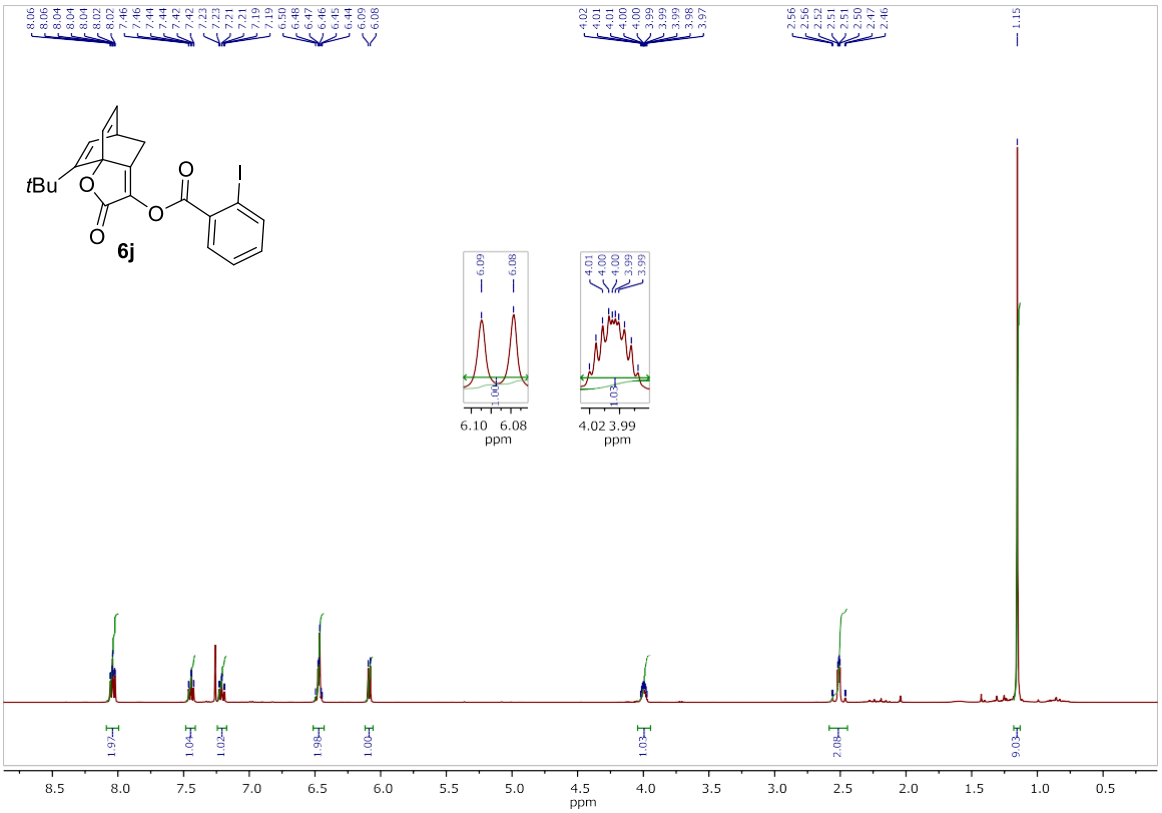
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6i**



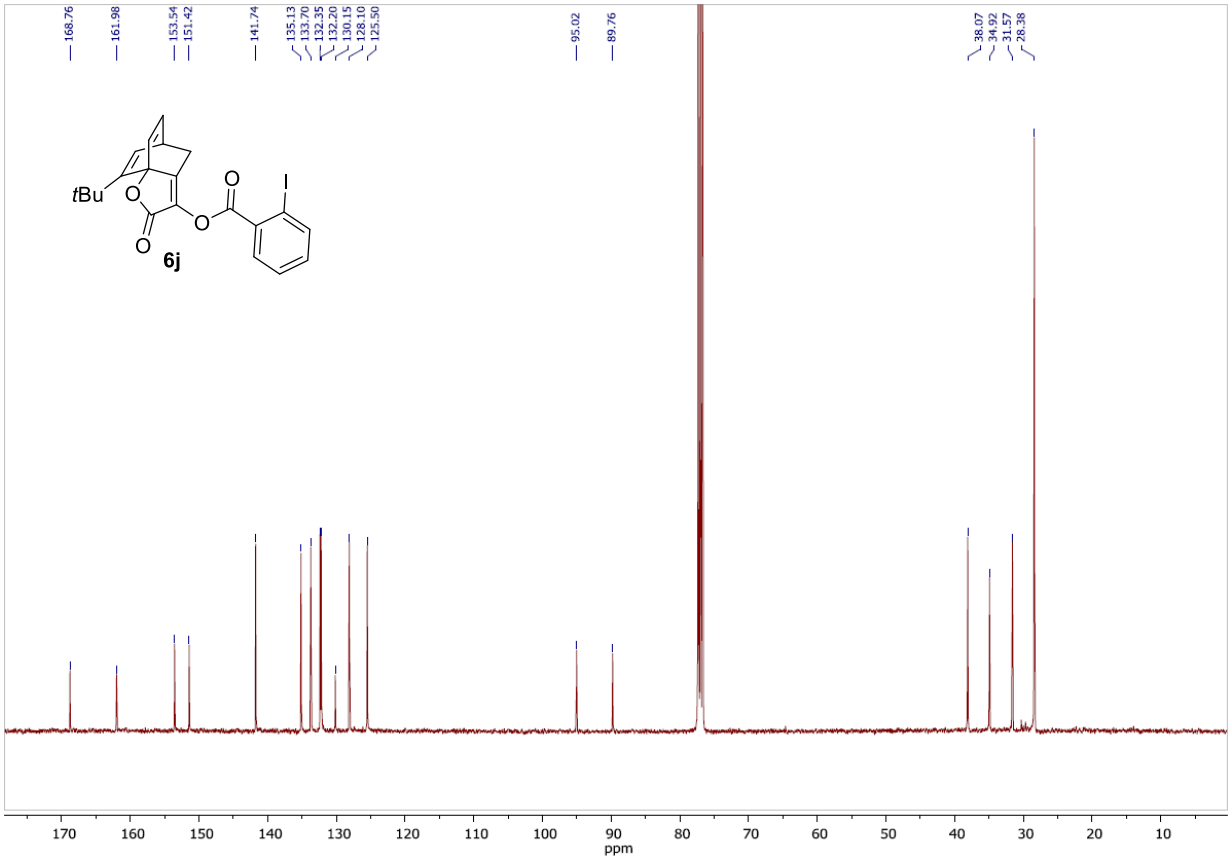
IR of compound **6i**



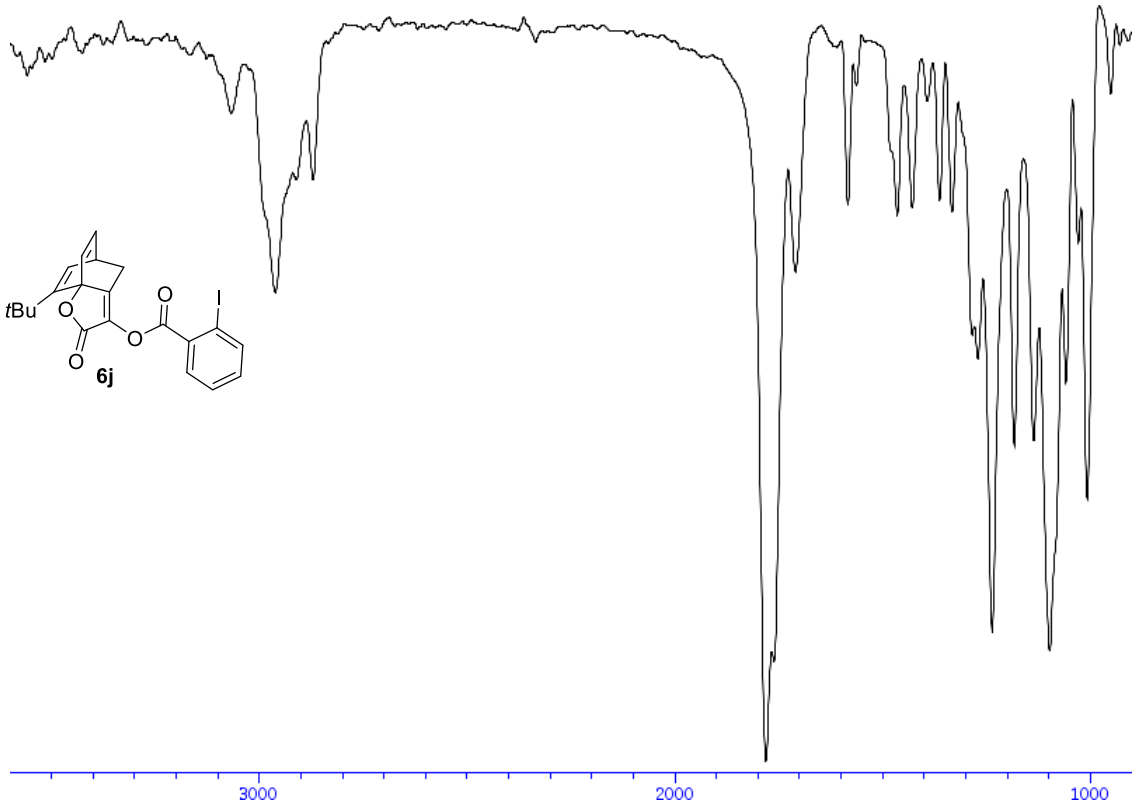
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6j**



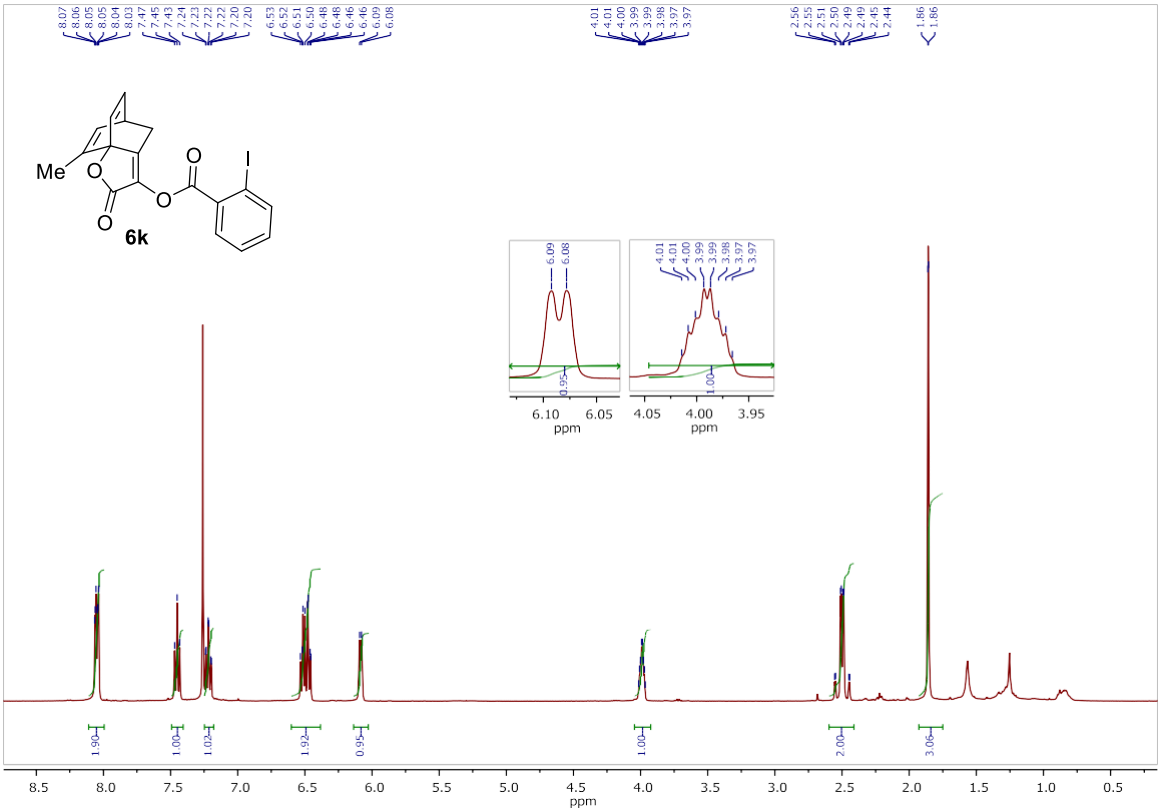
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6j**



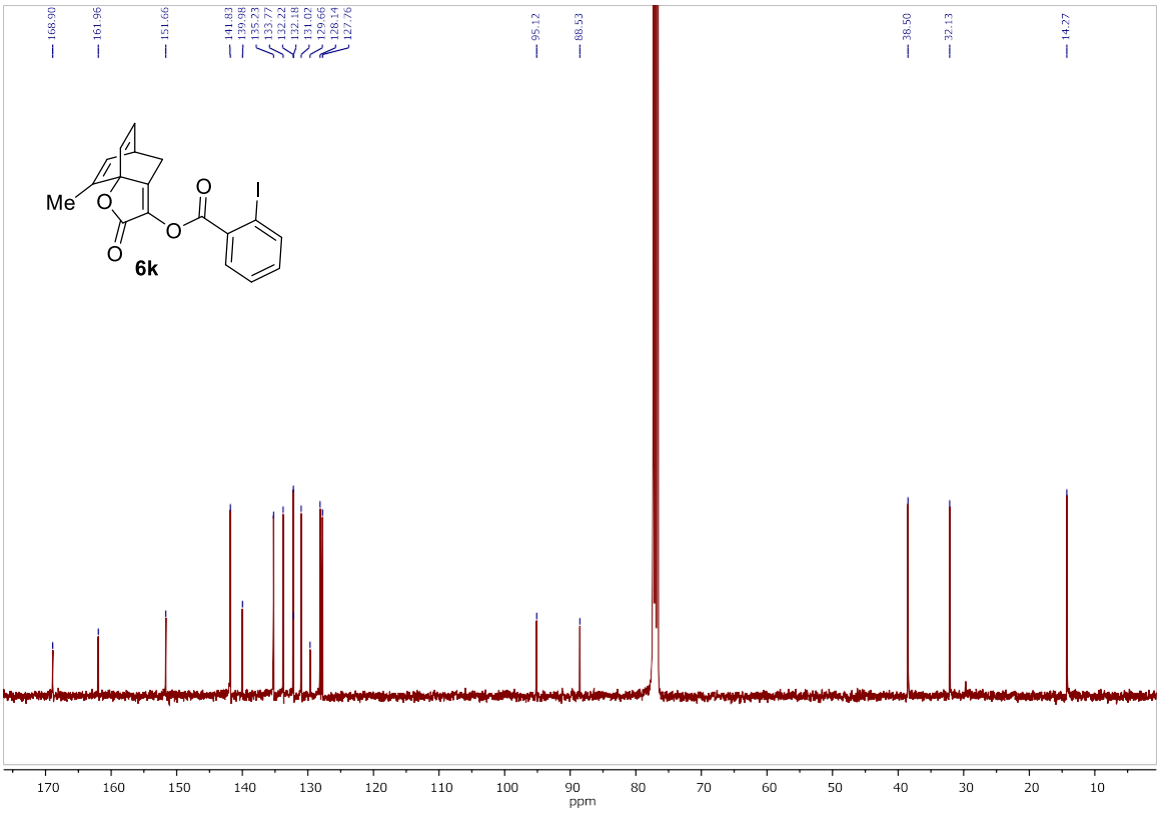
IR of compound **6j**



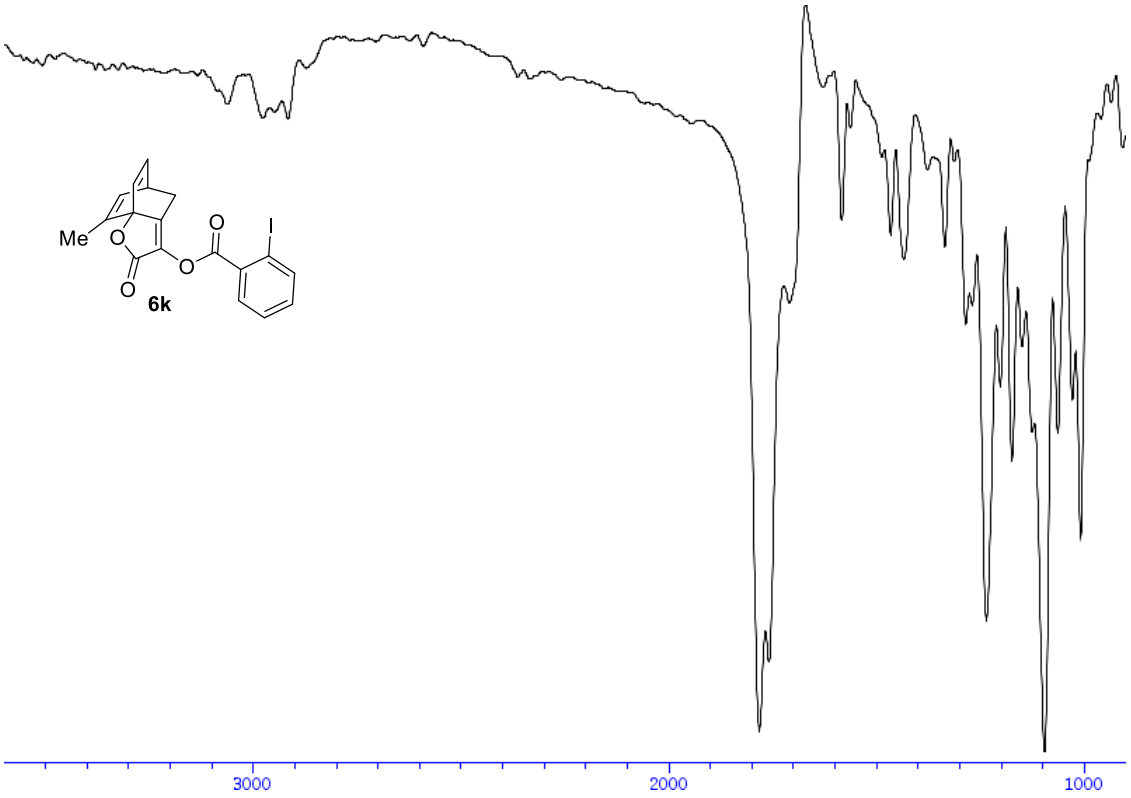
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6k**



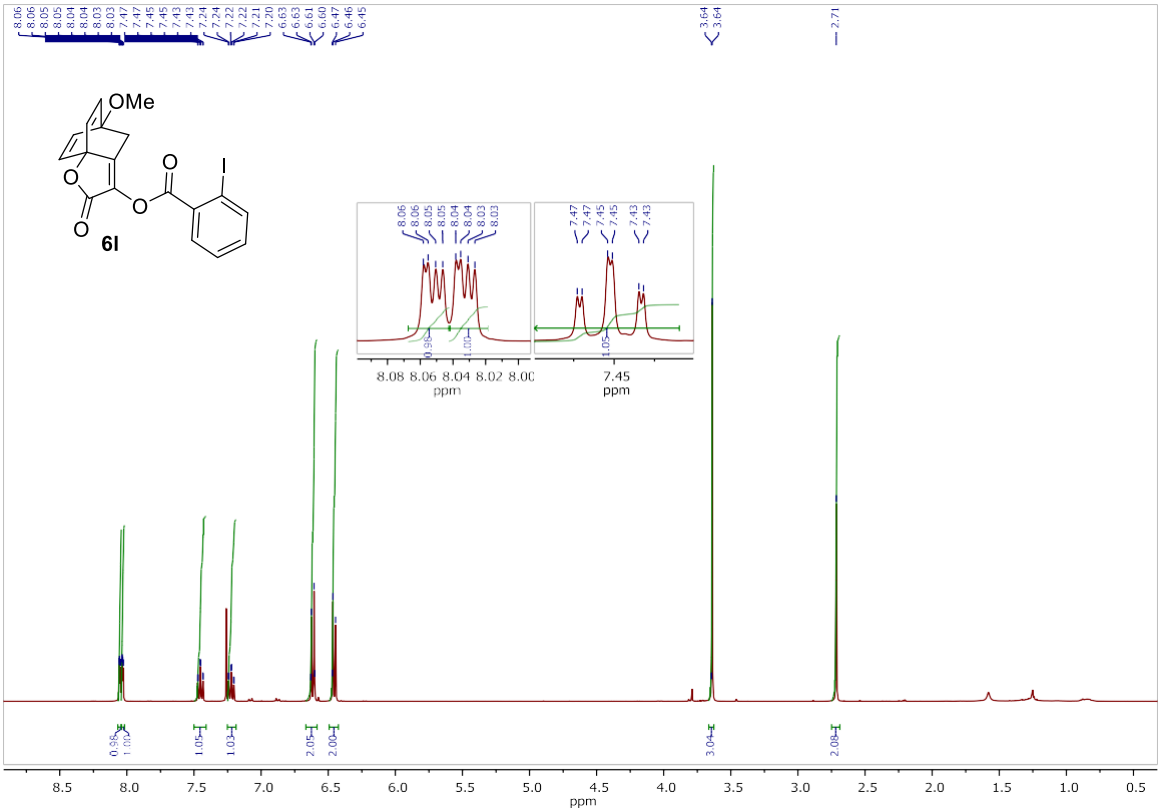
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6k**



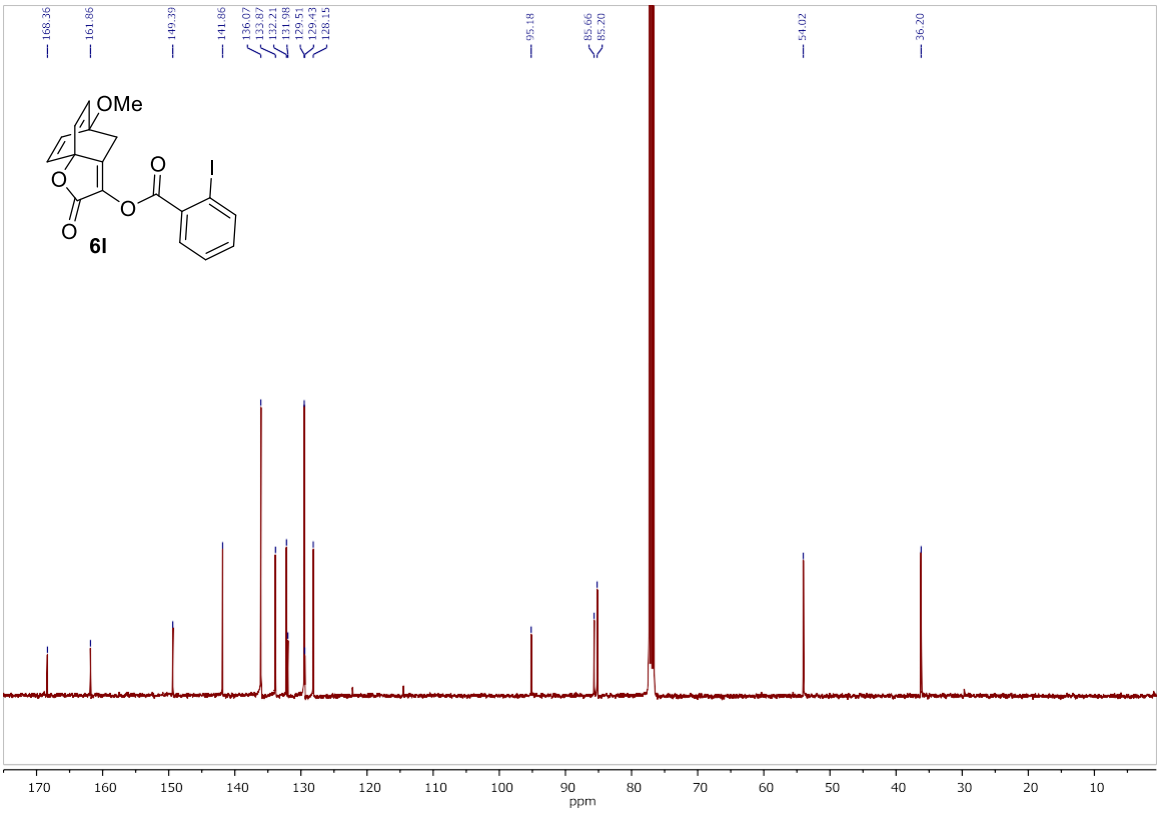
IR of compound **6k**



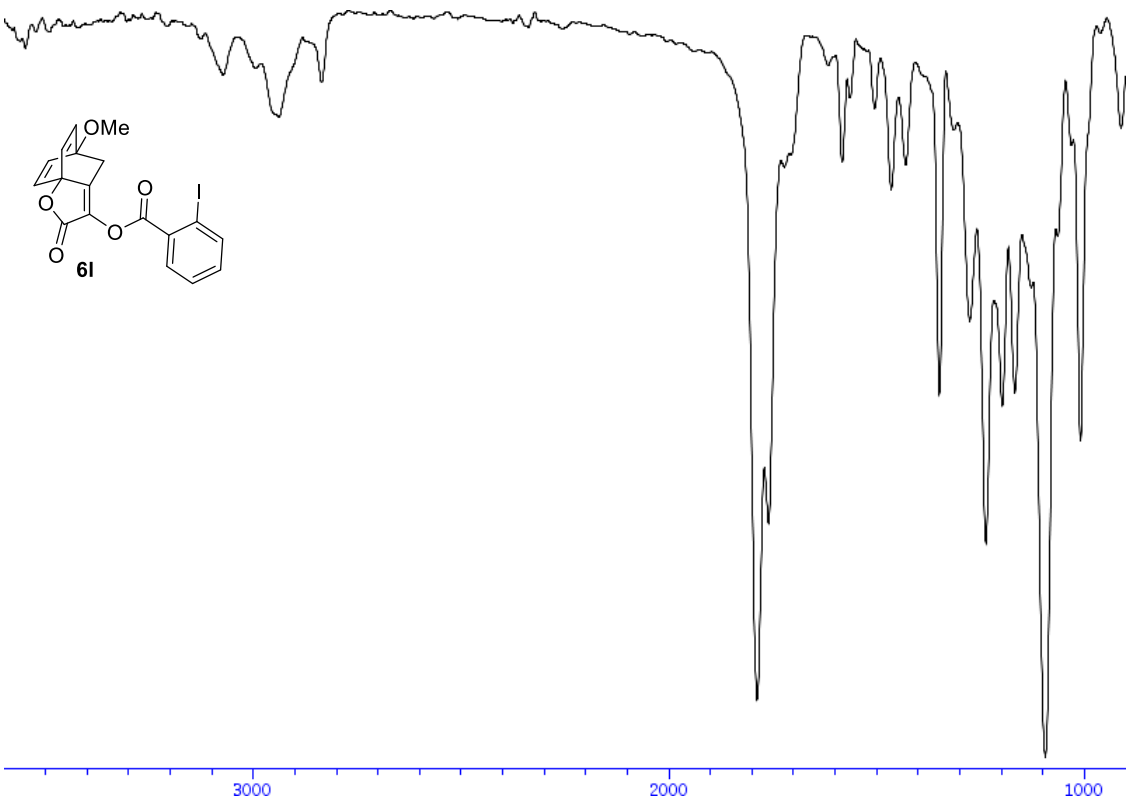
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6l**



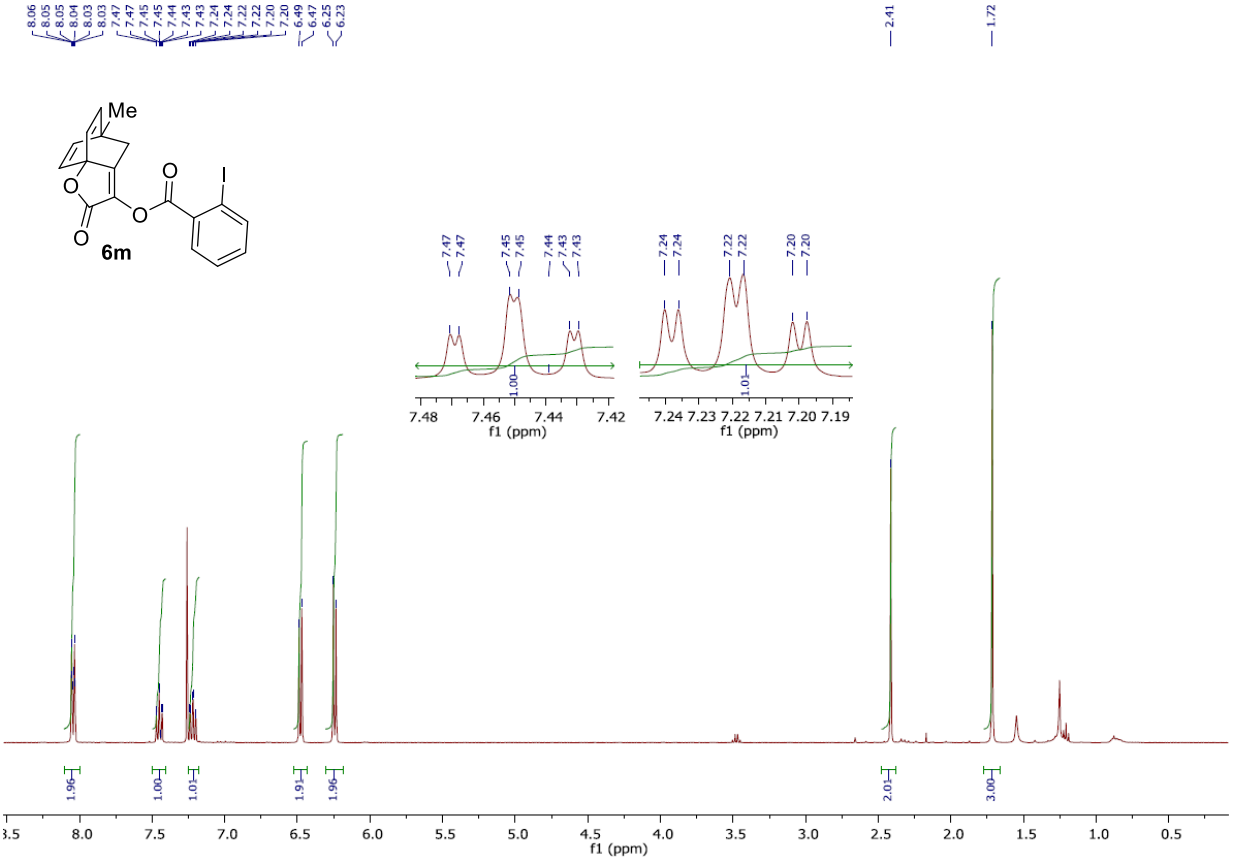
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6l**



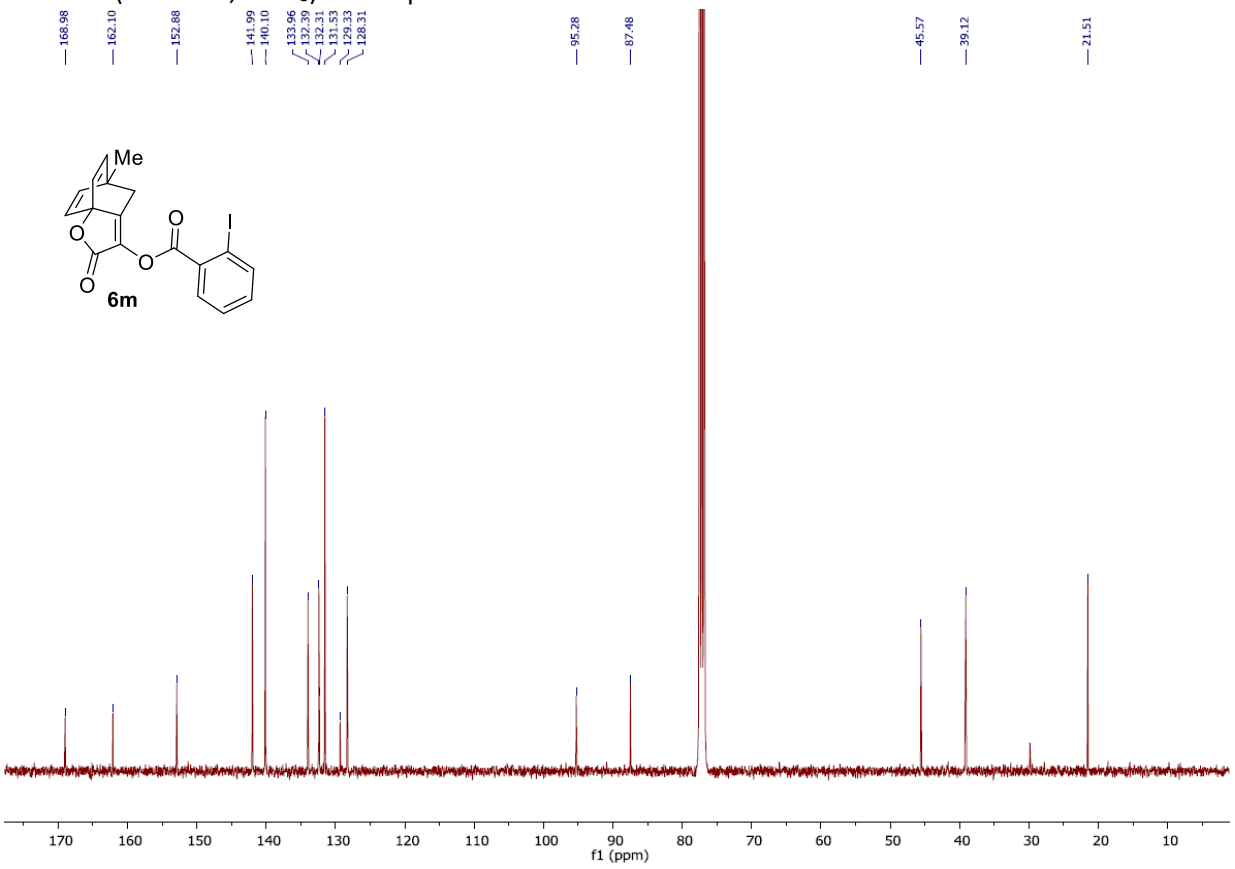
IR of compound **6l**



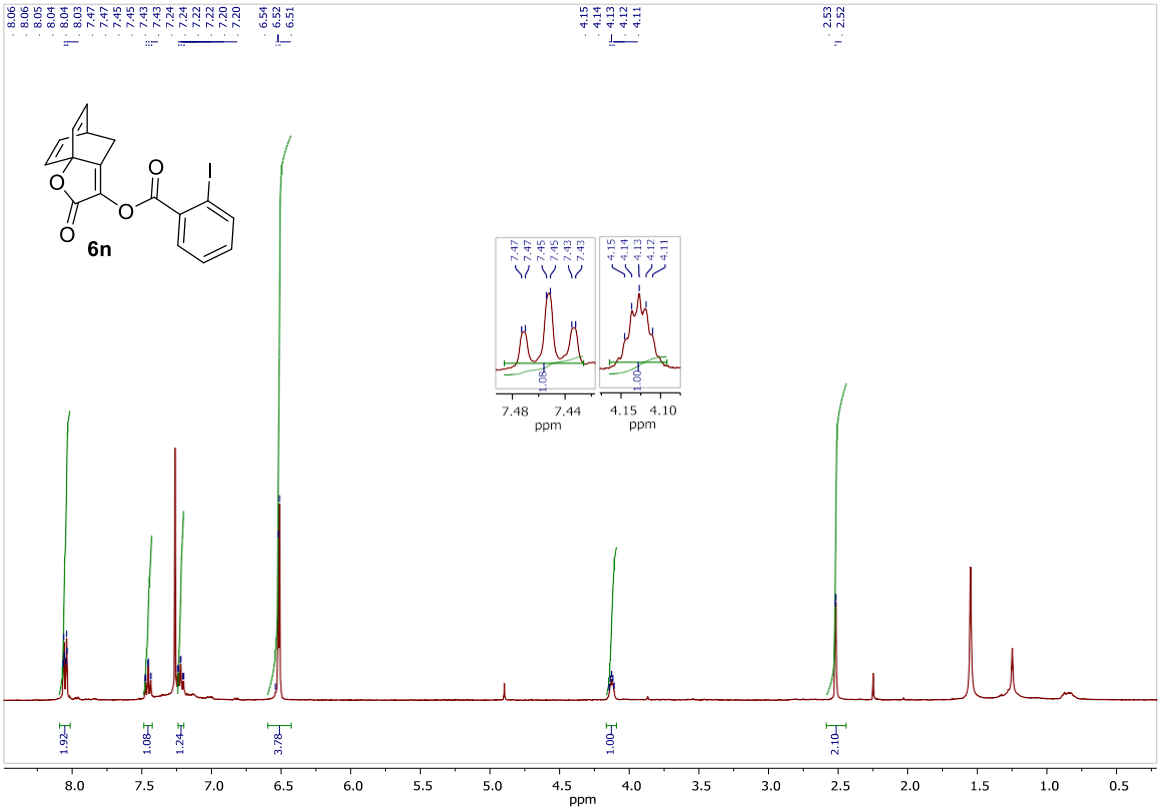
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6m**



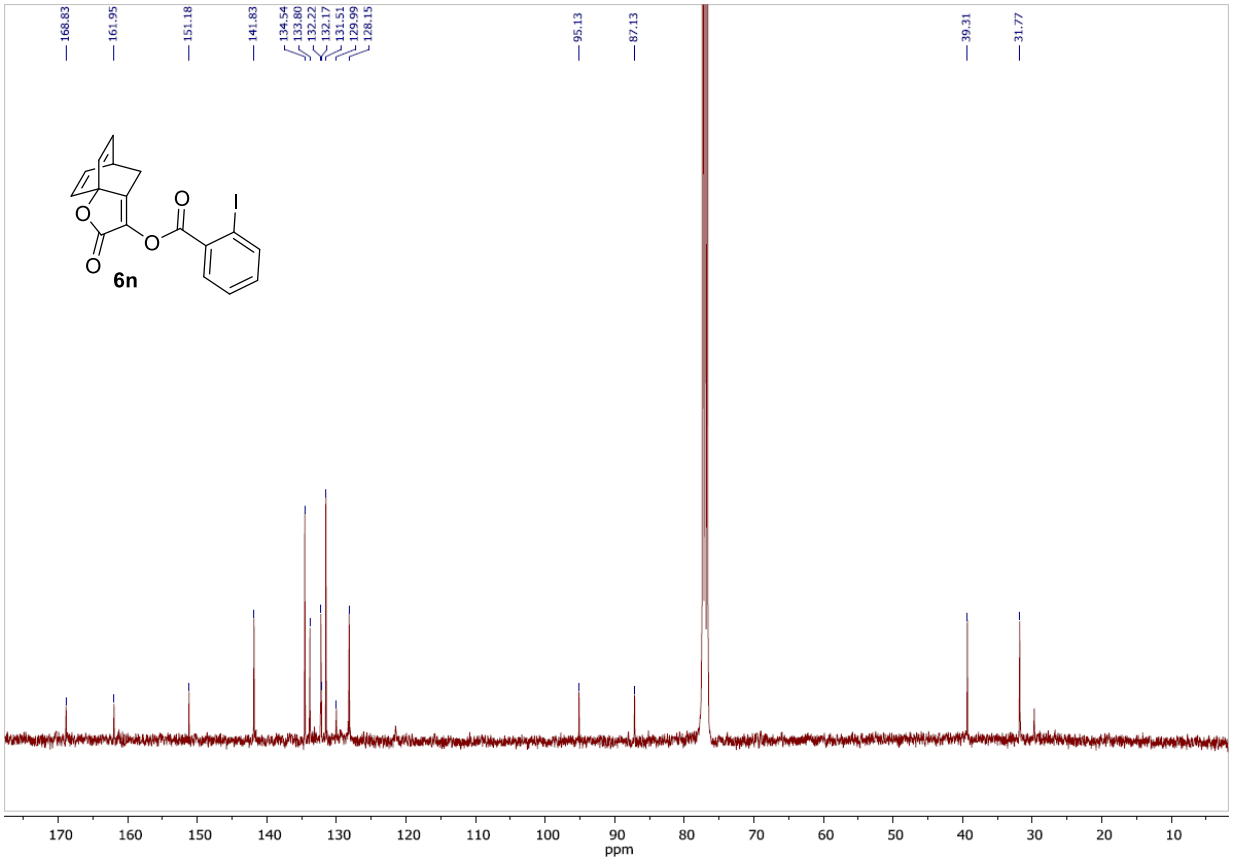
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6m**



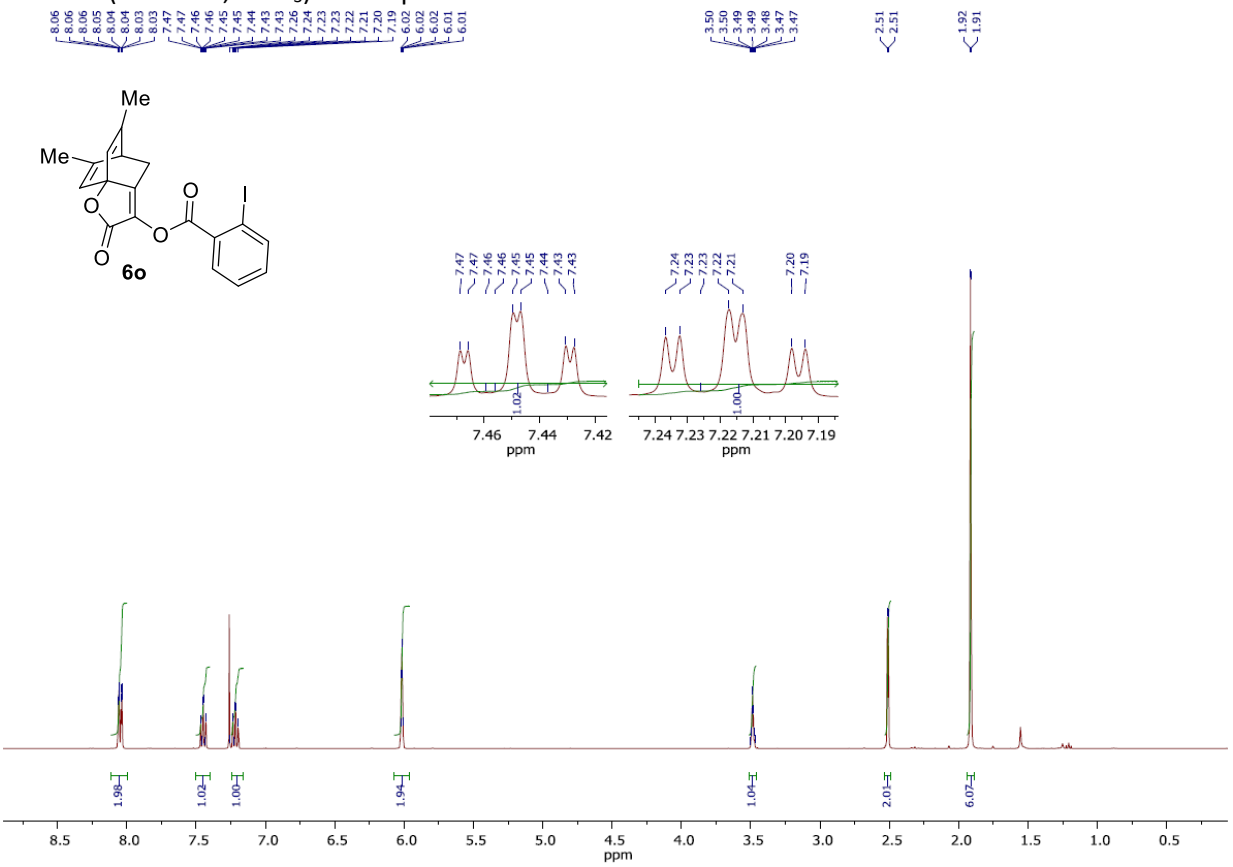
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6n**



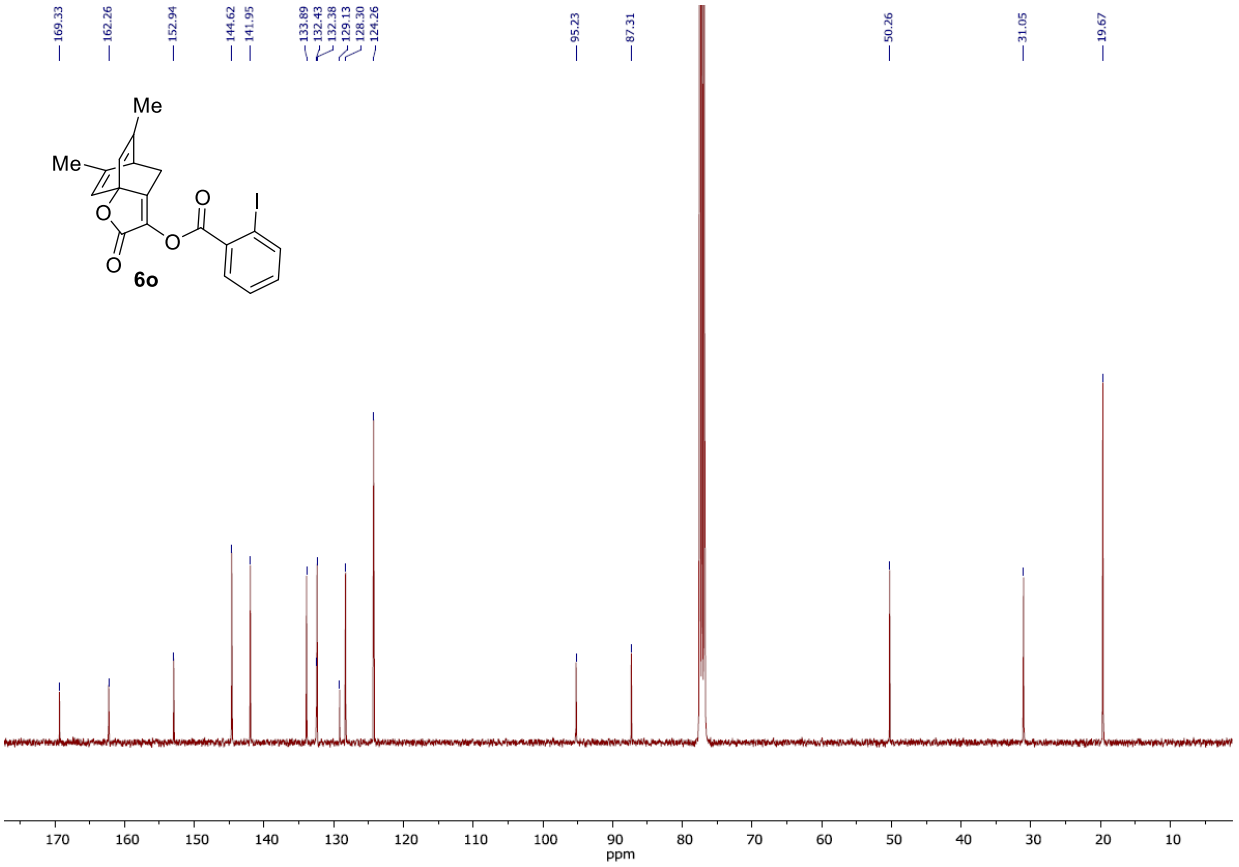
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6n**



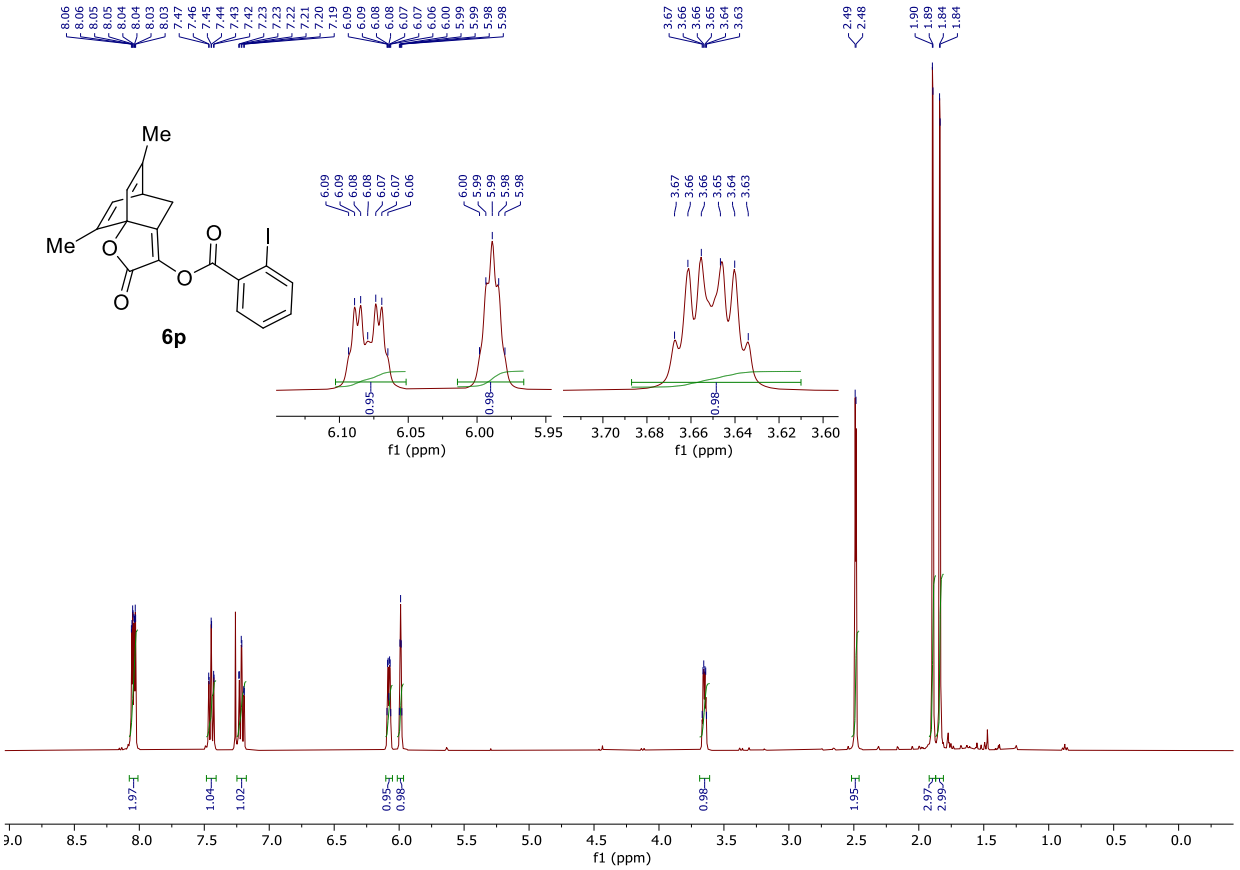
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6o**



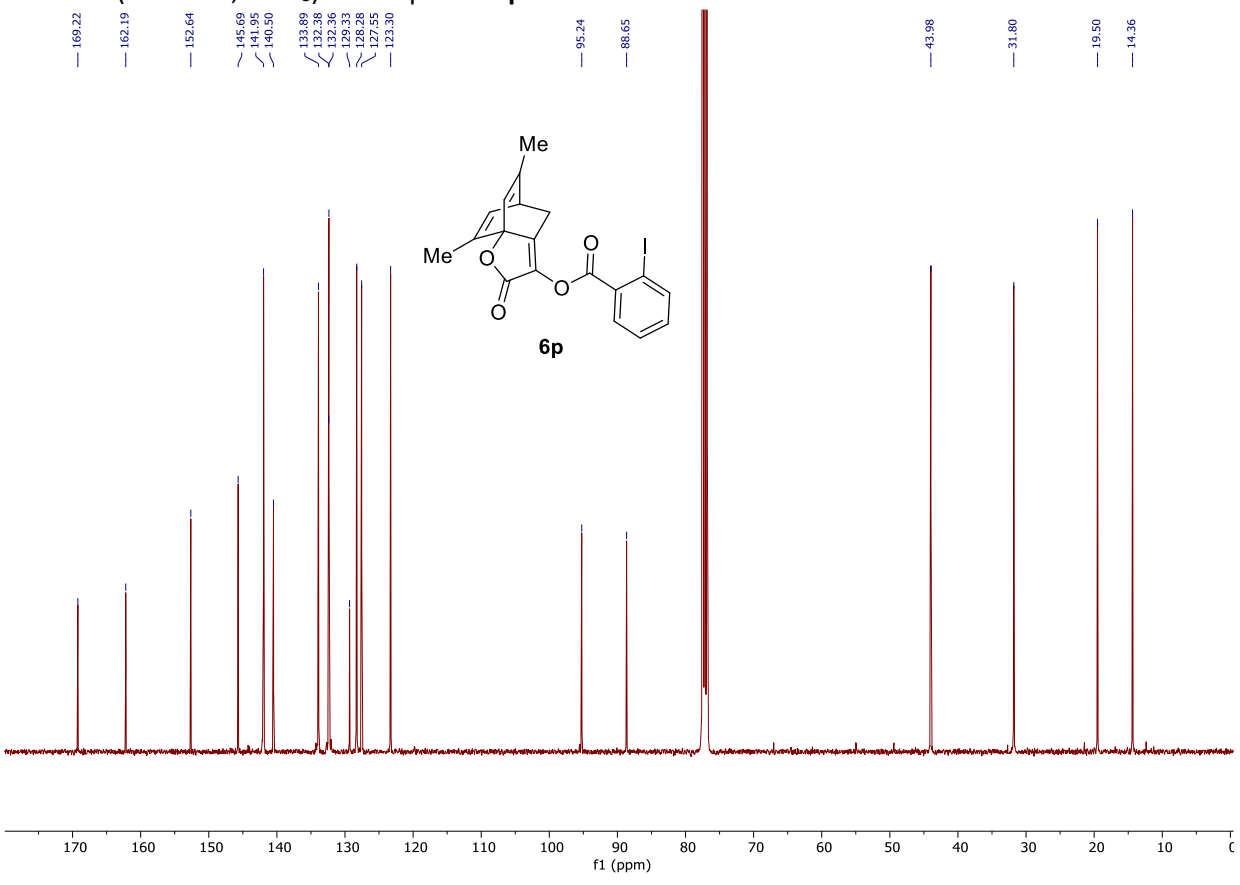
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6o**



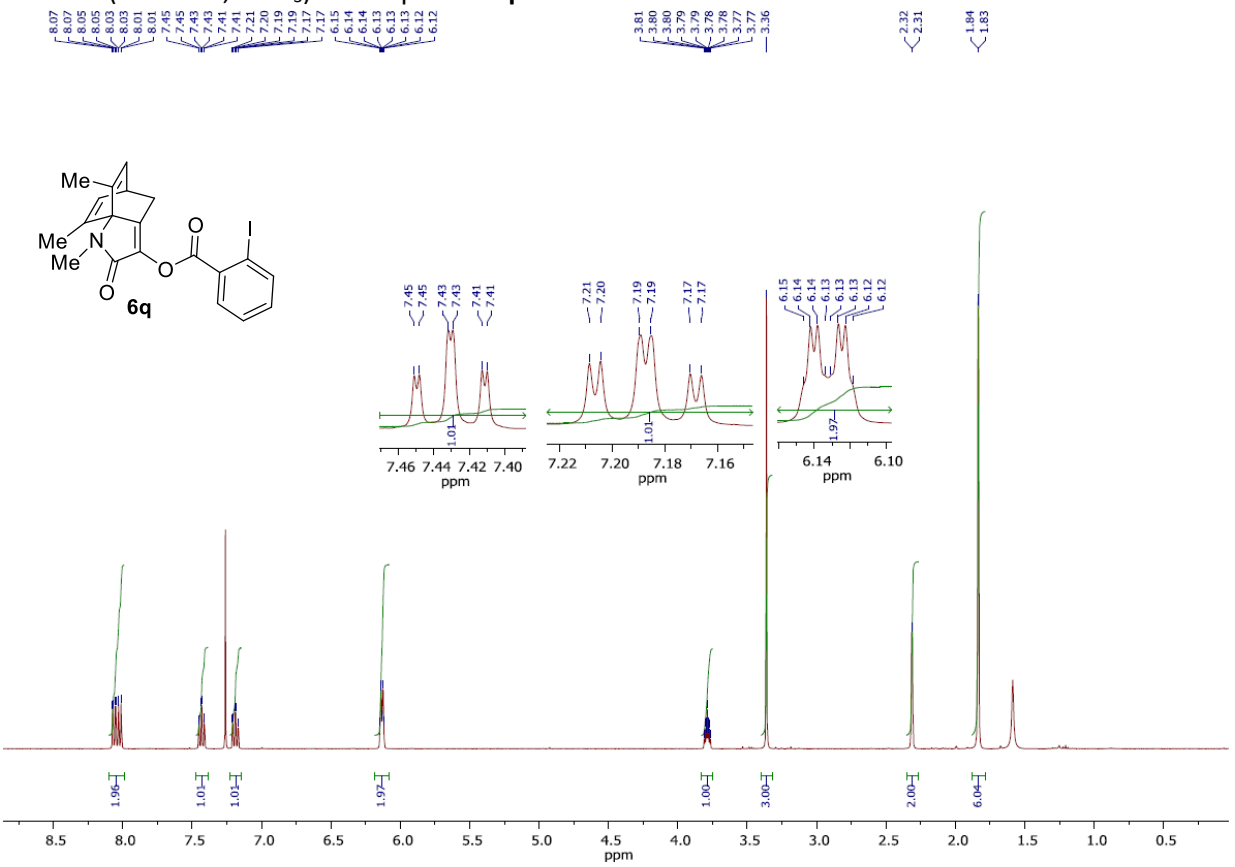
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6p**



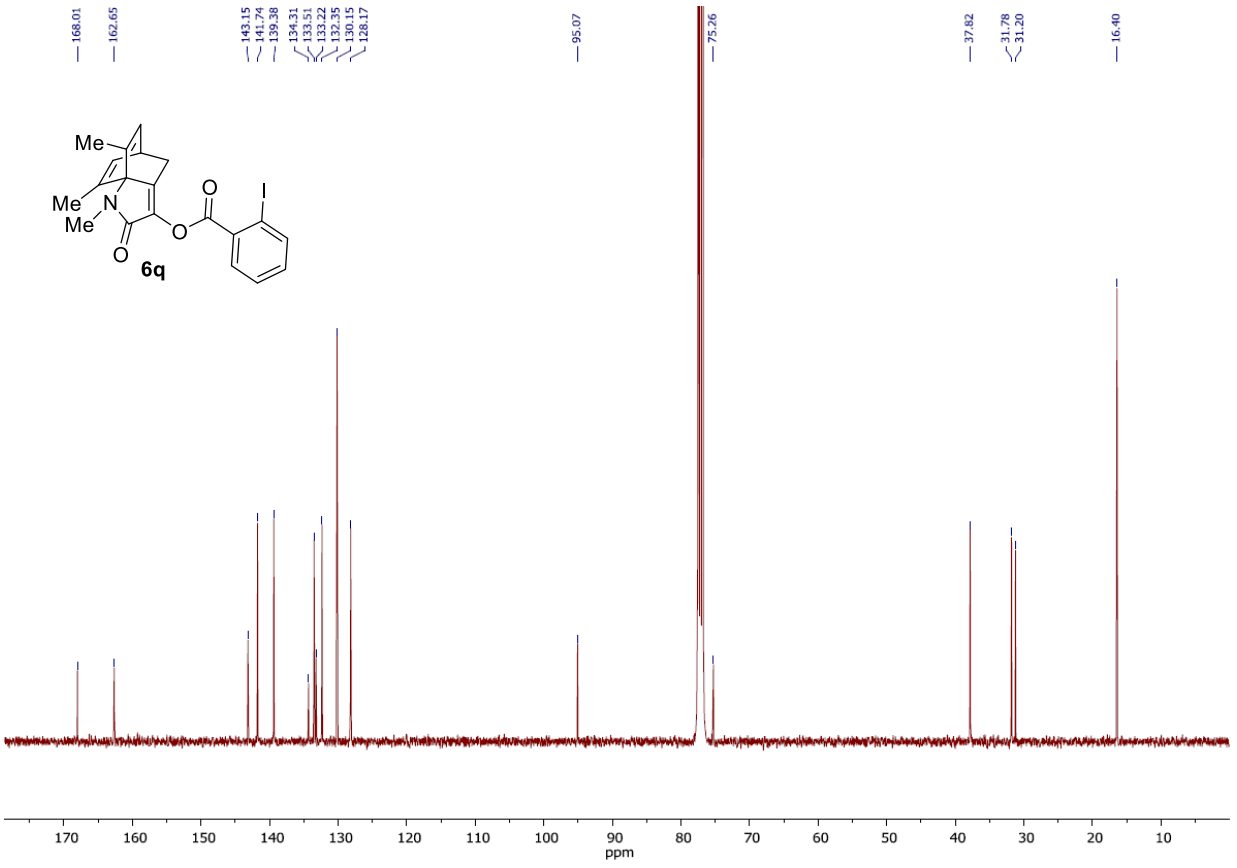
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6p**



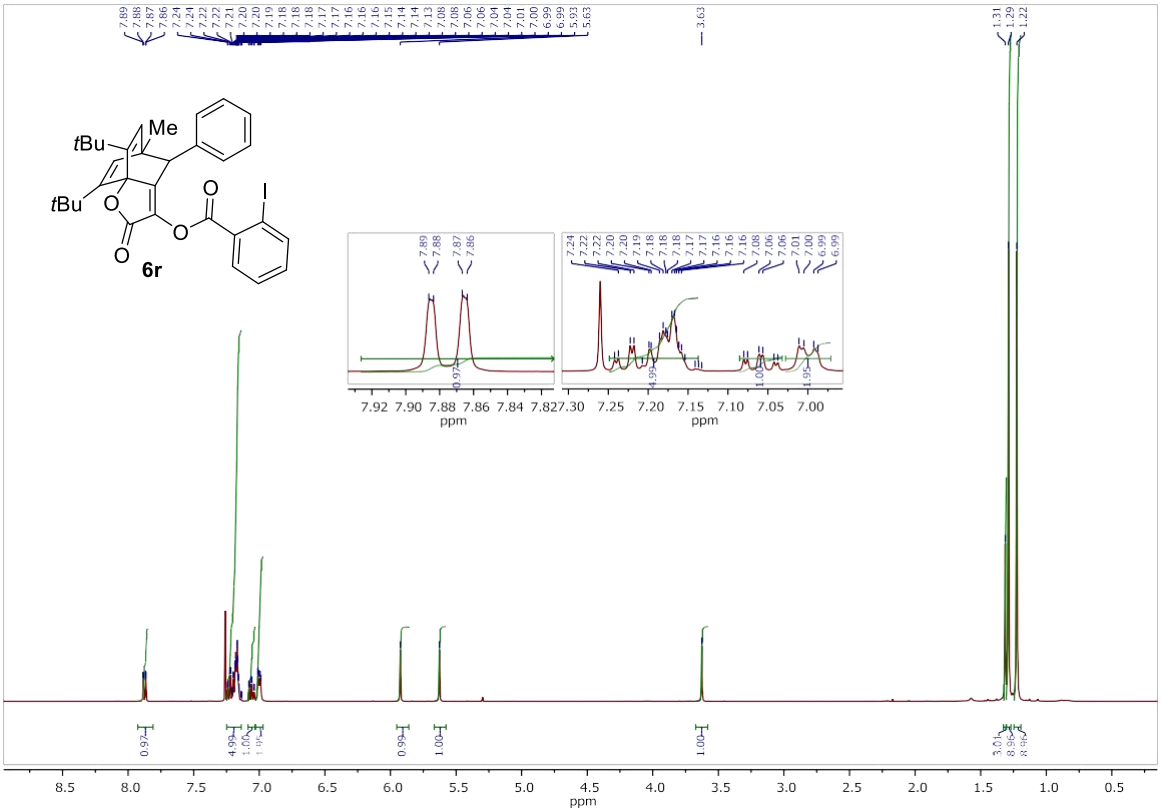
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6q**



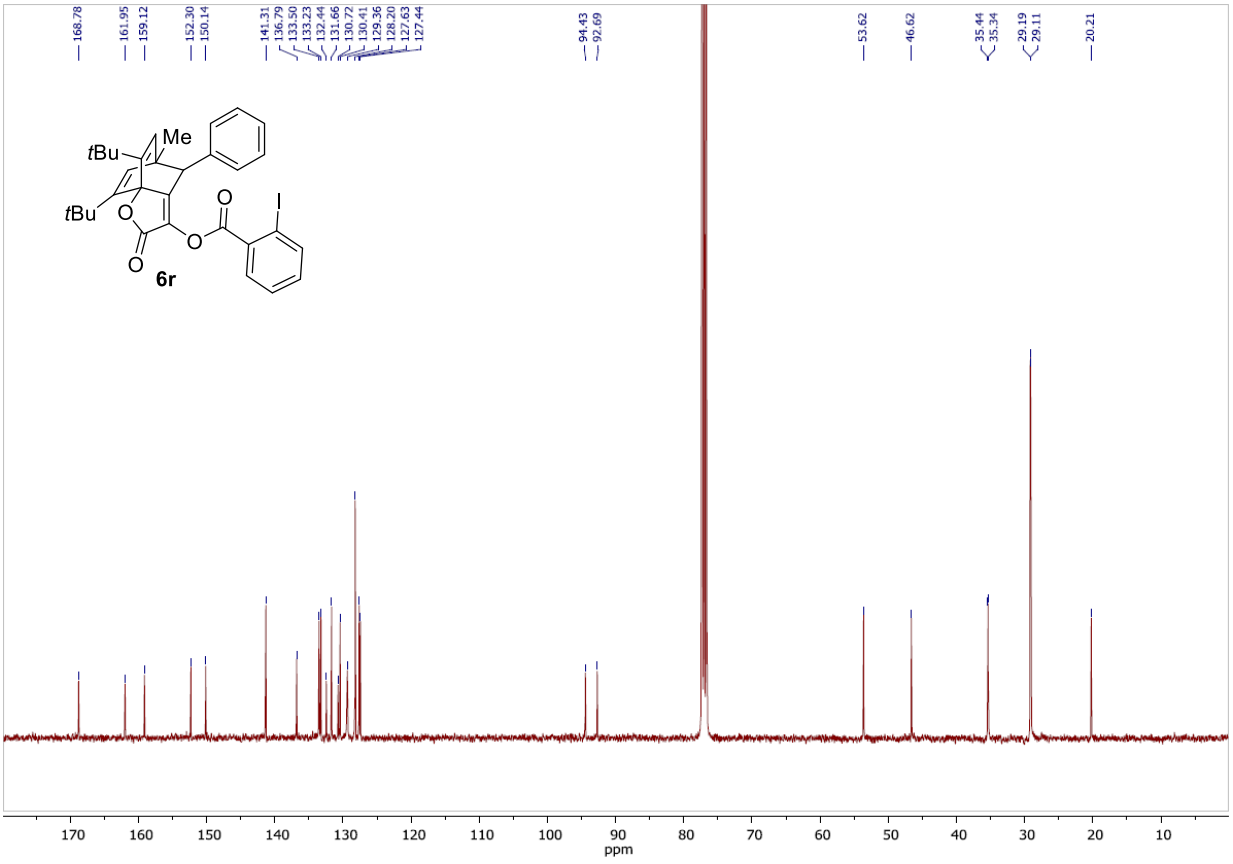
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6q**



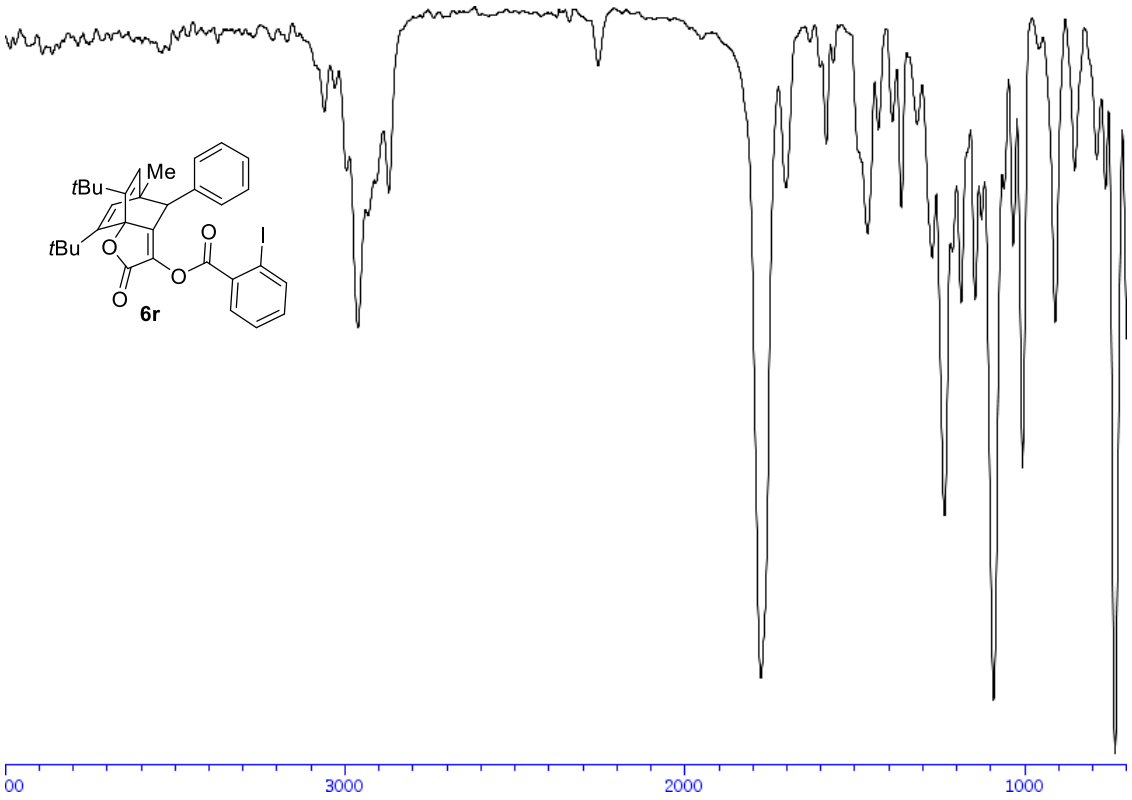
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6r**



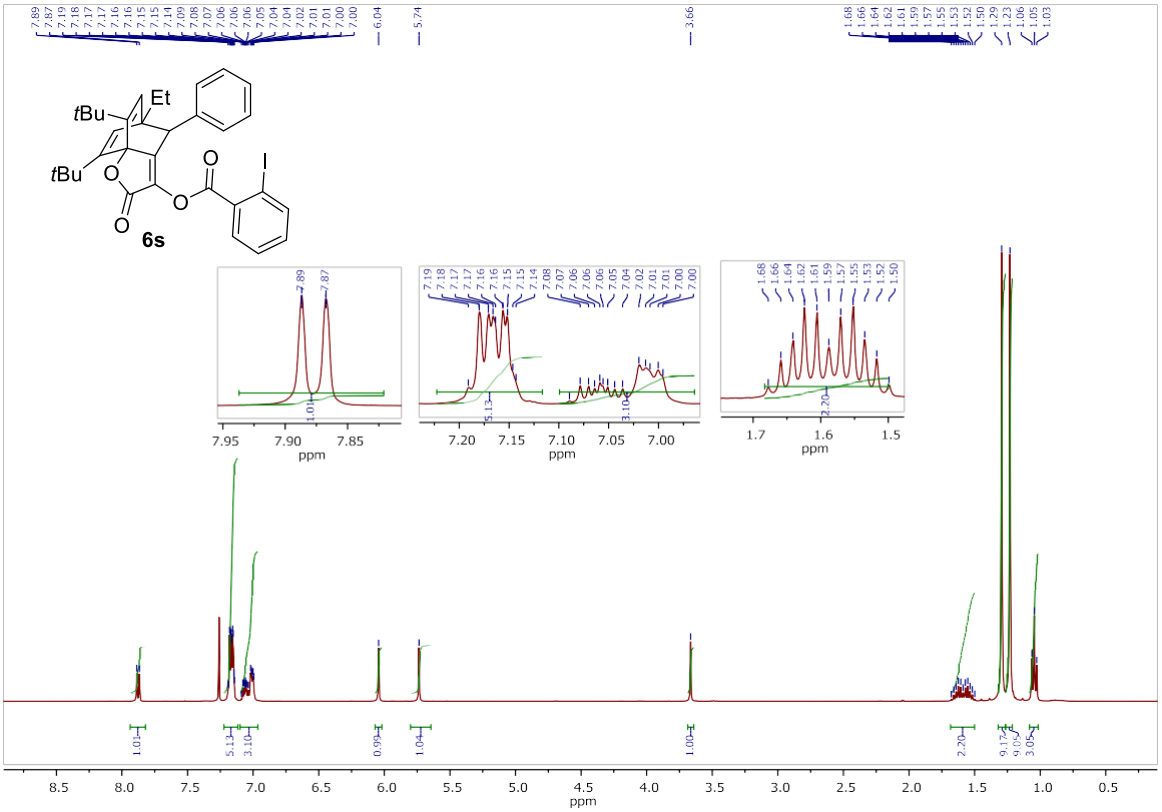
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6r**



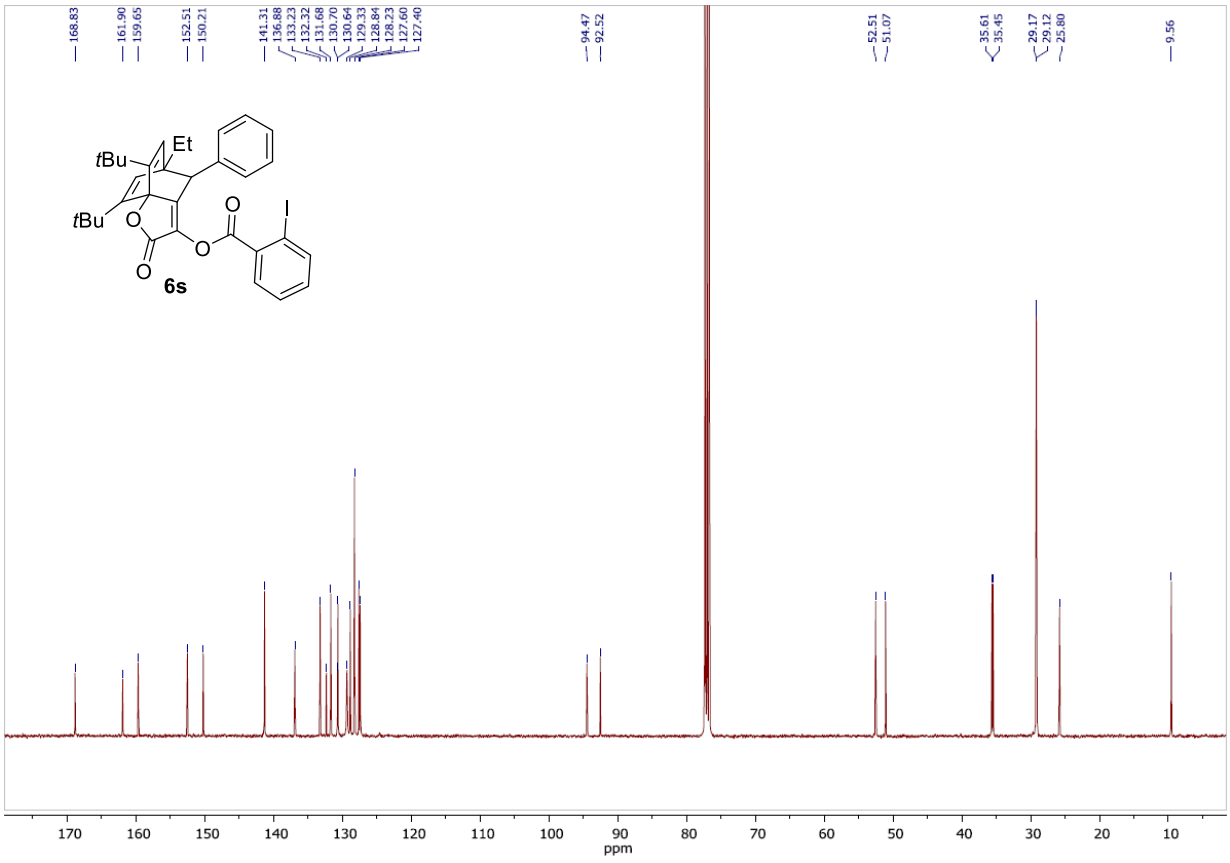
IR of compound **6r**



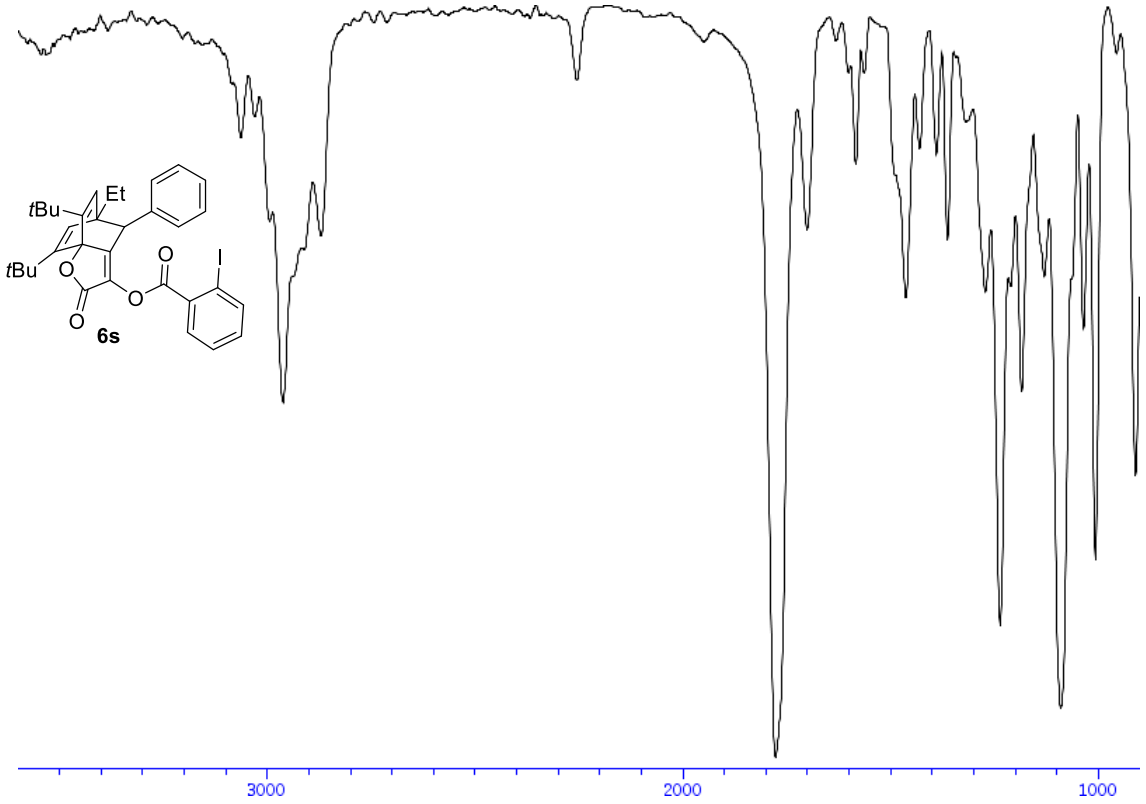
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6s**



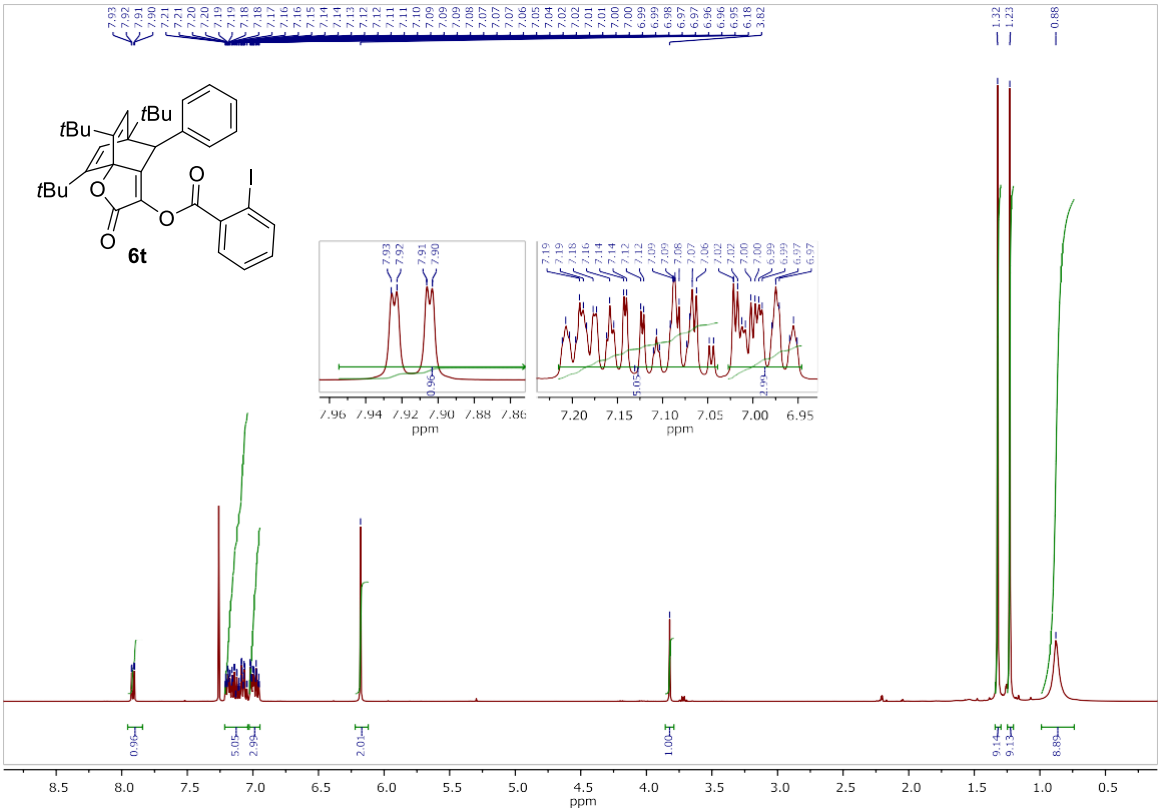
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6s**



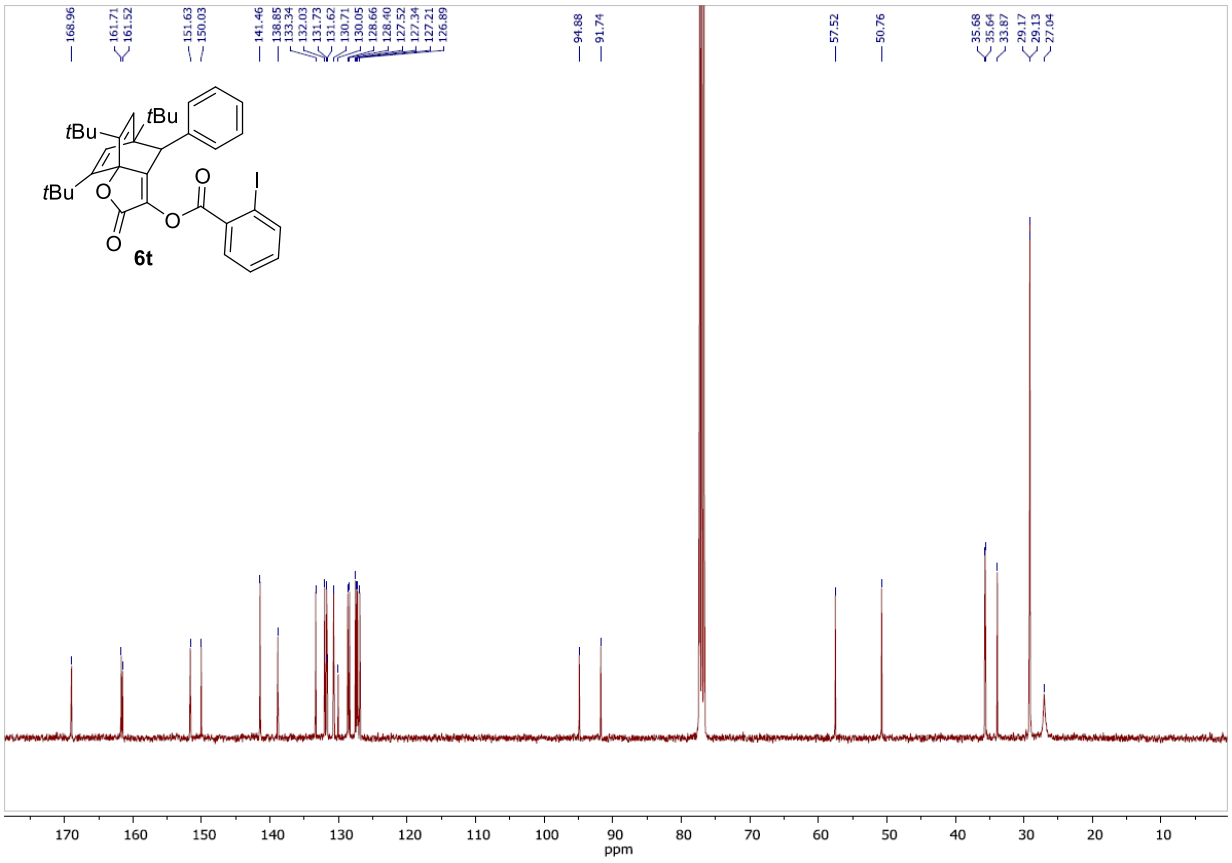
IR of compound **6s**



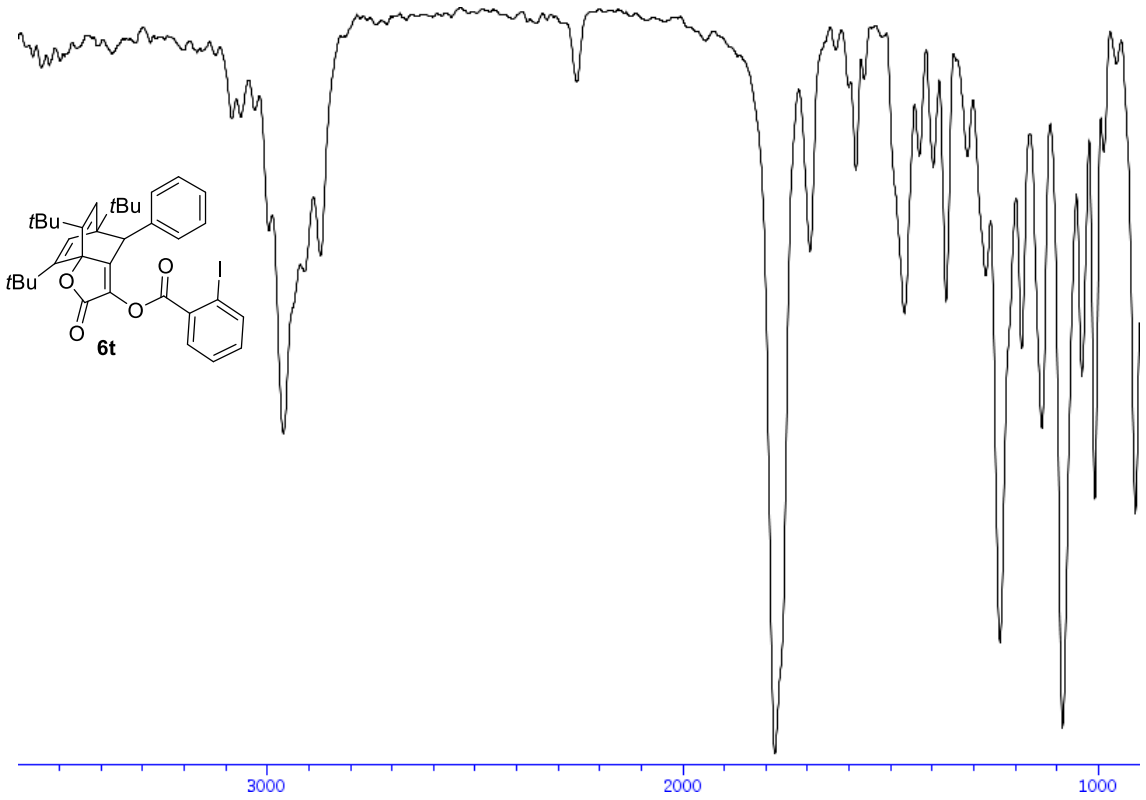
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6t**



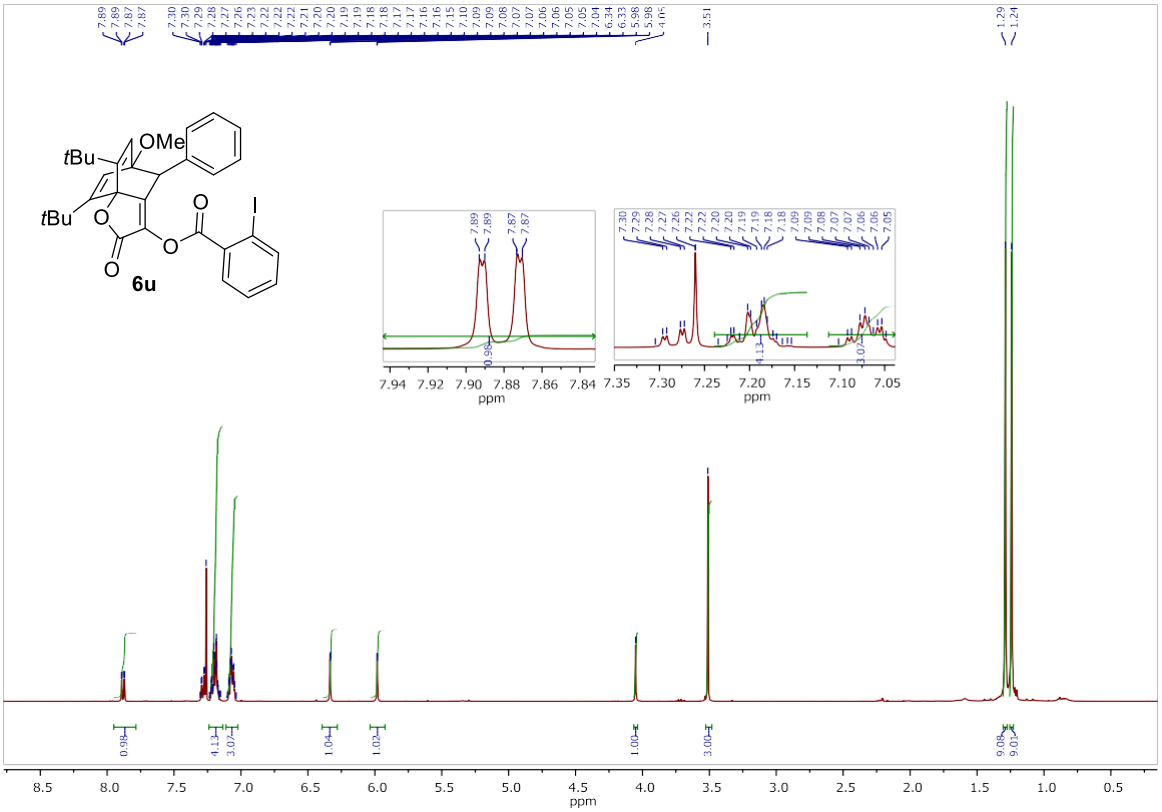
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6t**



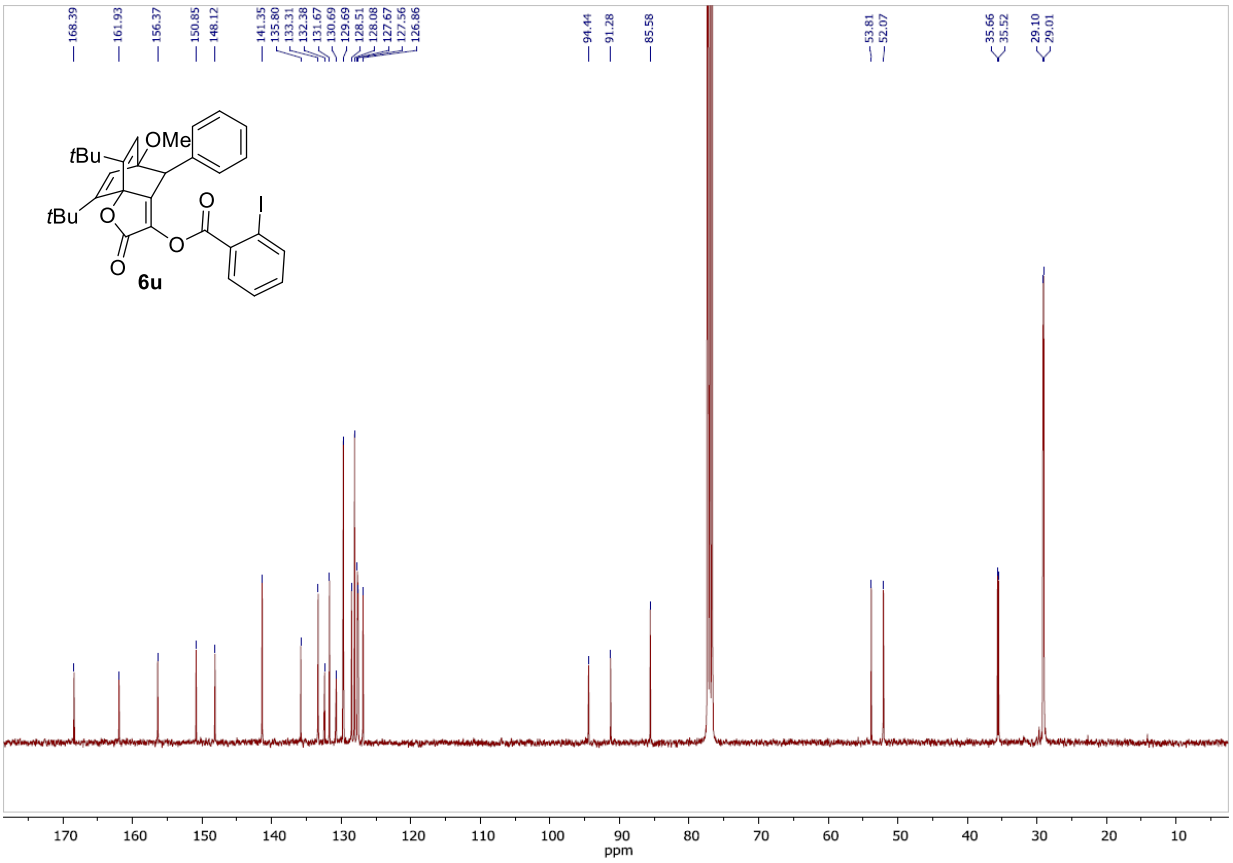
IR of compound **6t**



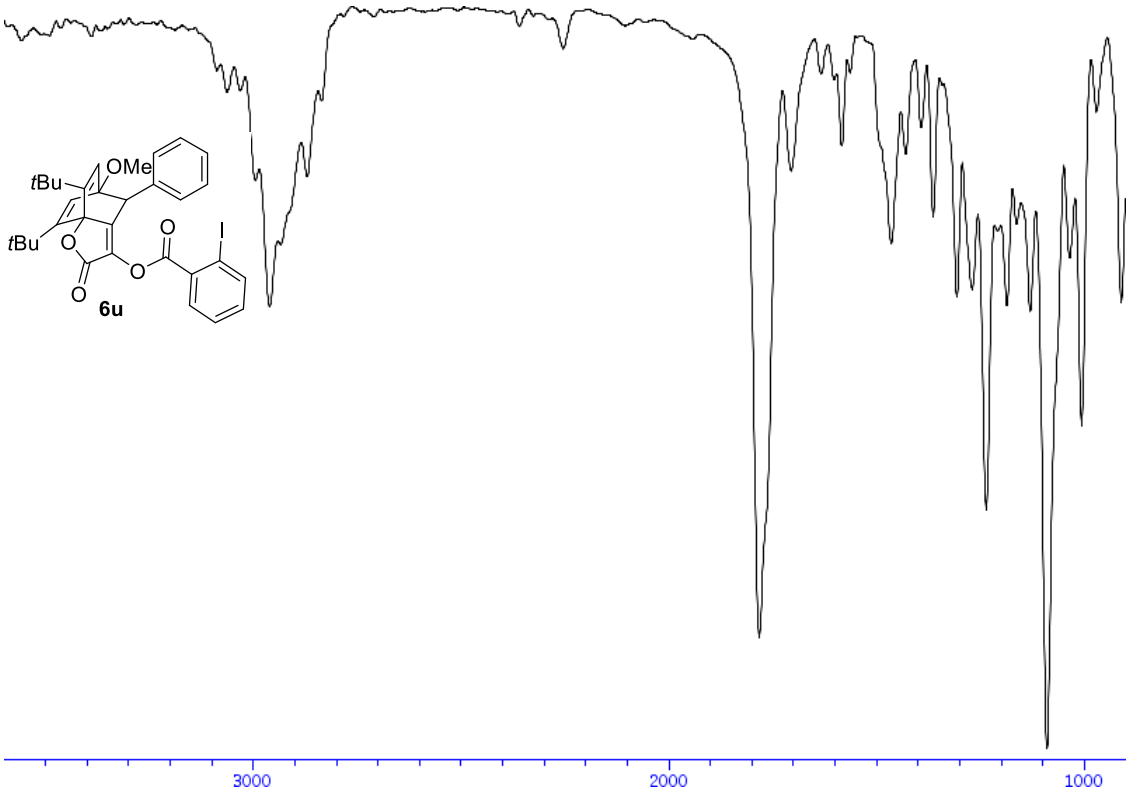
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6u**



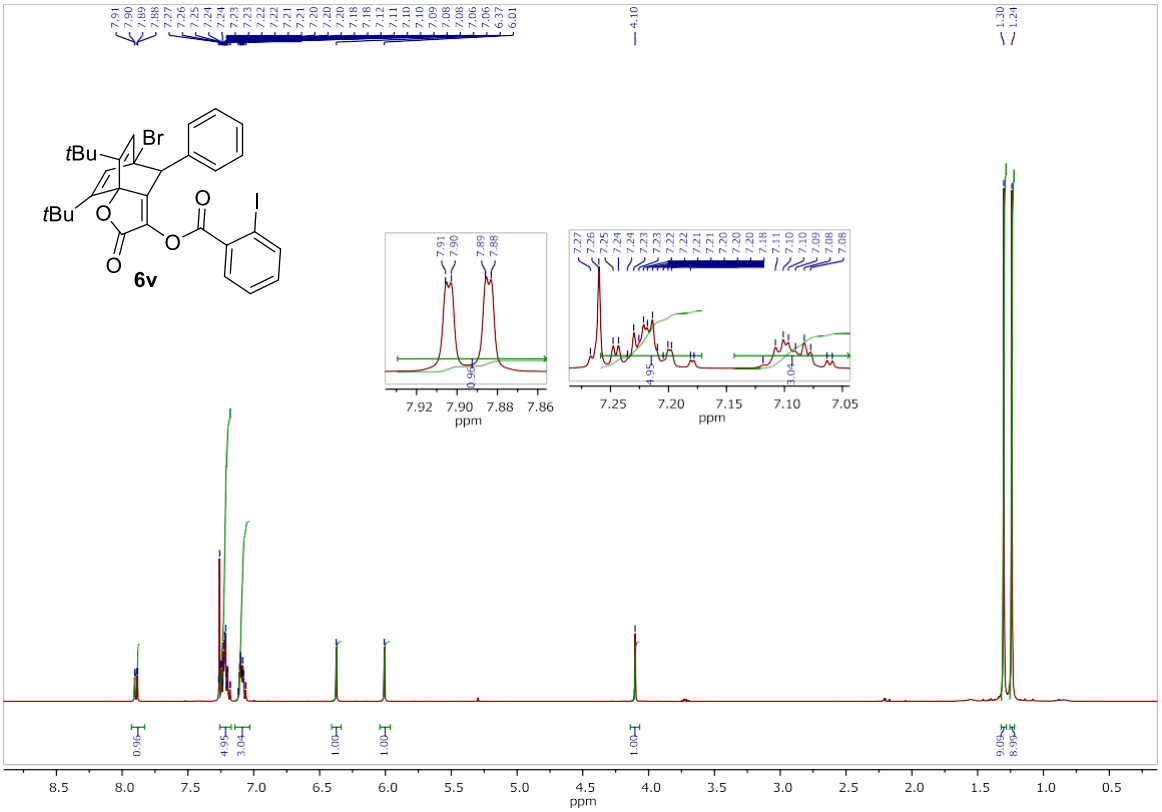
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6u**



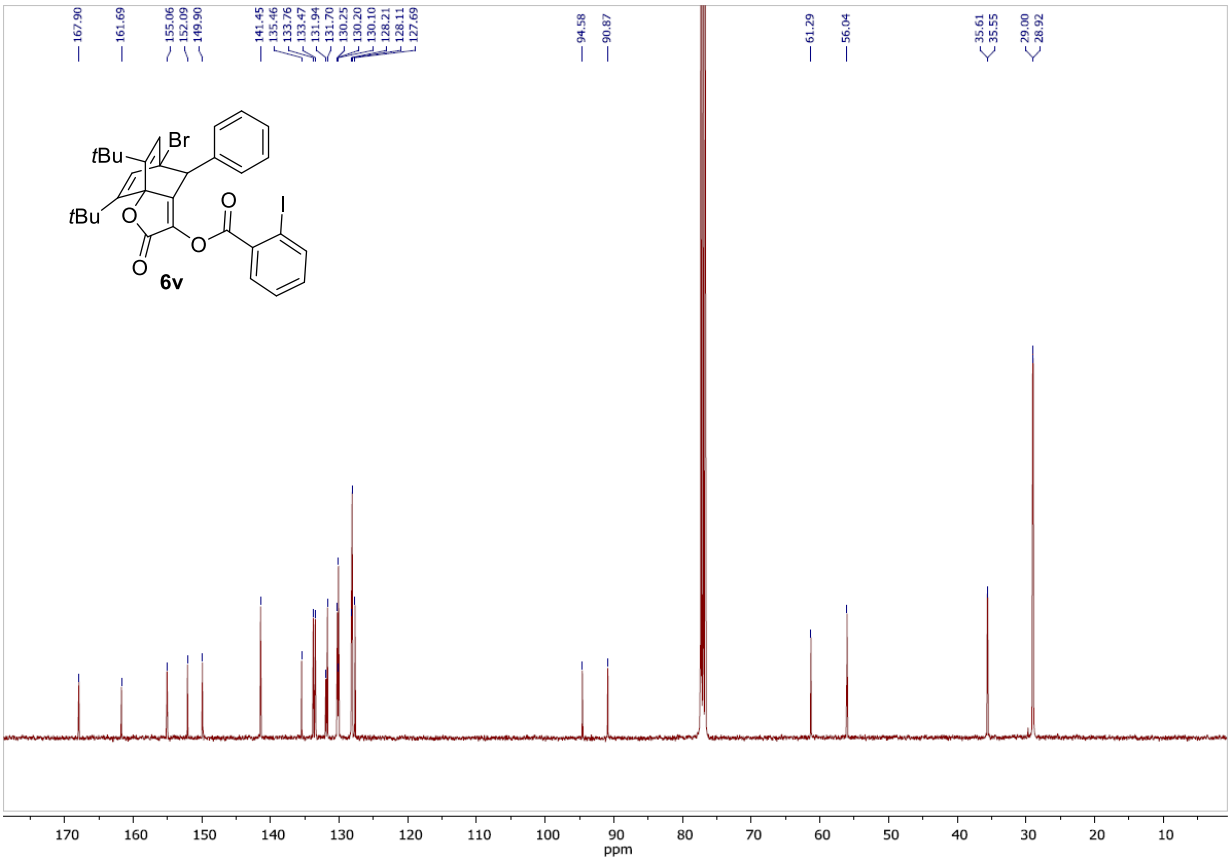
IR of compound **6u**



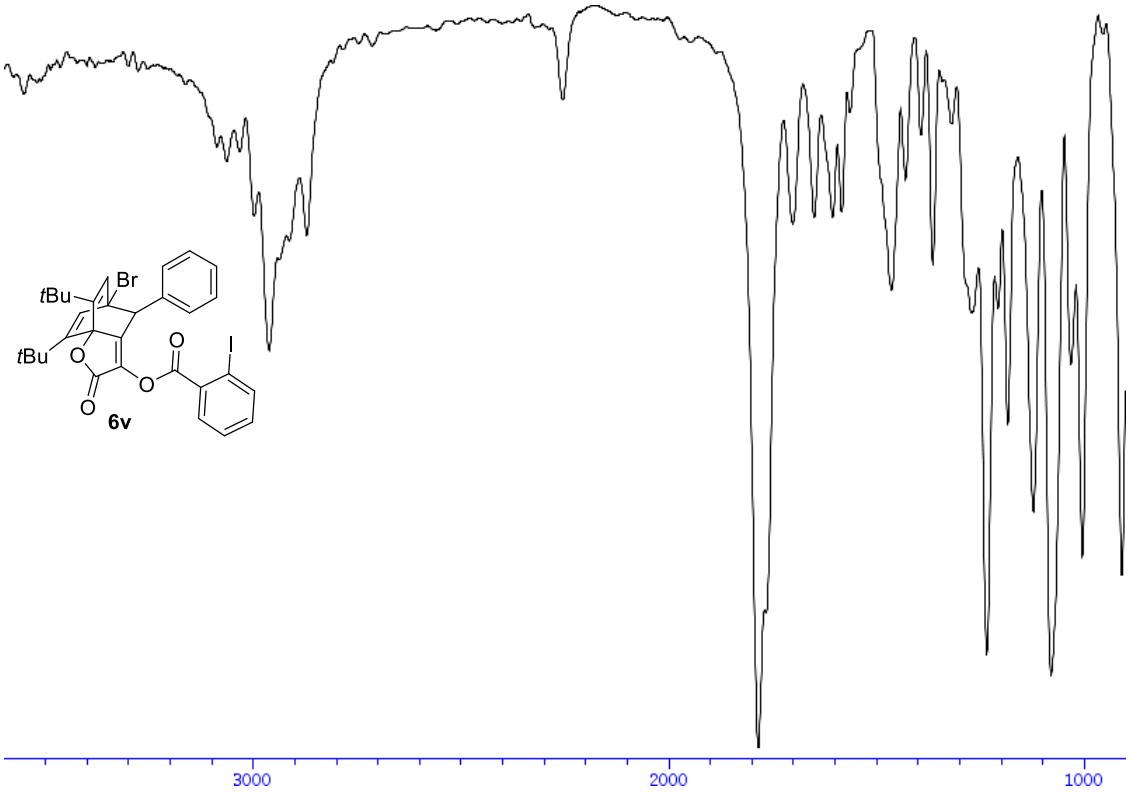
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6v**



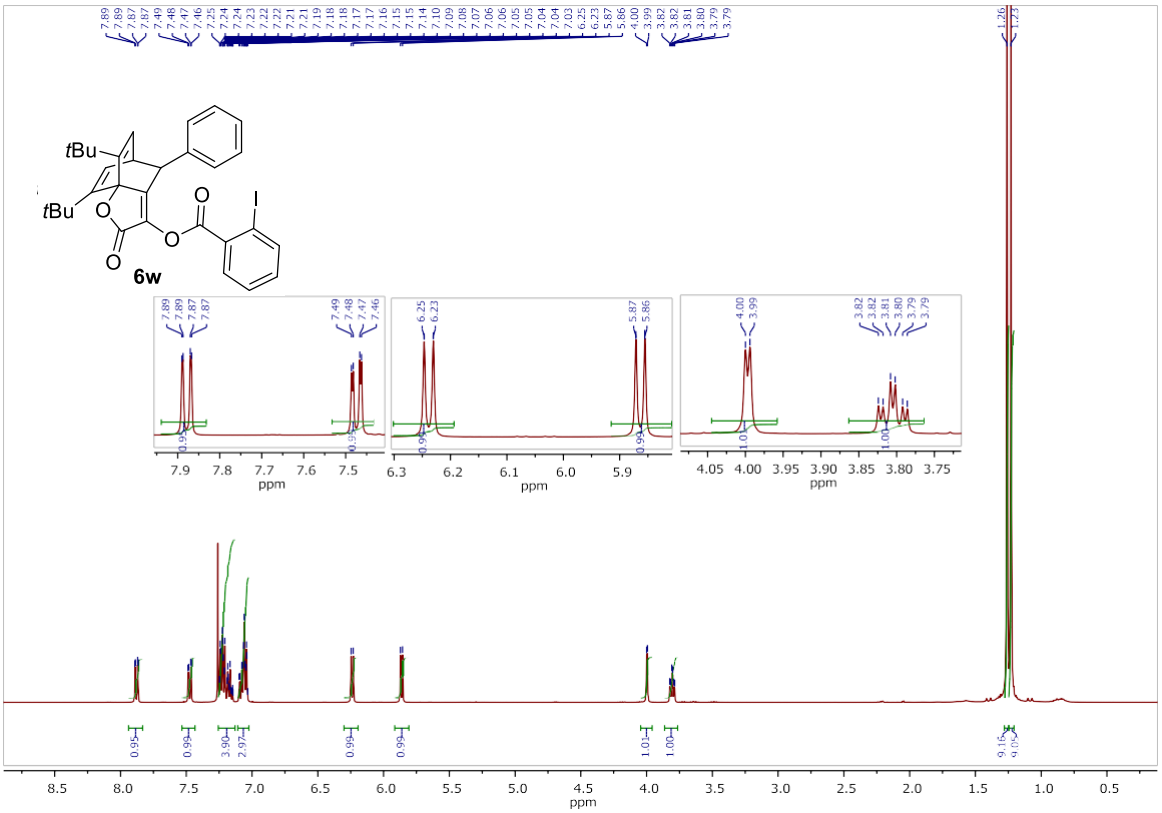
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6v**



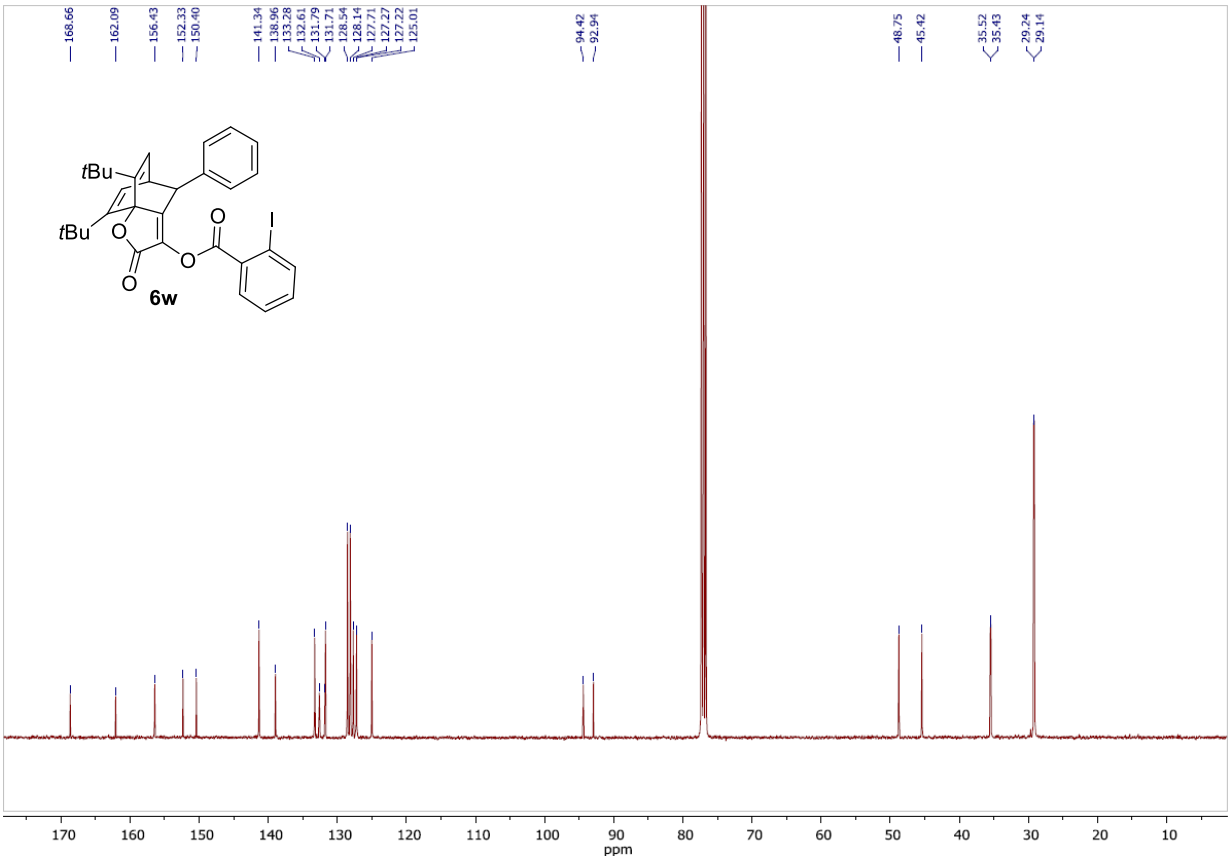
IR of compound **6v**



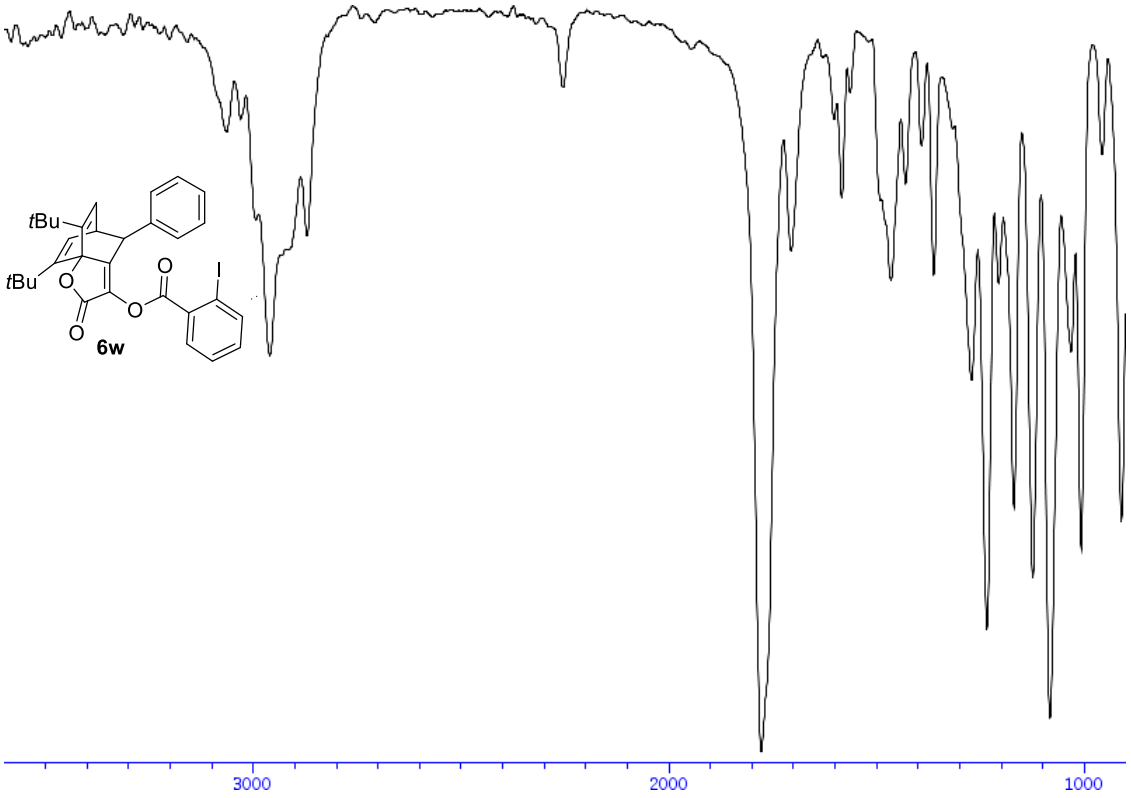
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6w**



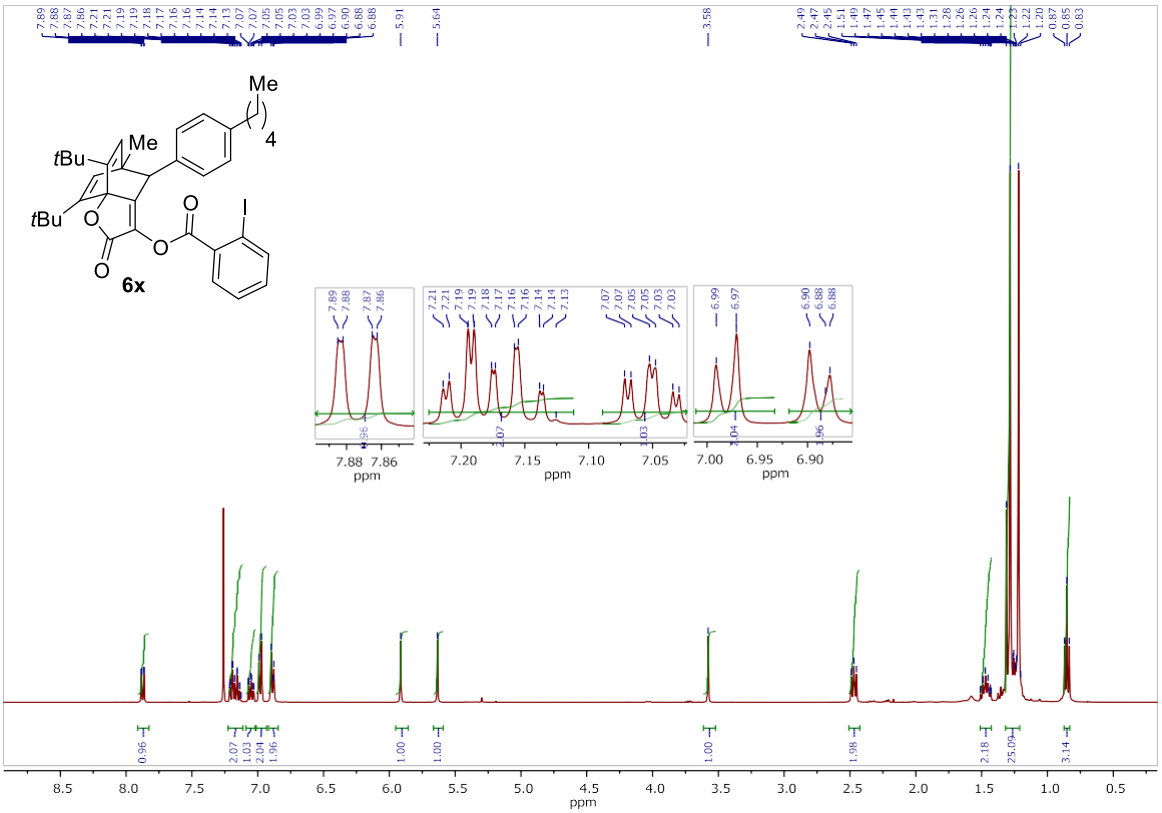
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6w**



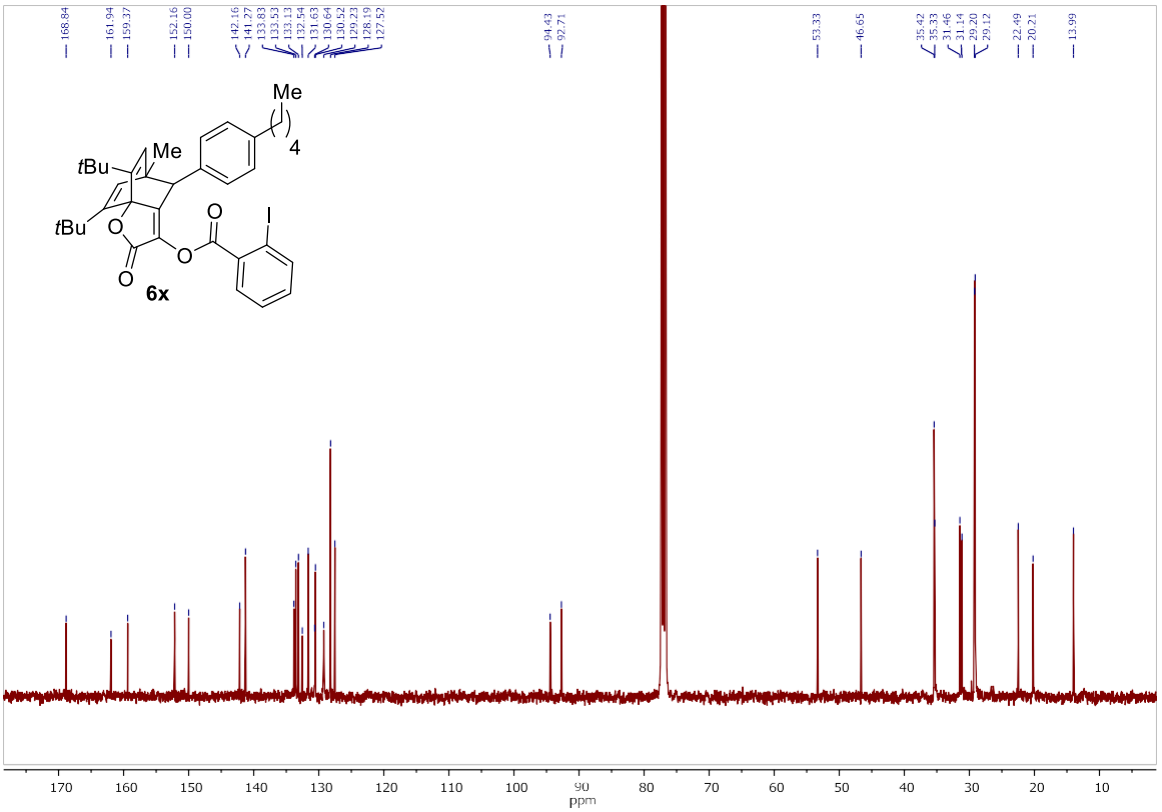
IR of compound **6w**



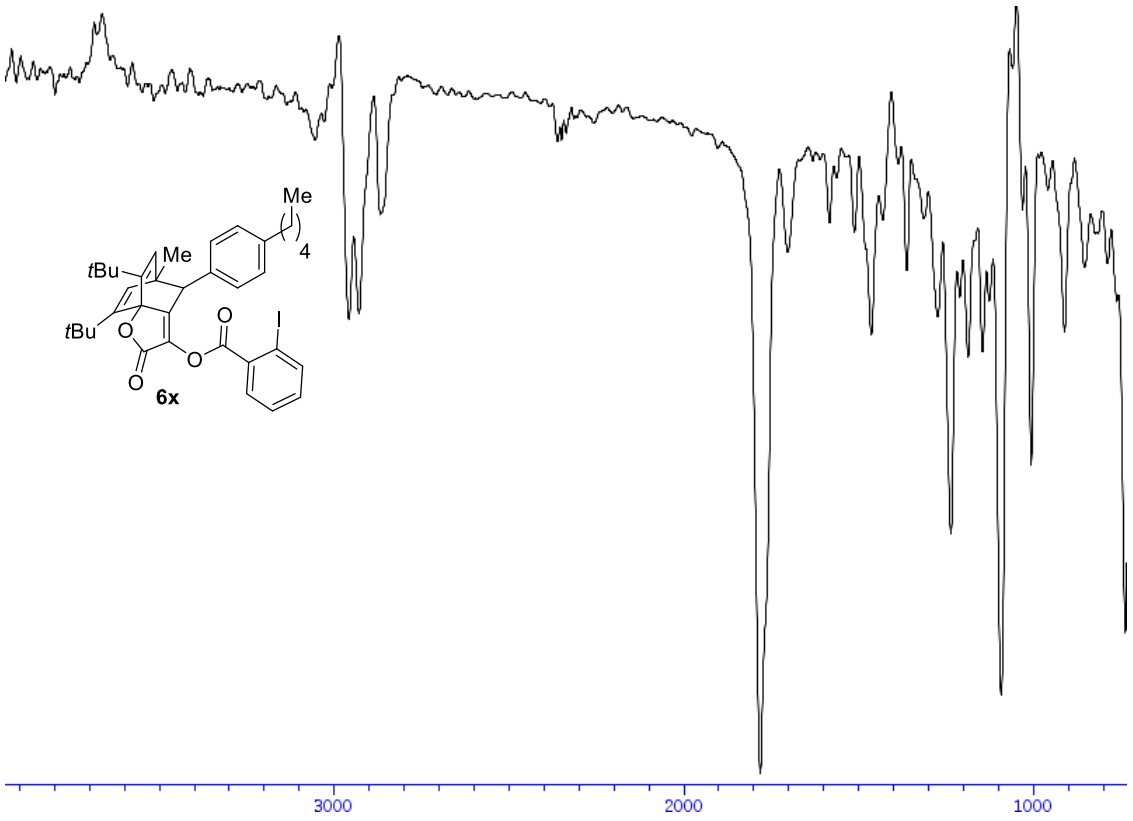
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6x**



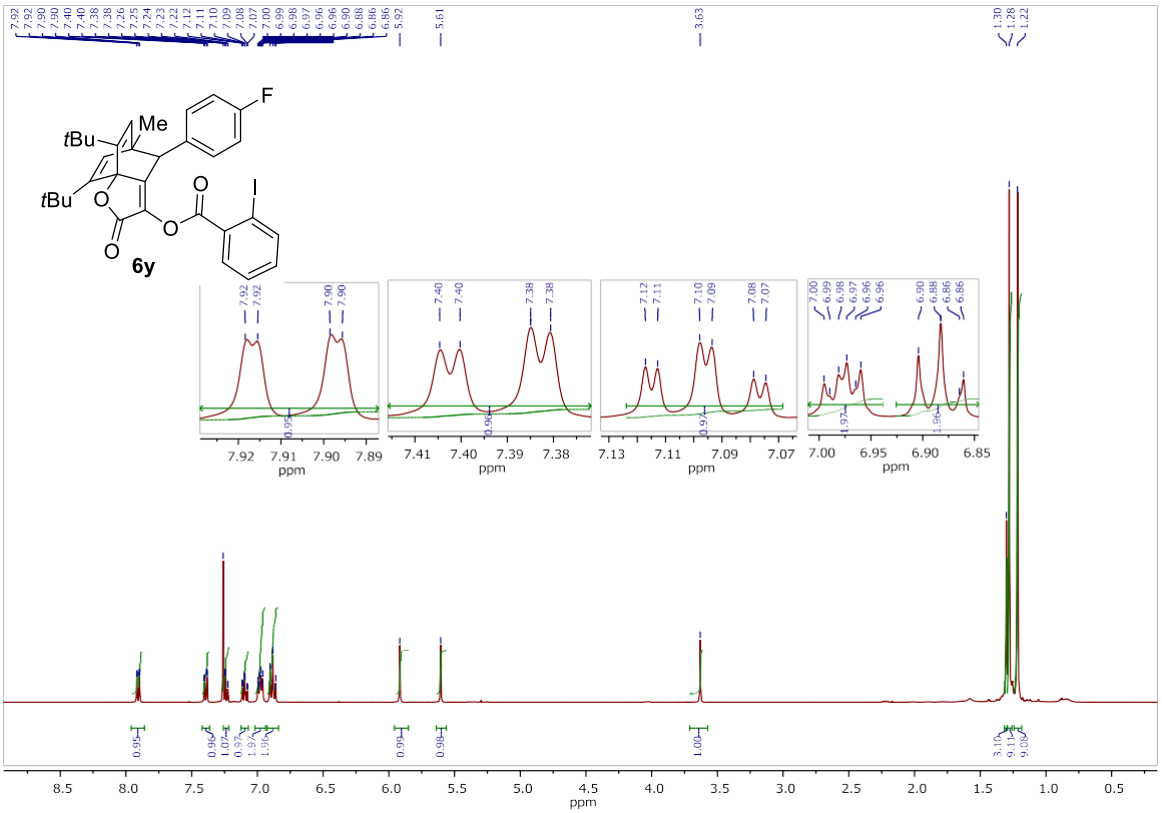
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6x**



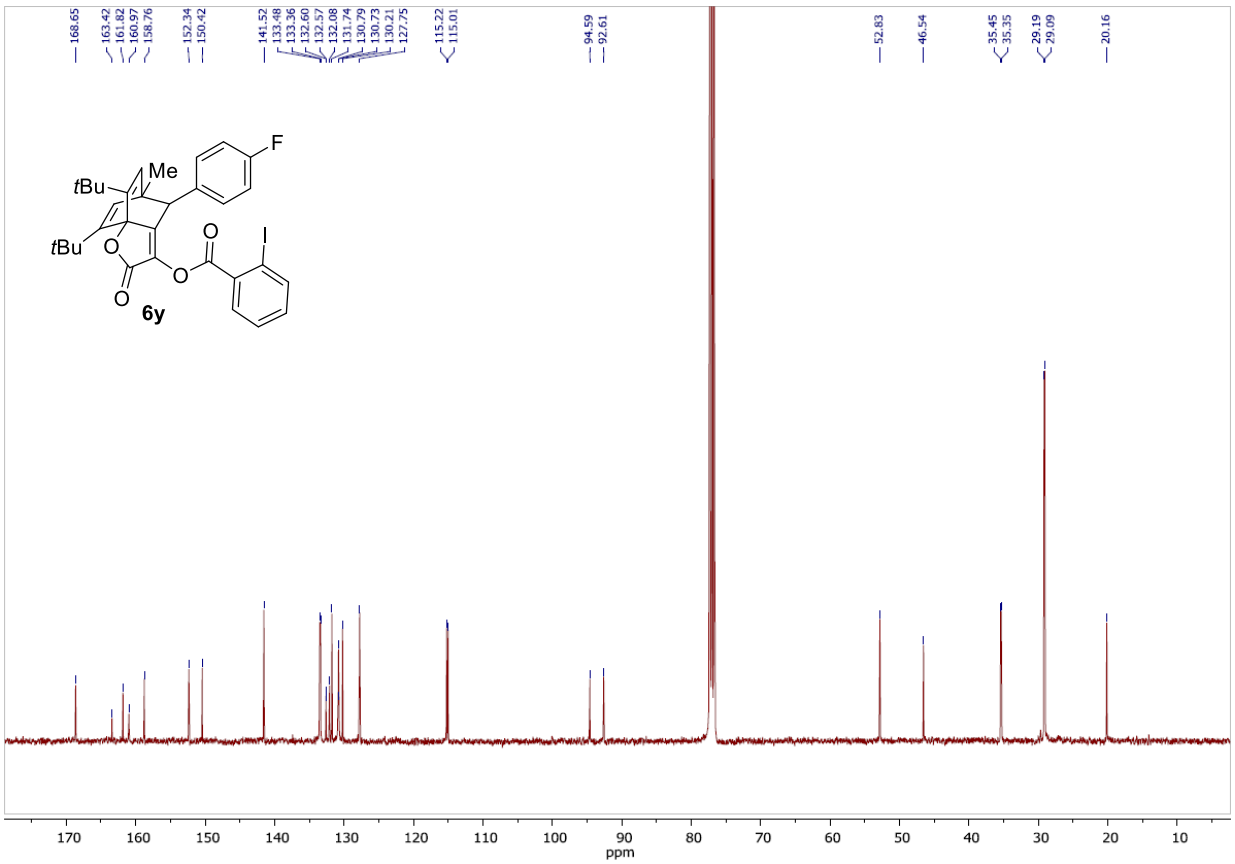
IR of compound **6x**



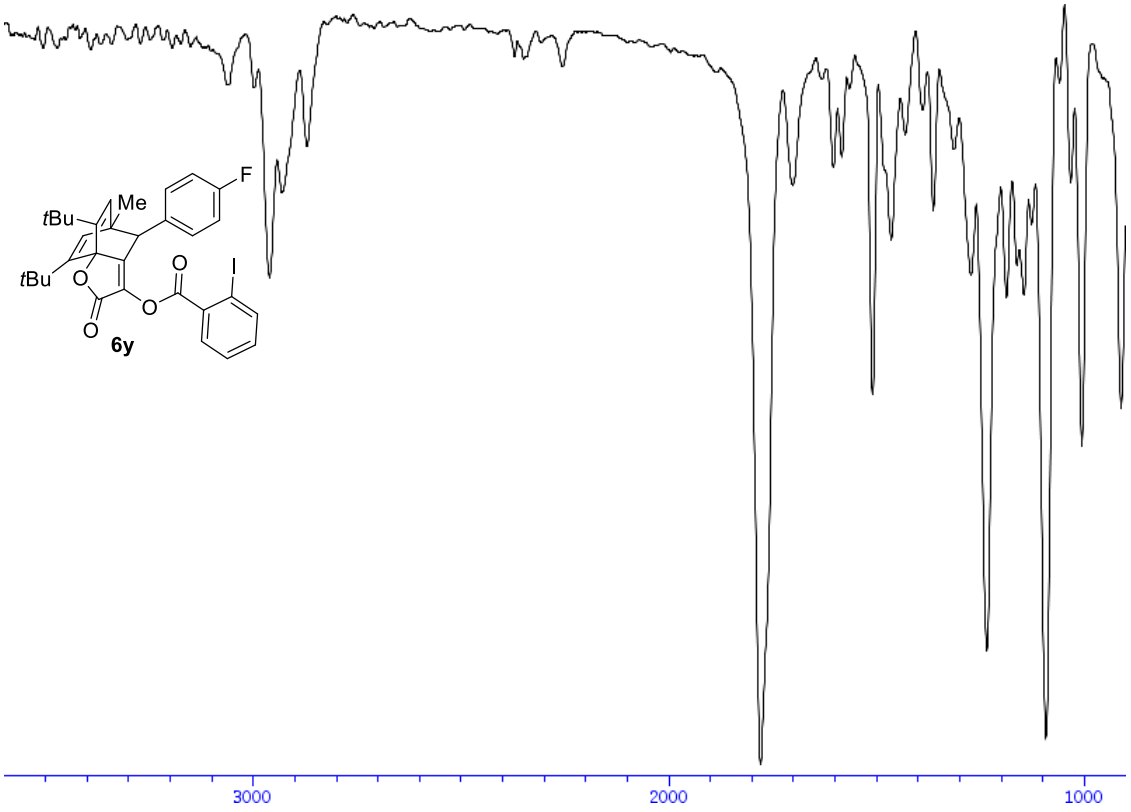
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6y**



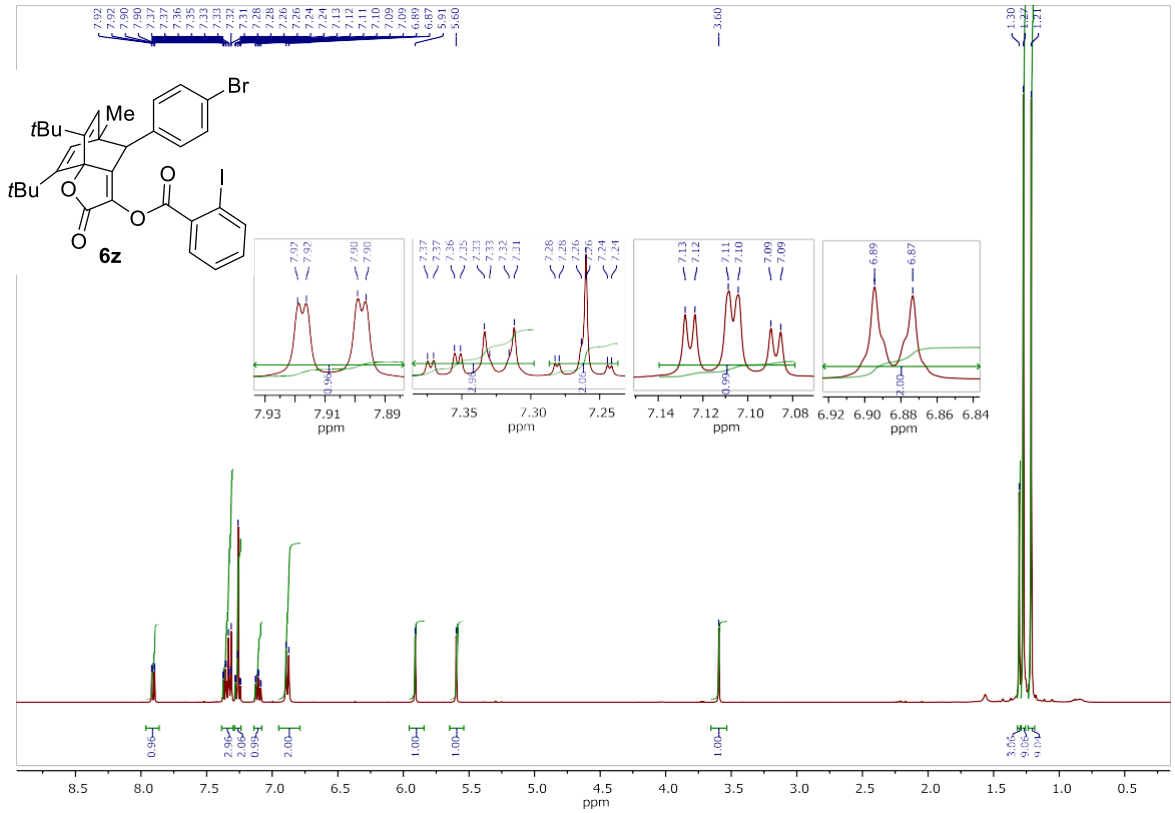
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6y**



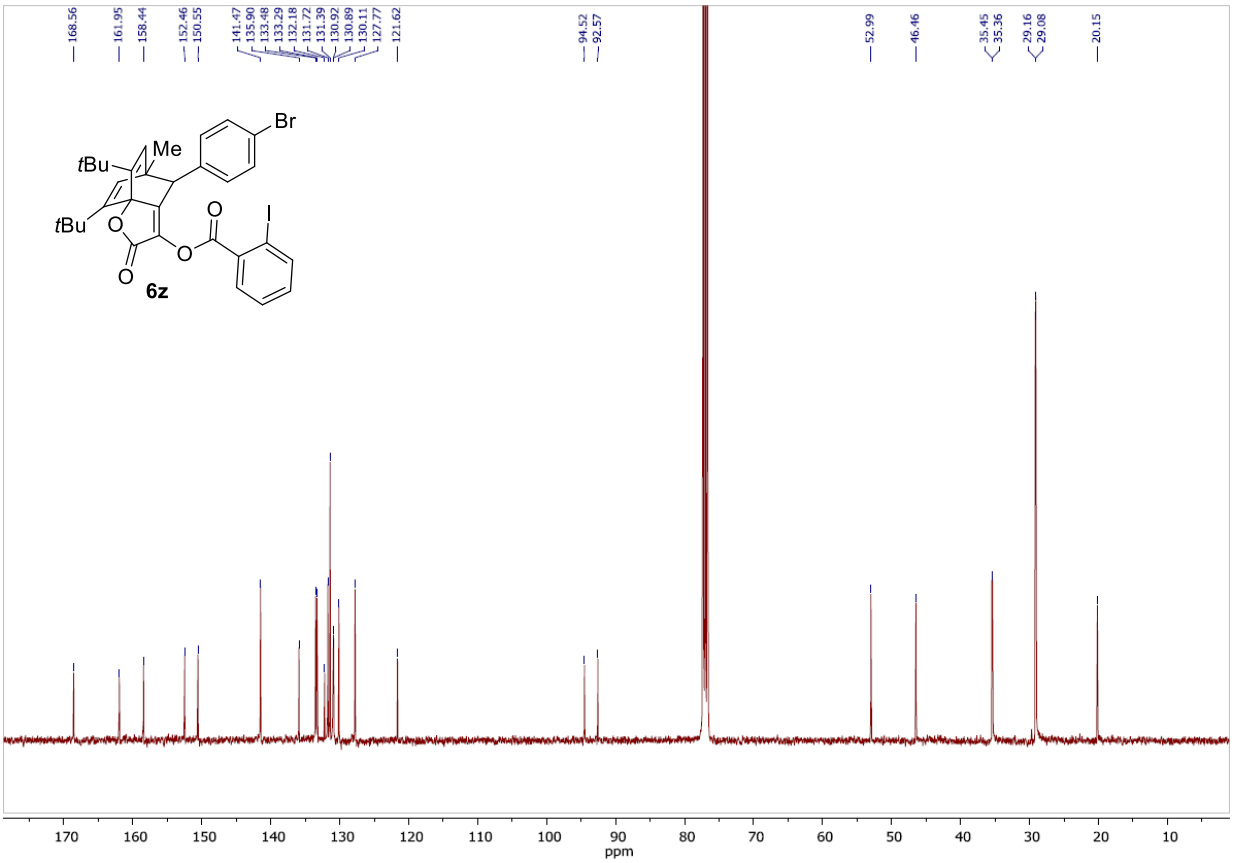
IR of compound **6y**



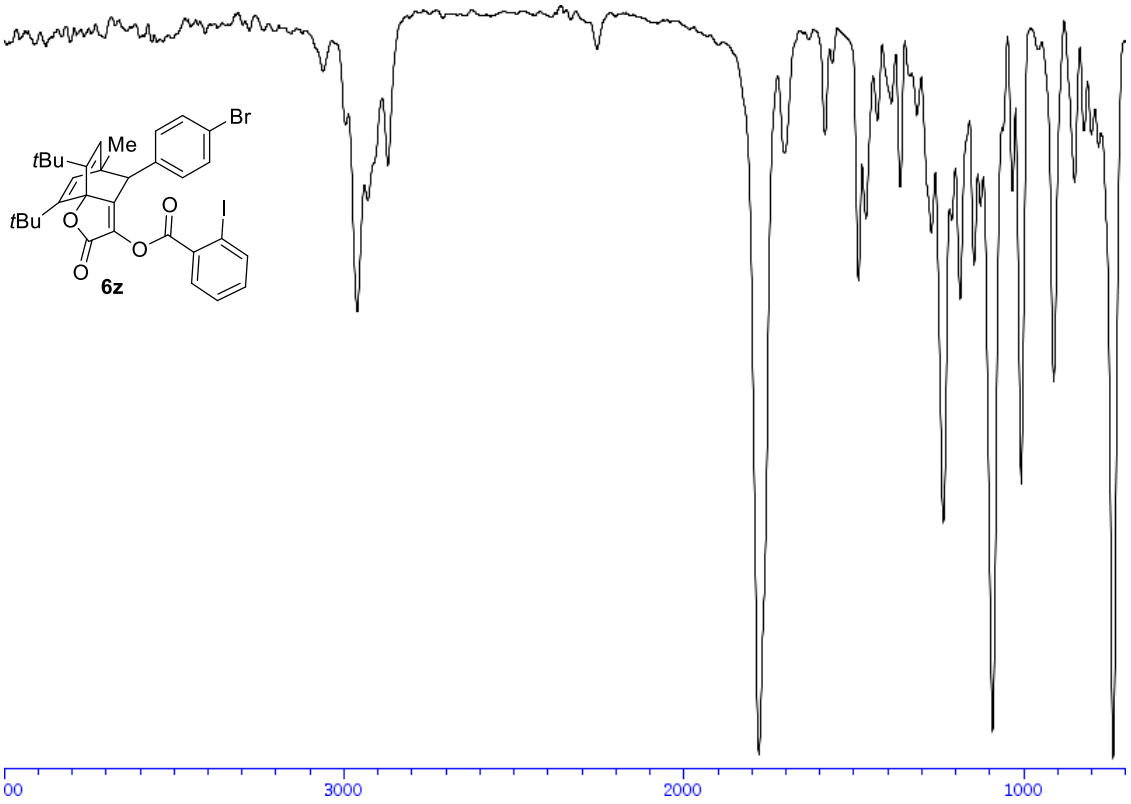
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6z**



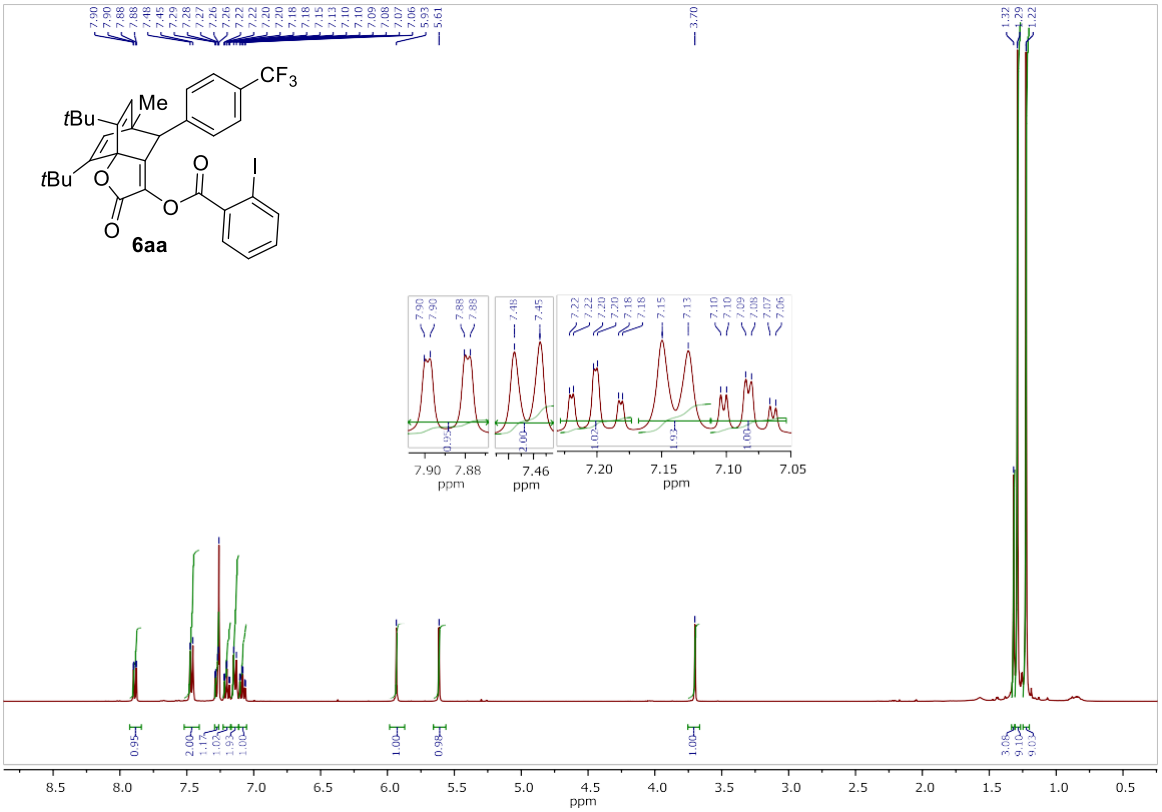
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6z**



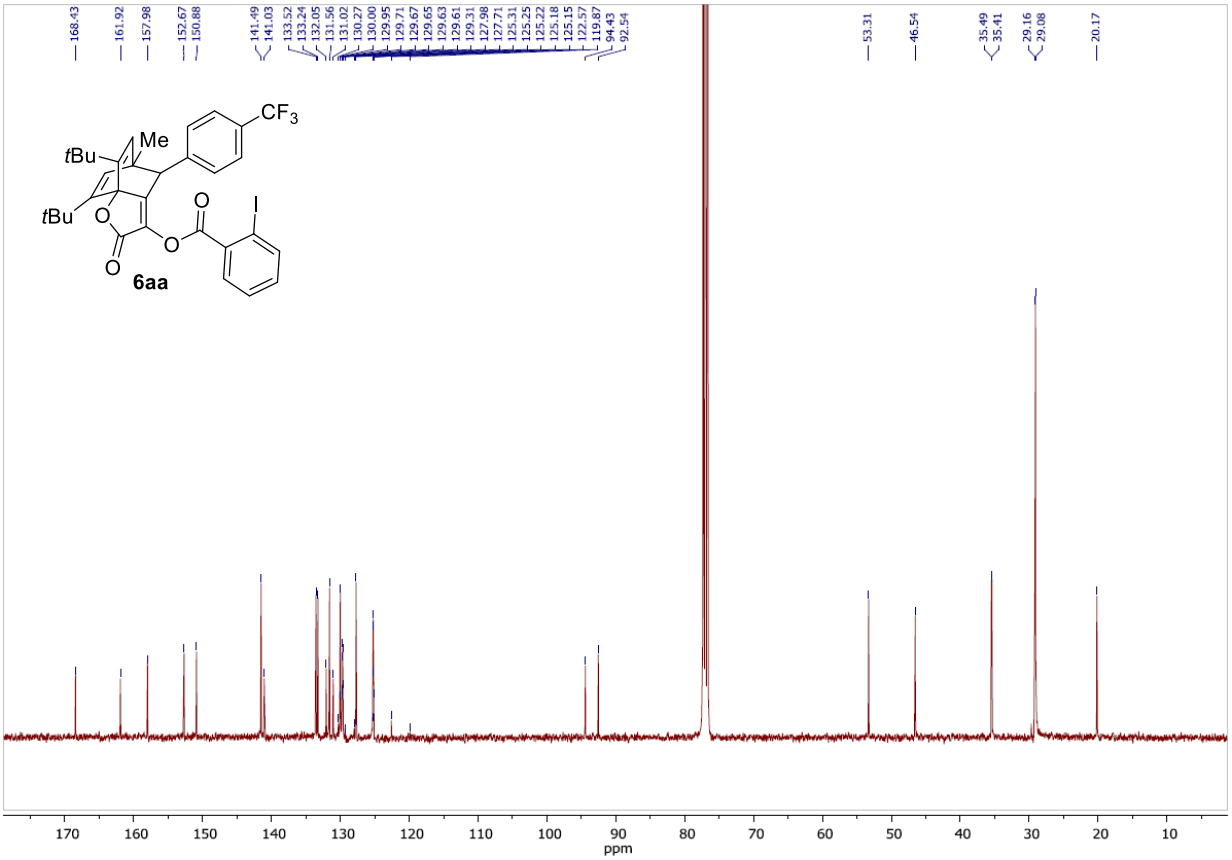
IR of compound **6z**



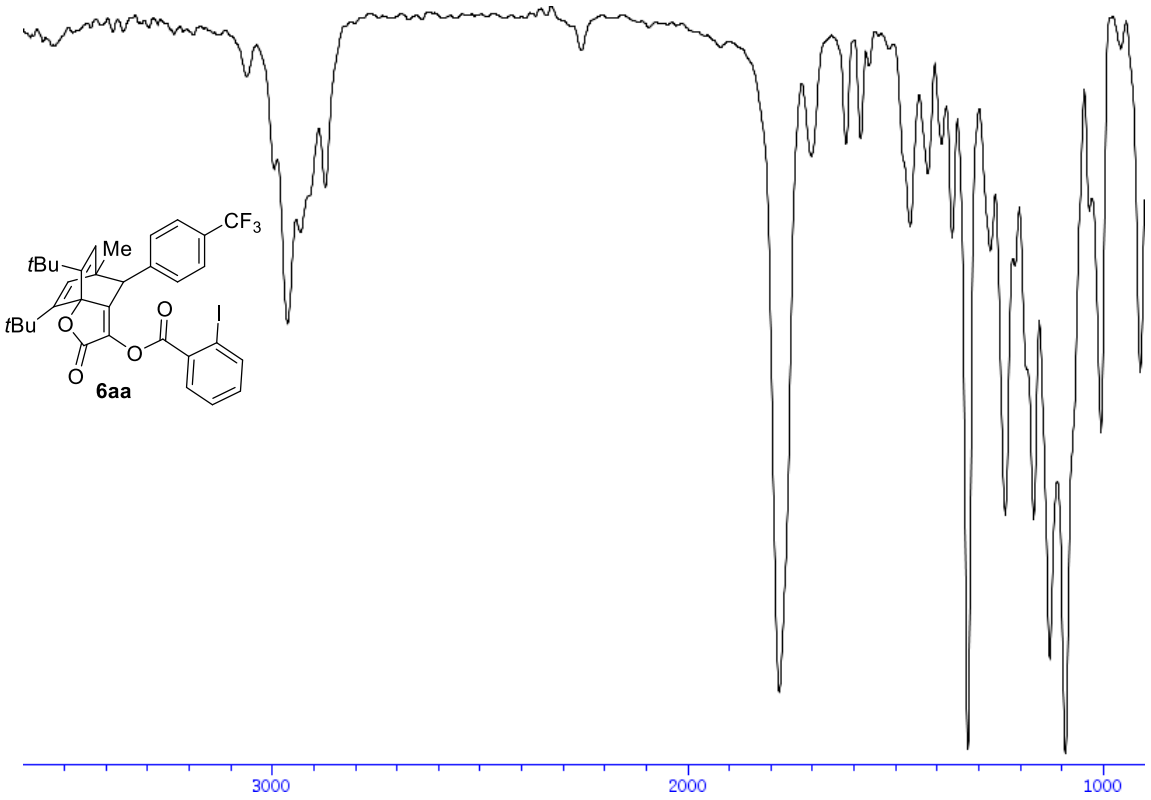
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6aa**



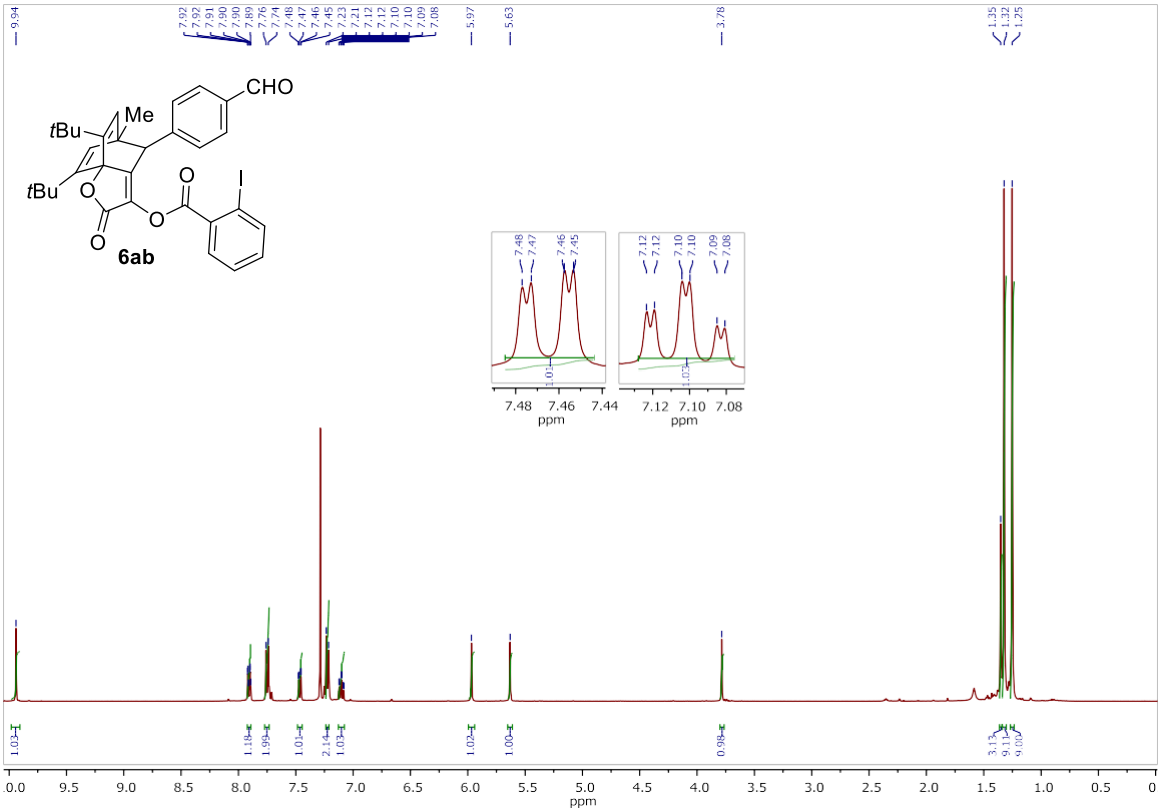
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6aa**



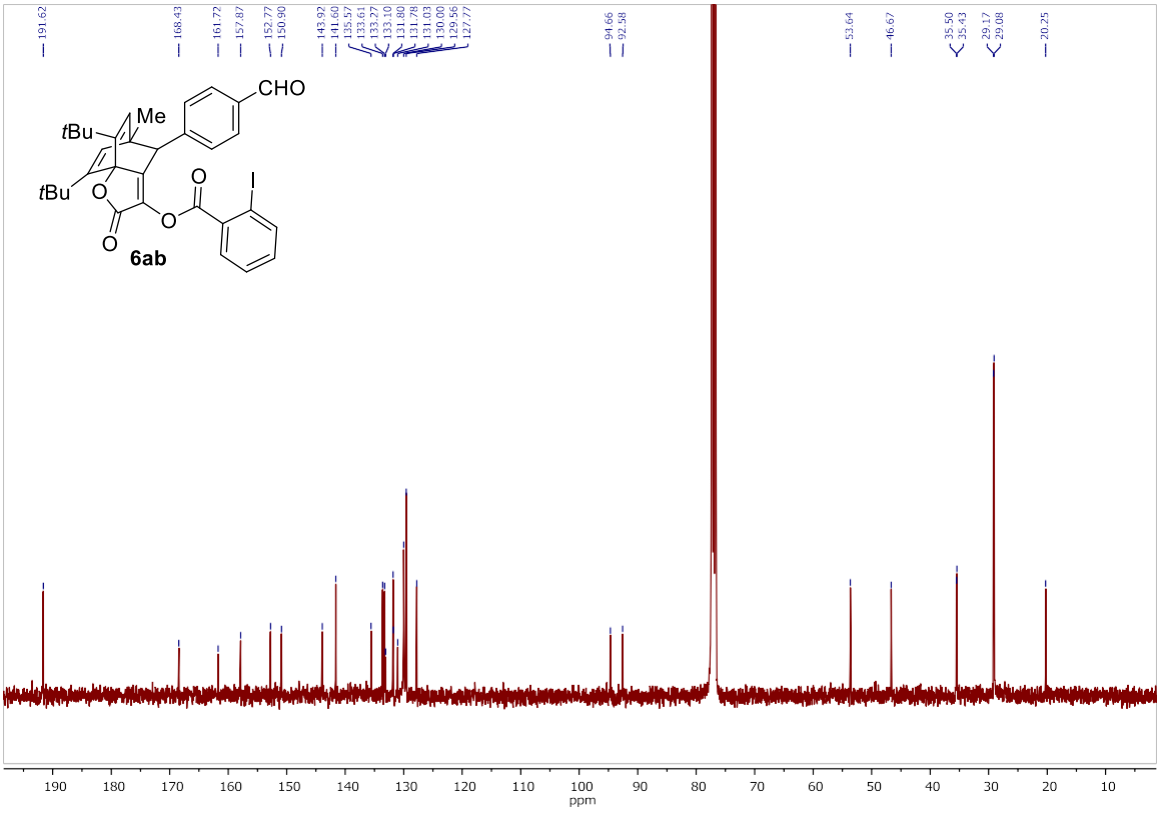
IR of compound **6aa**



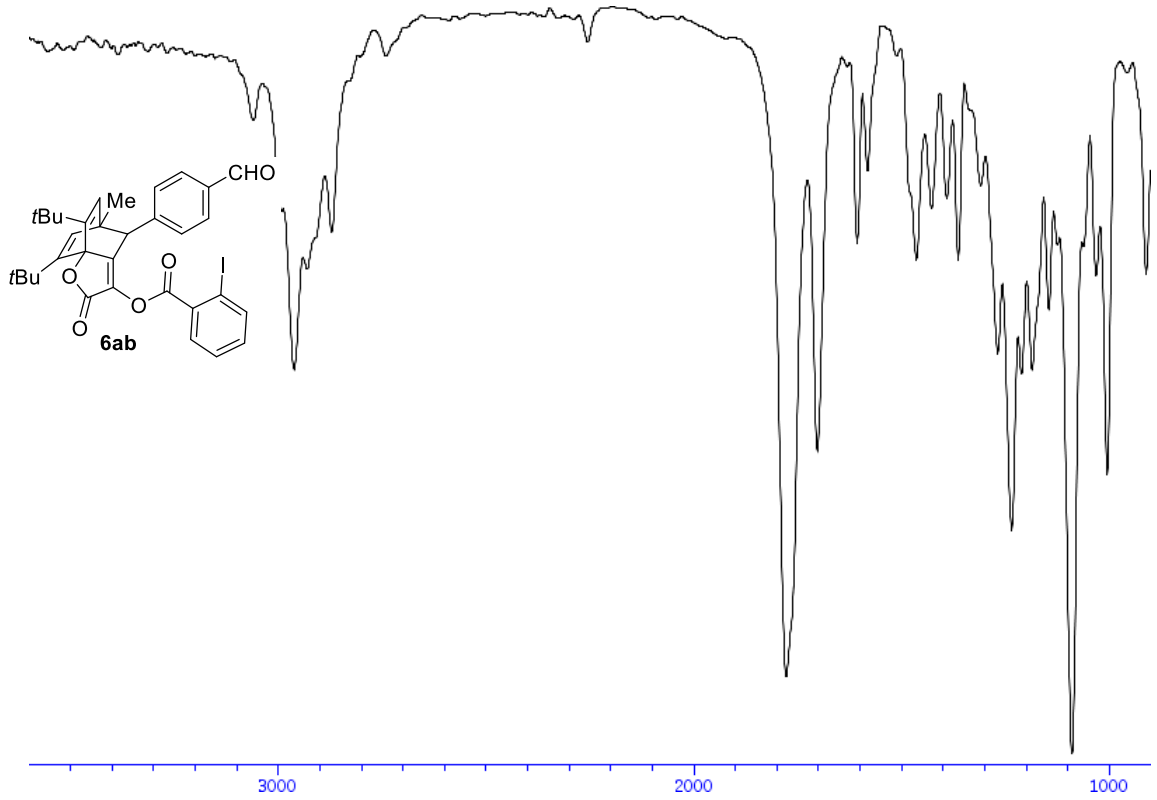
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ab**



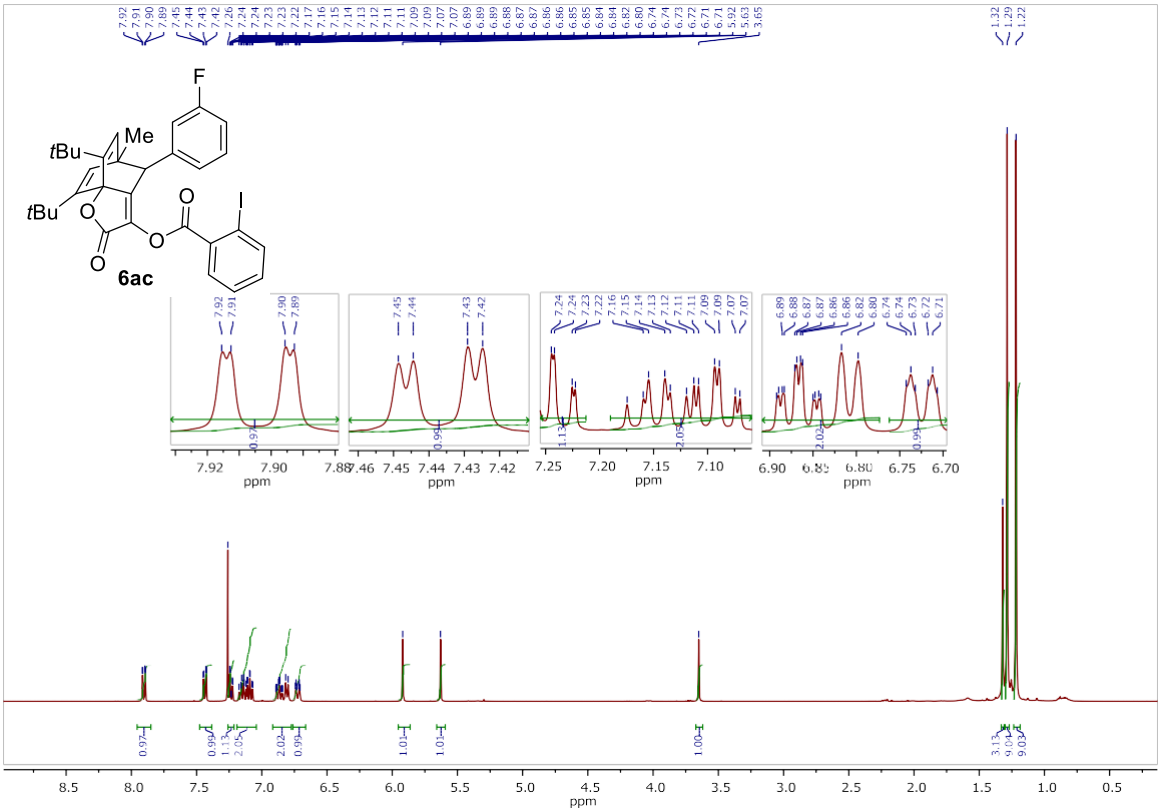
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ab**



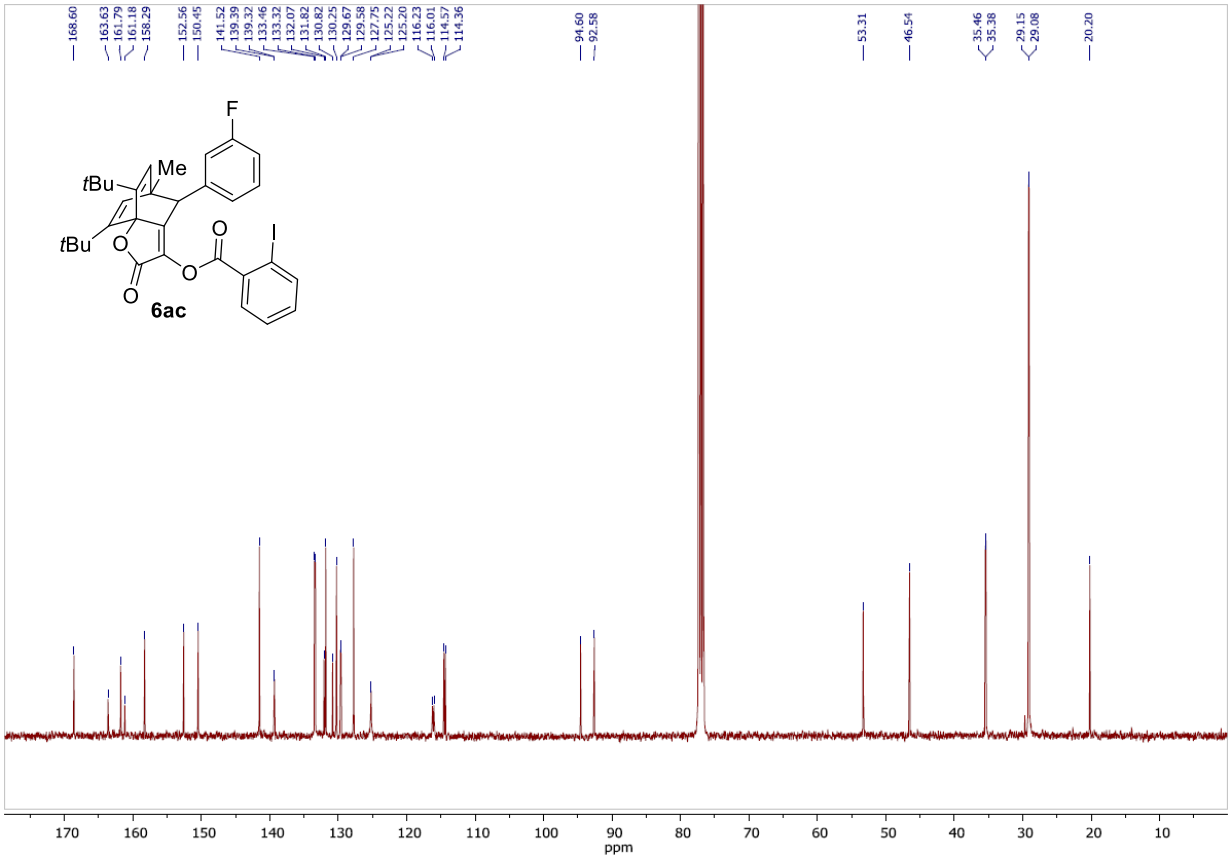
IR of compound **6ab**



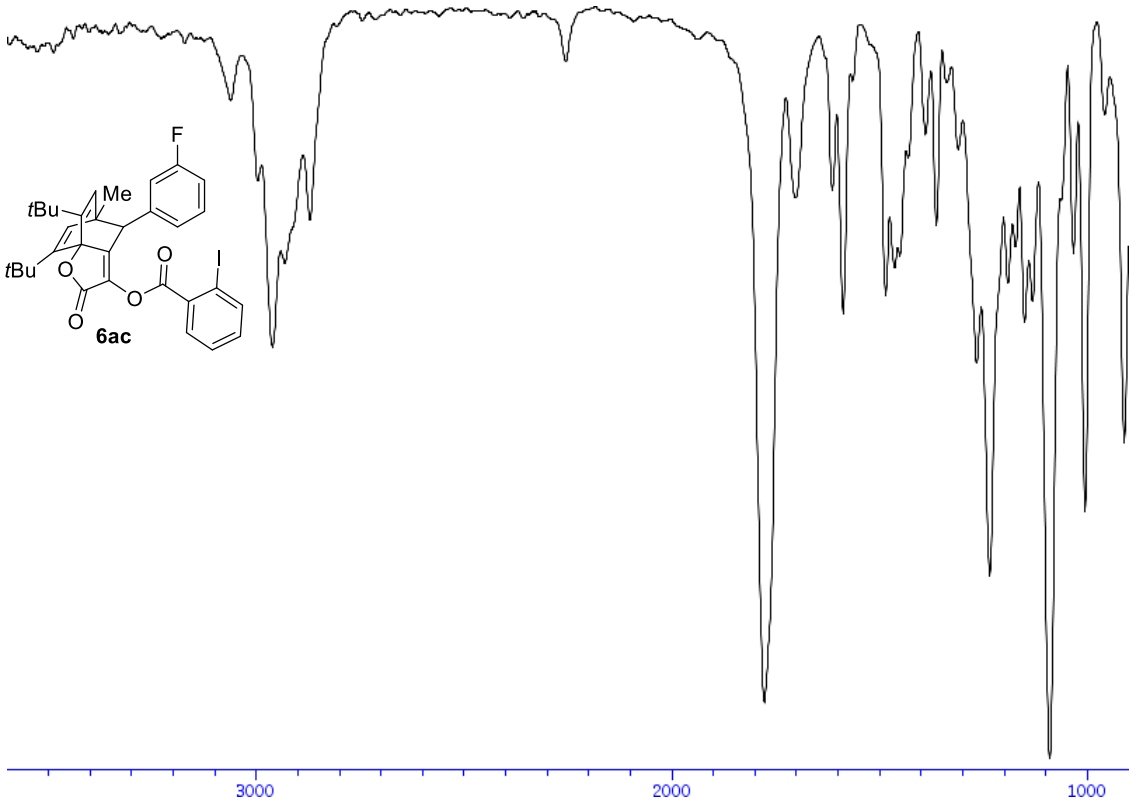
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ac**



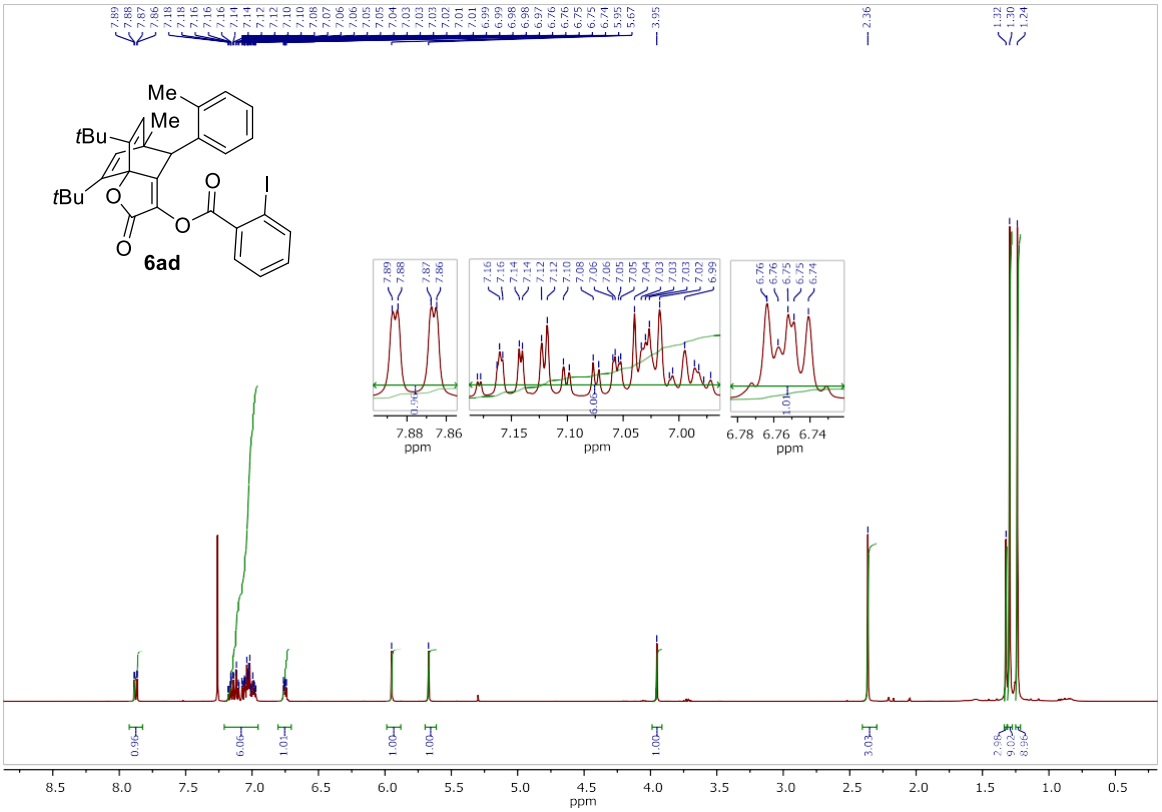
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ac**



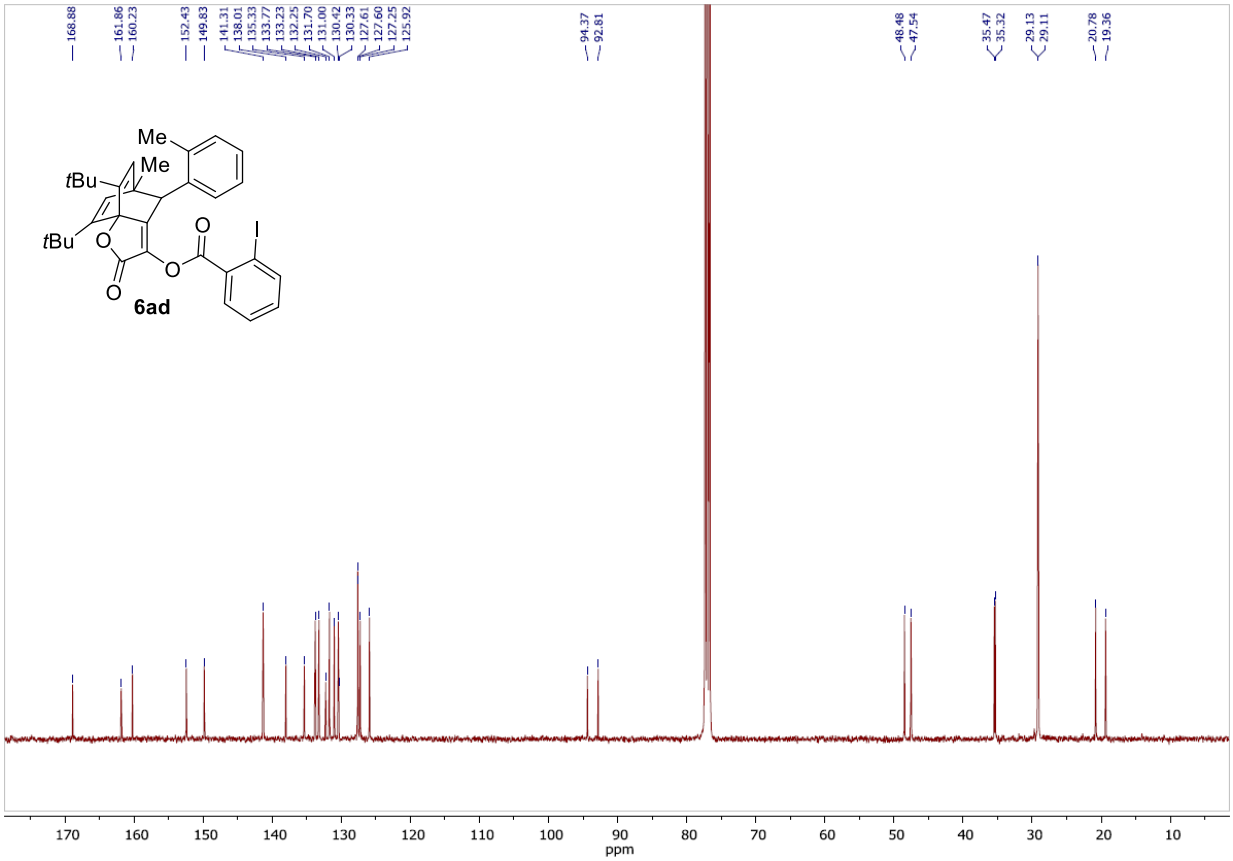
IR of compound **6ac**



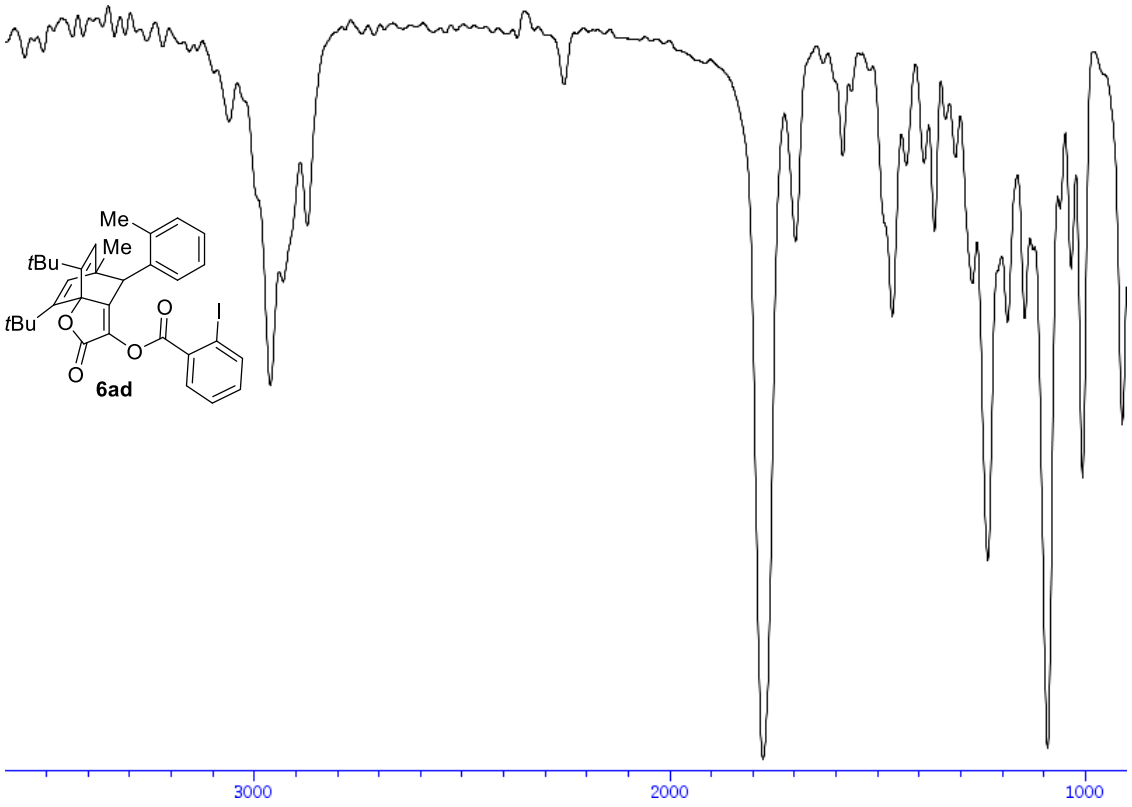
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ad**



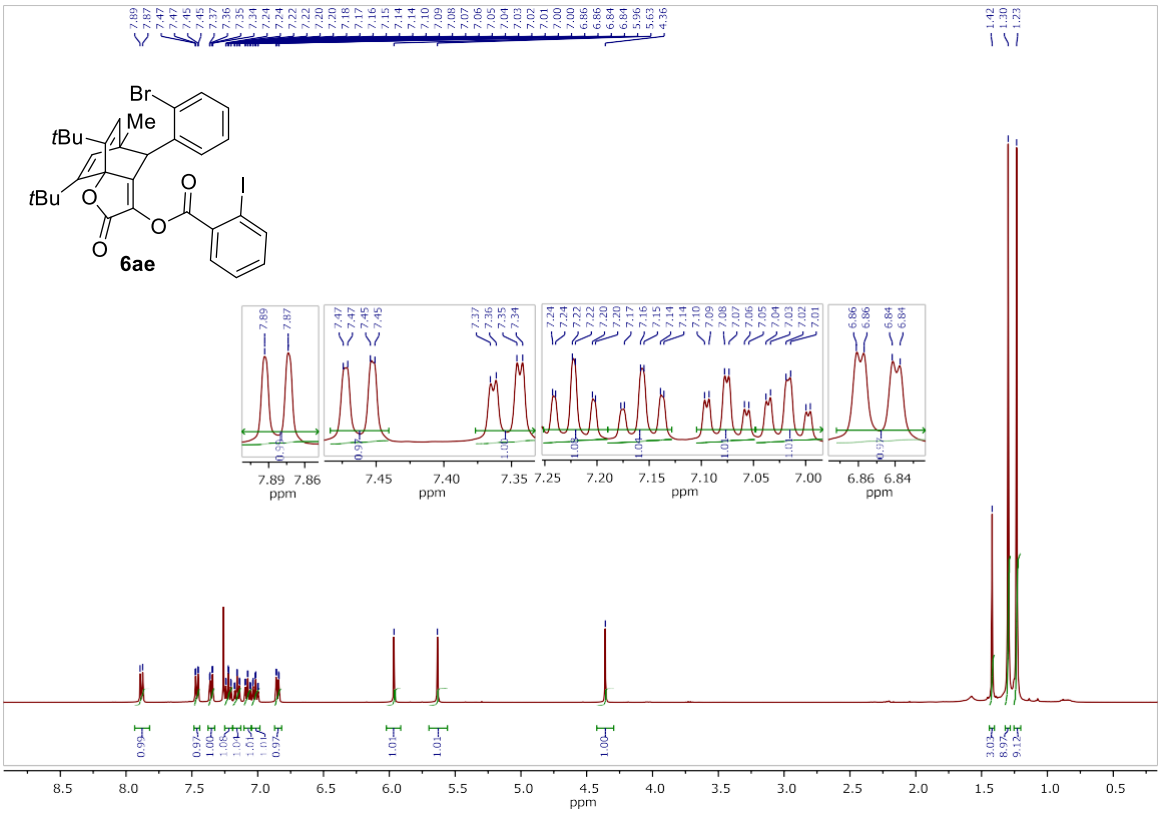
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ad**



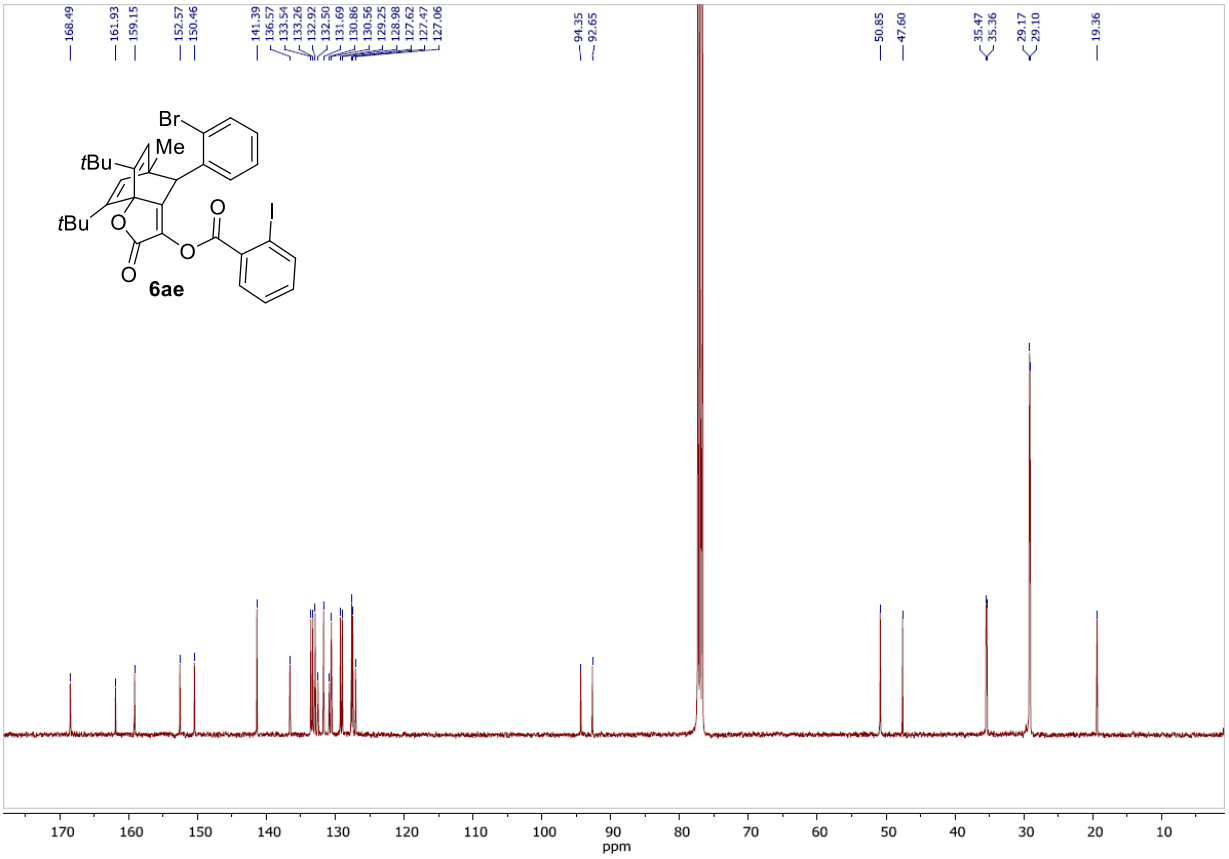
IR of compound **6ad**



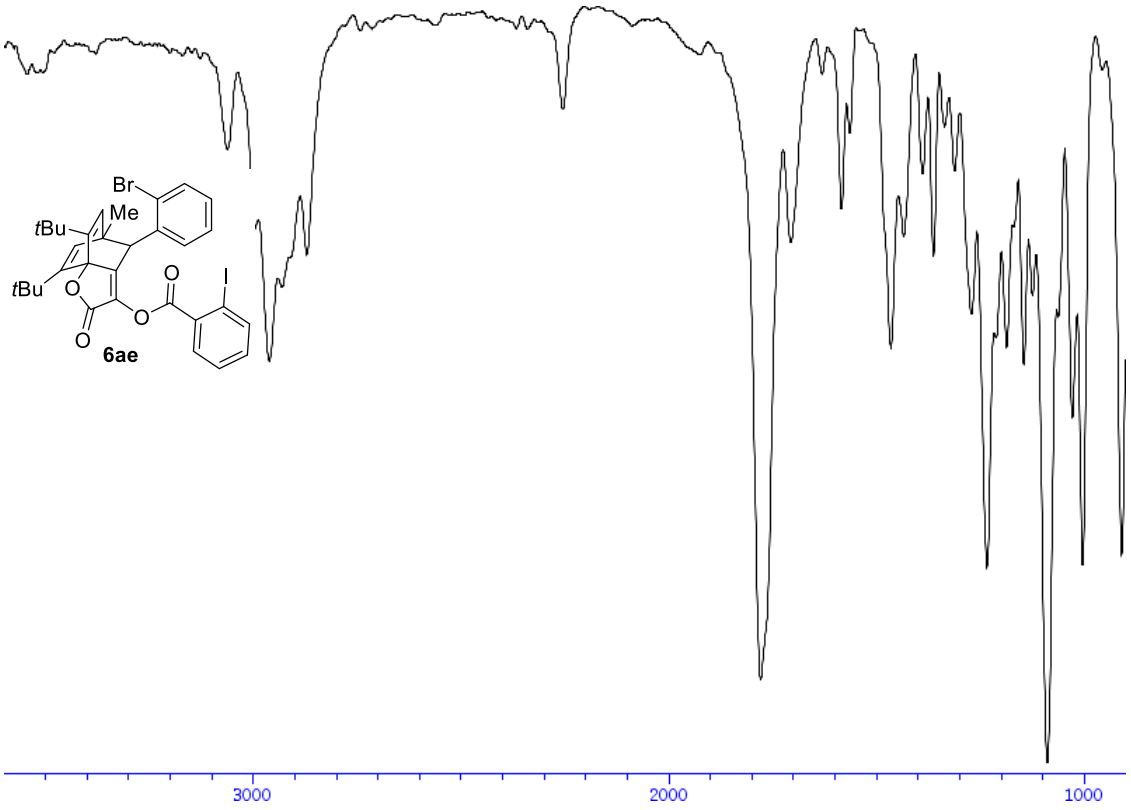
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ae**



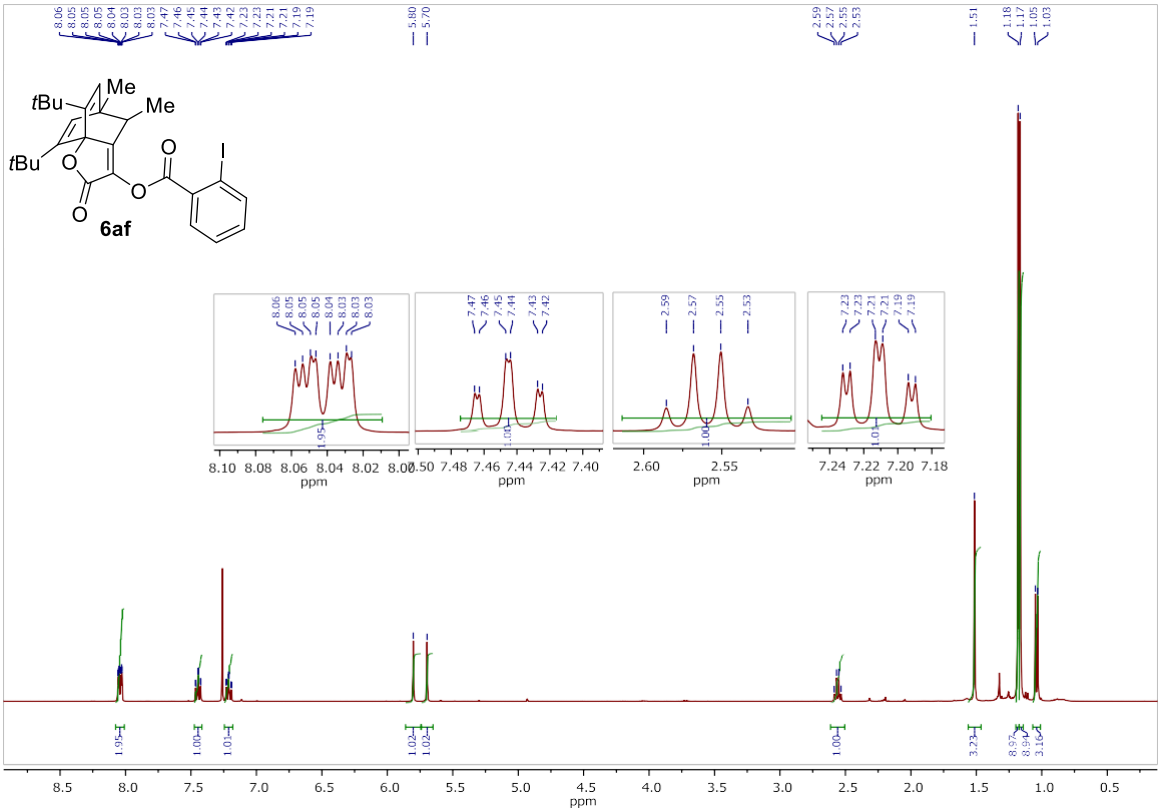
^{13}C-NMR (100 MHz, $CDCl_3$) of of compound **6ae**



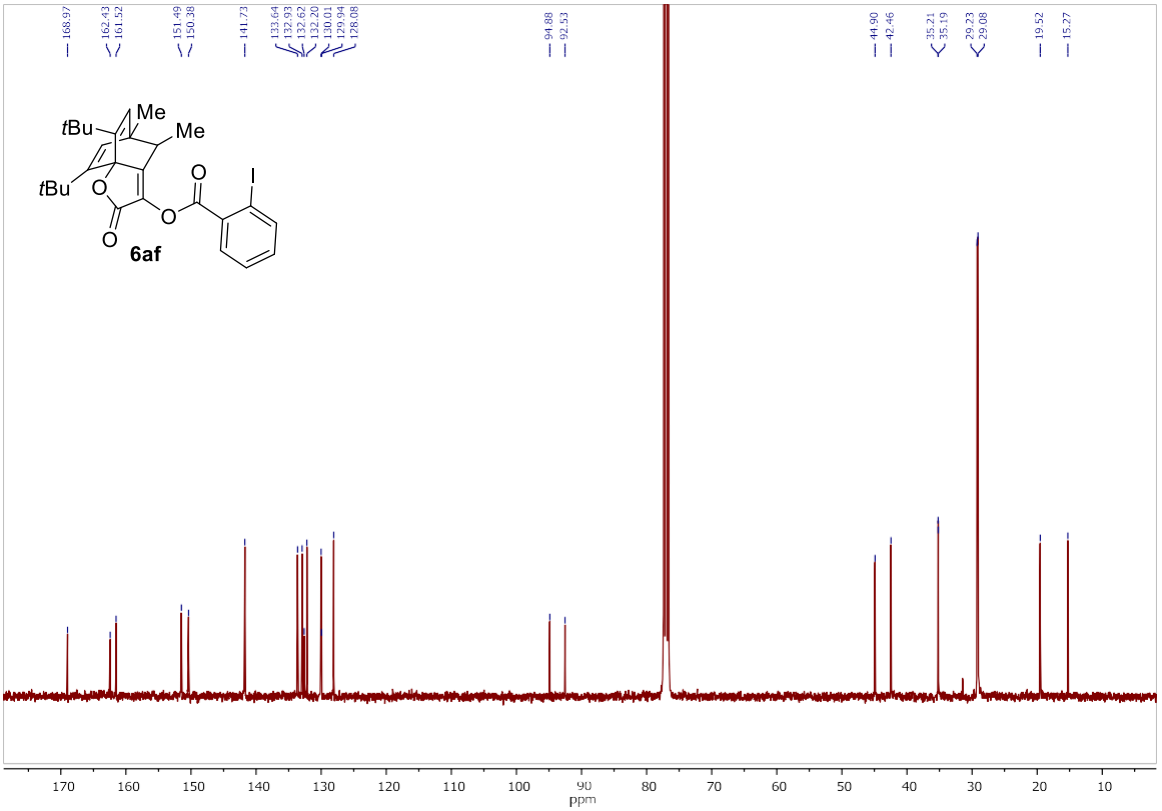
IR of compound **6ae**



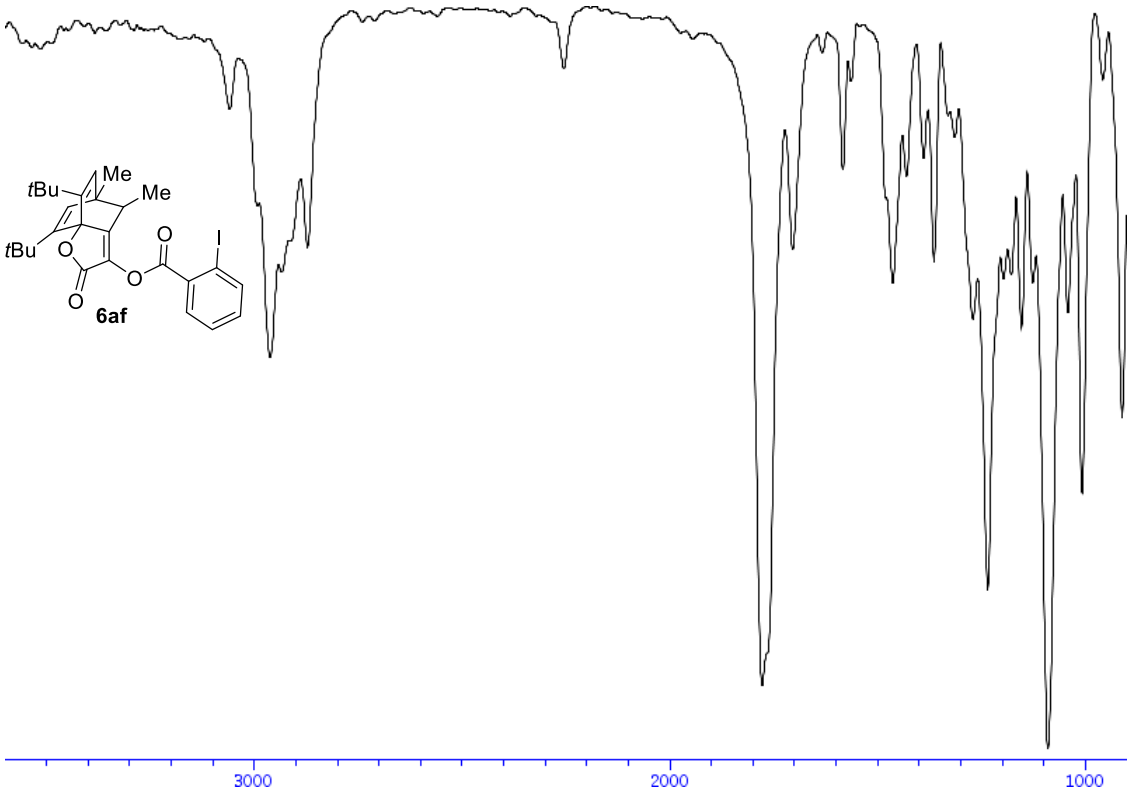
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6af**



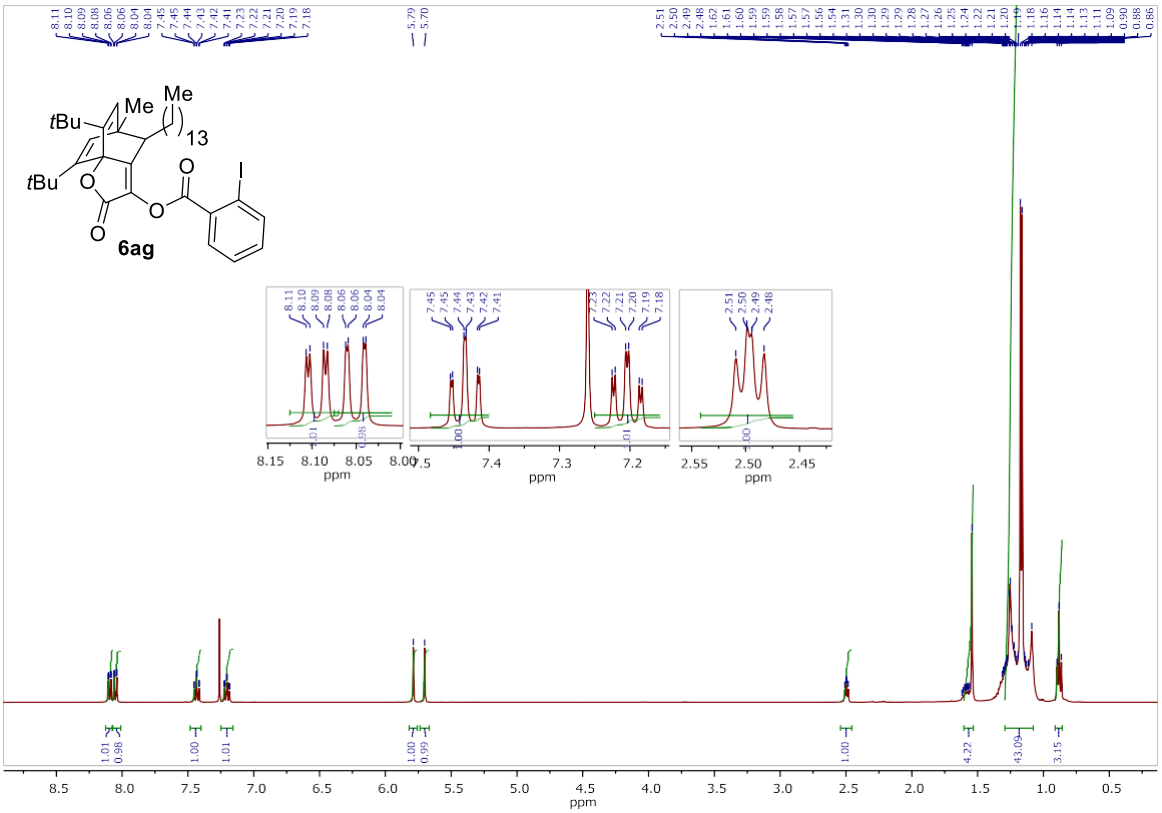
^{13}C-NMR (100 MHz, $CDCl_3$) of of compound **6af**



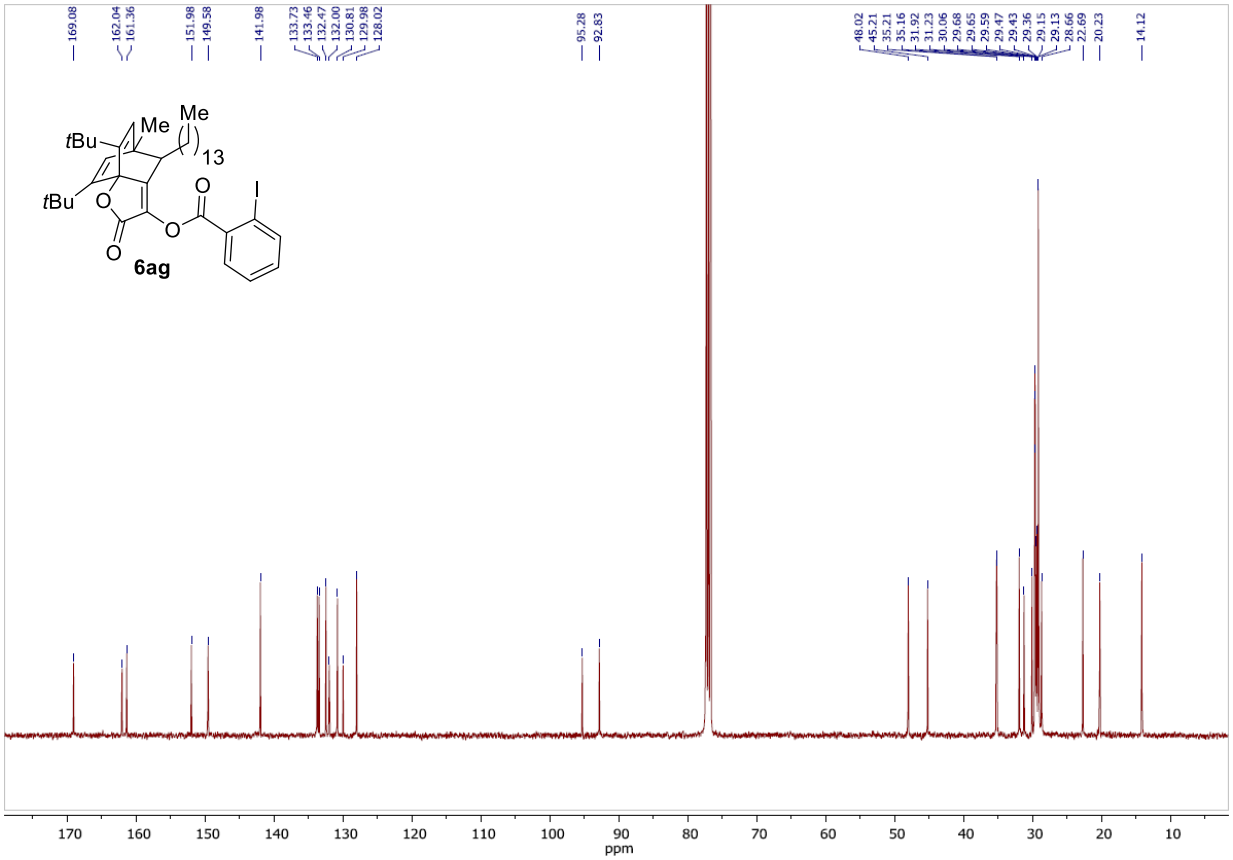
IR of compound **6af**



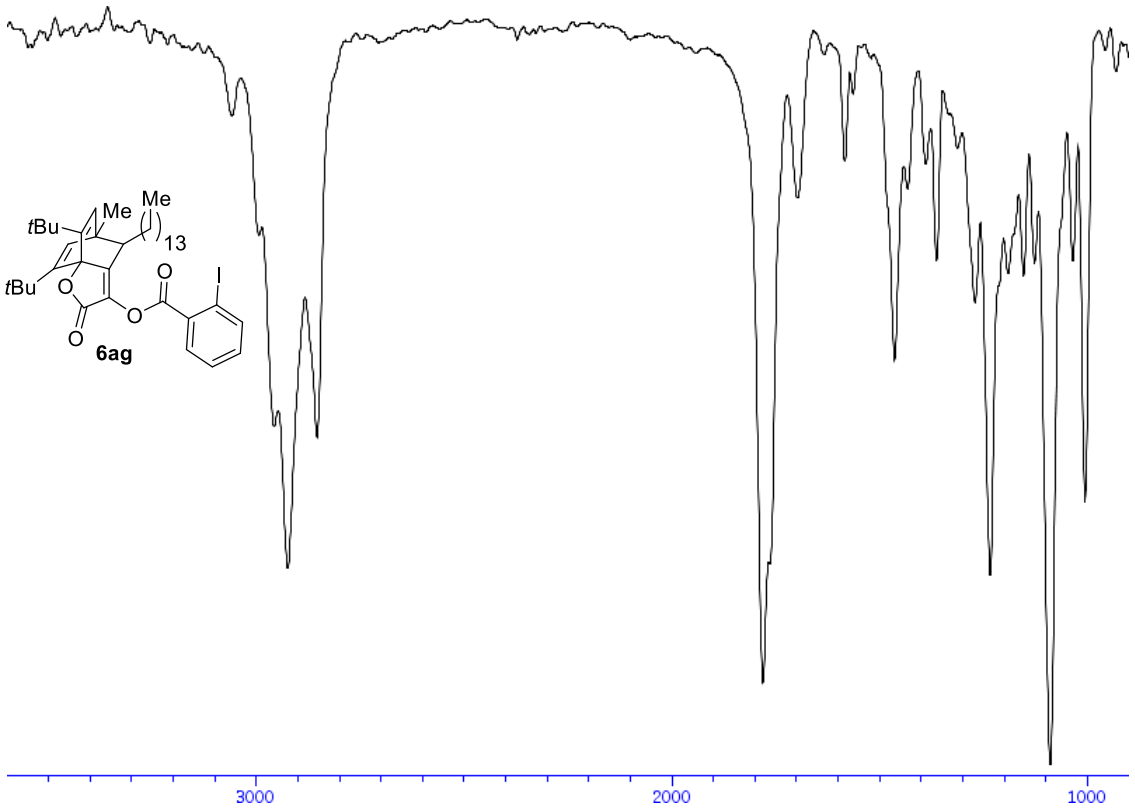
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ag**



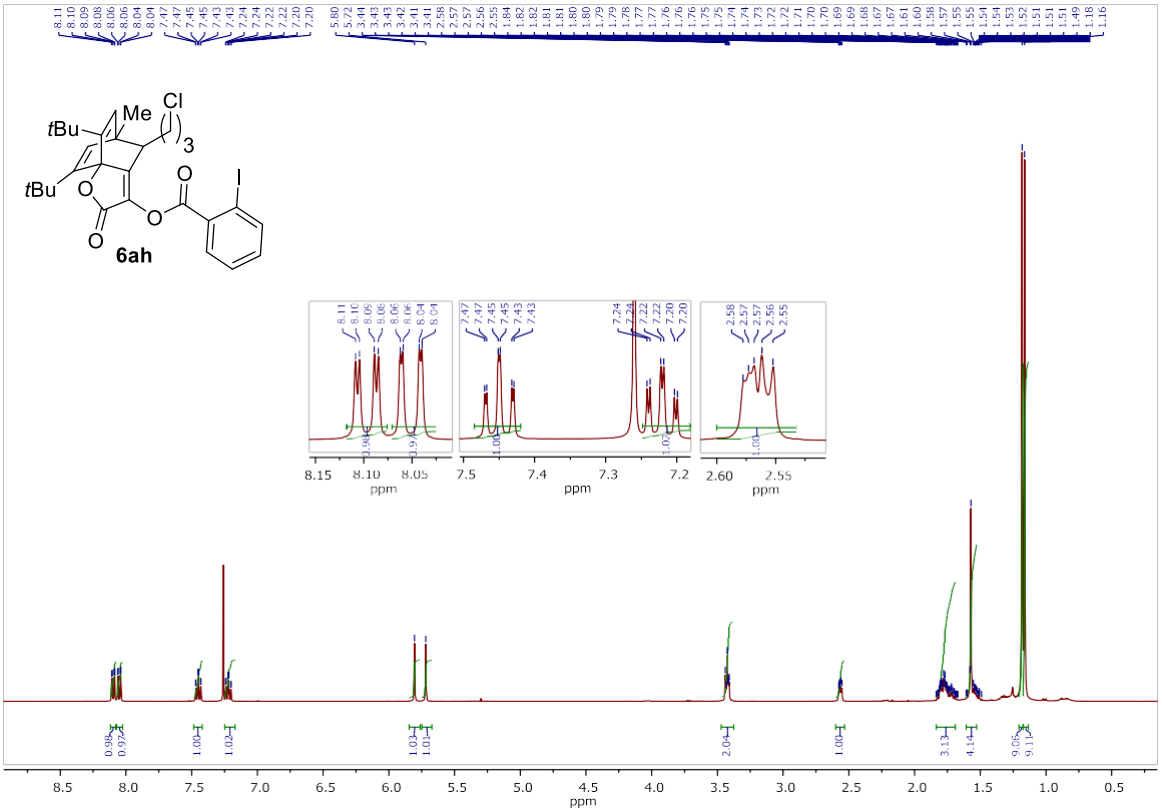
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ag**



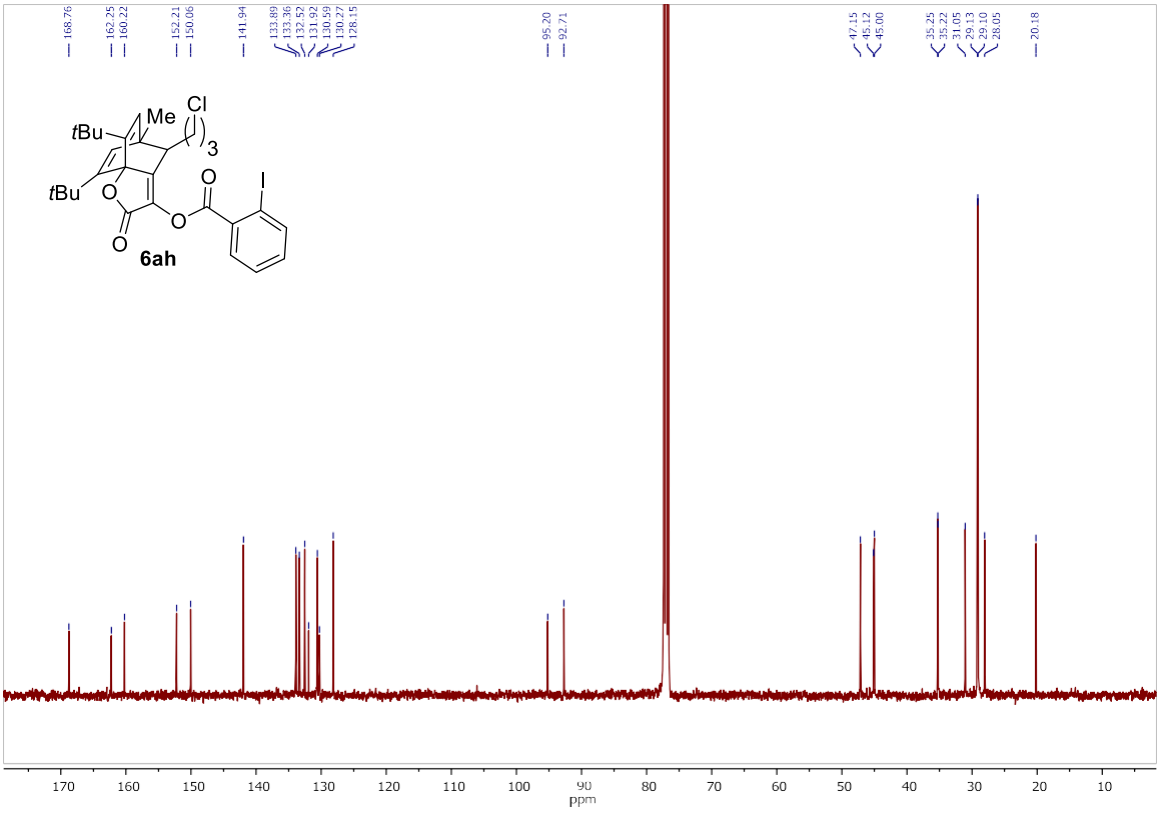
IR of compound **6ag**



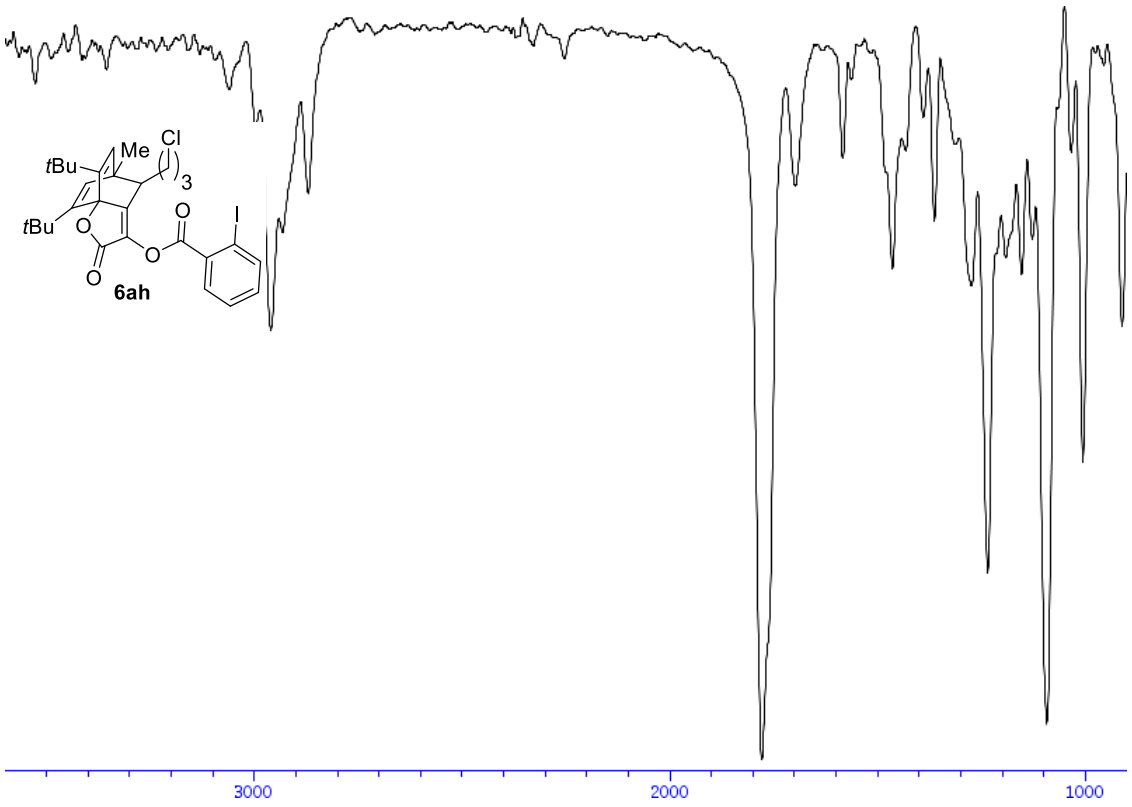
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ah**



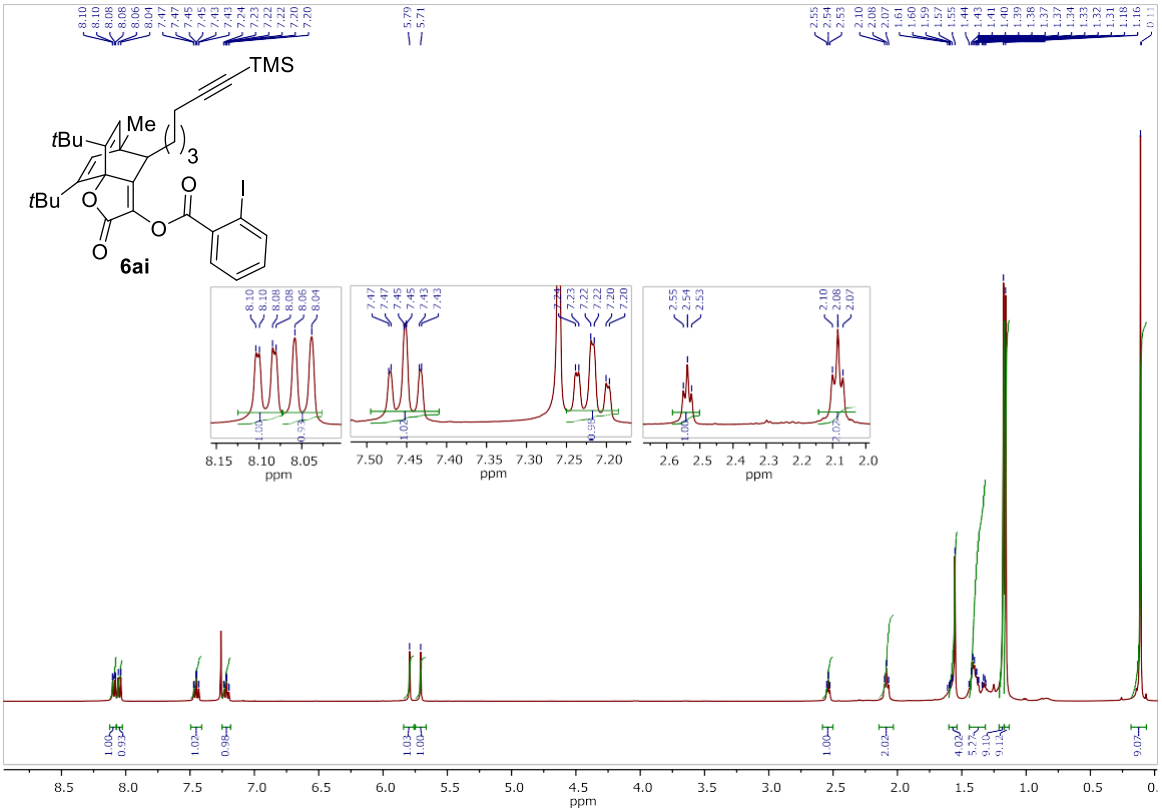
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ah**



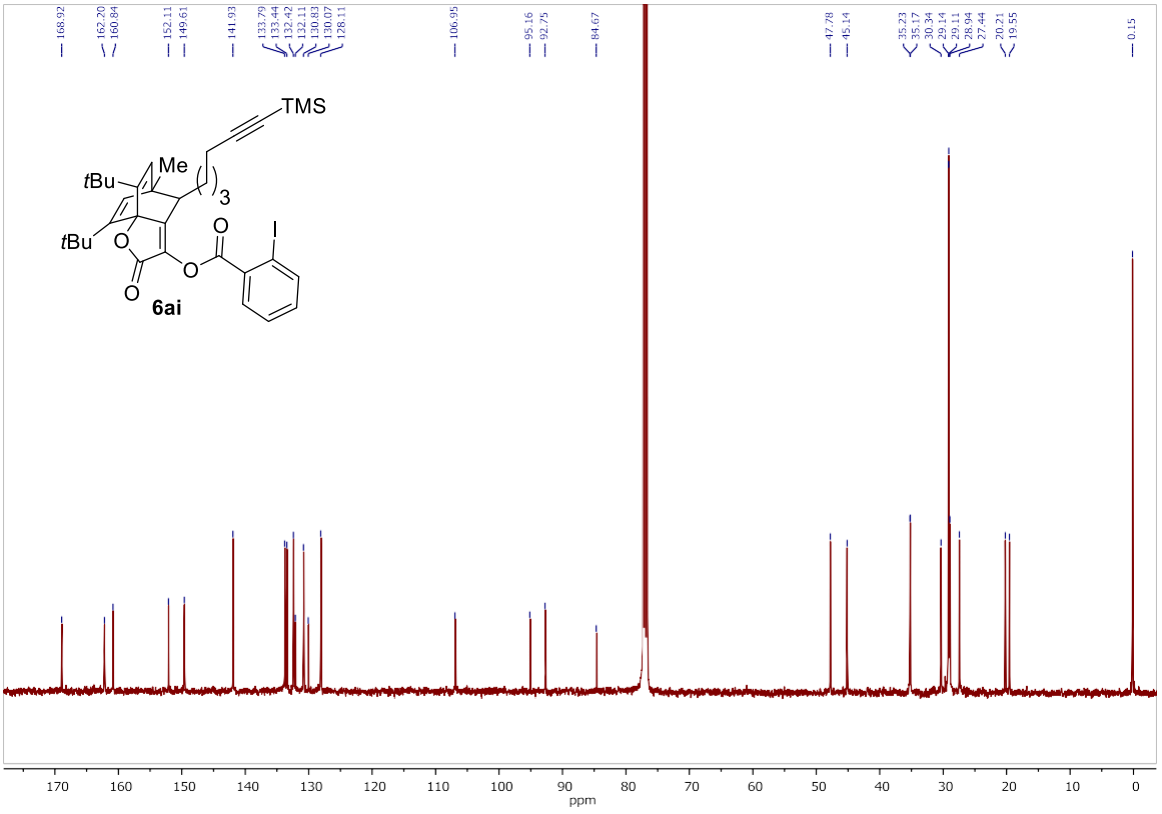
IR of compound **6ah**



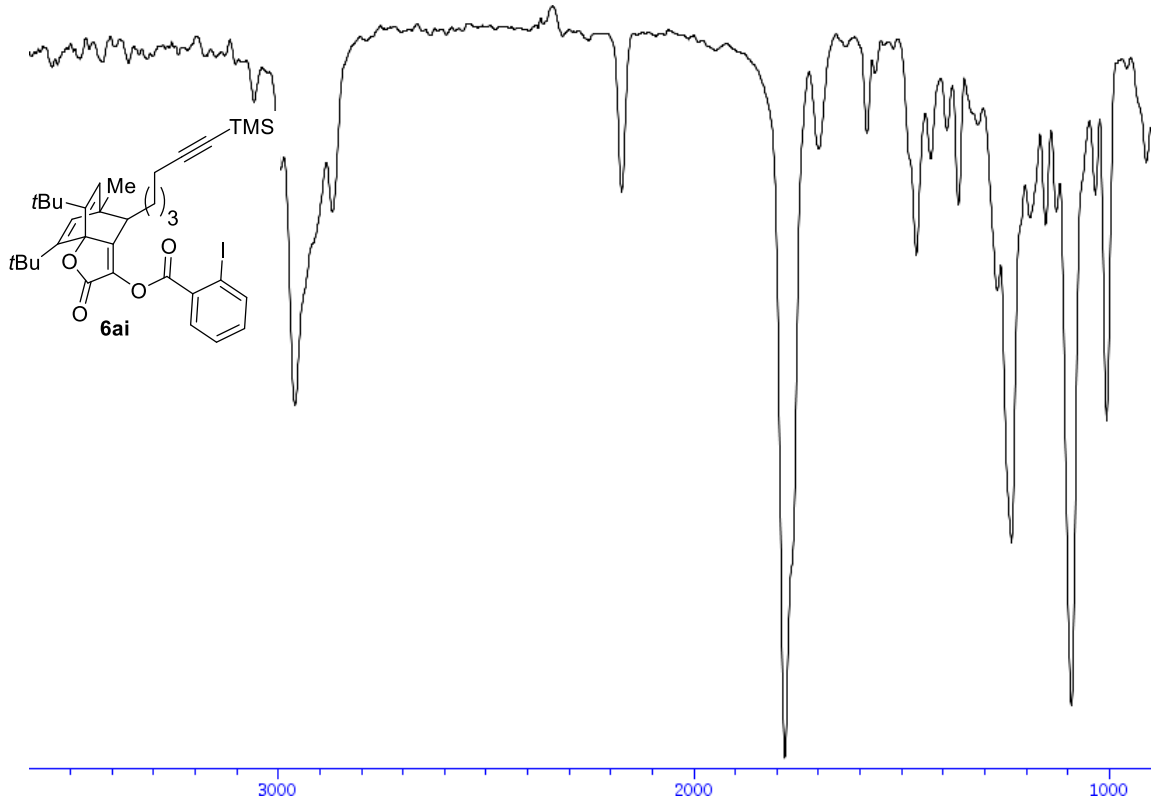
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ai**



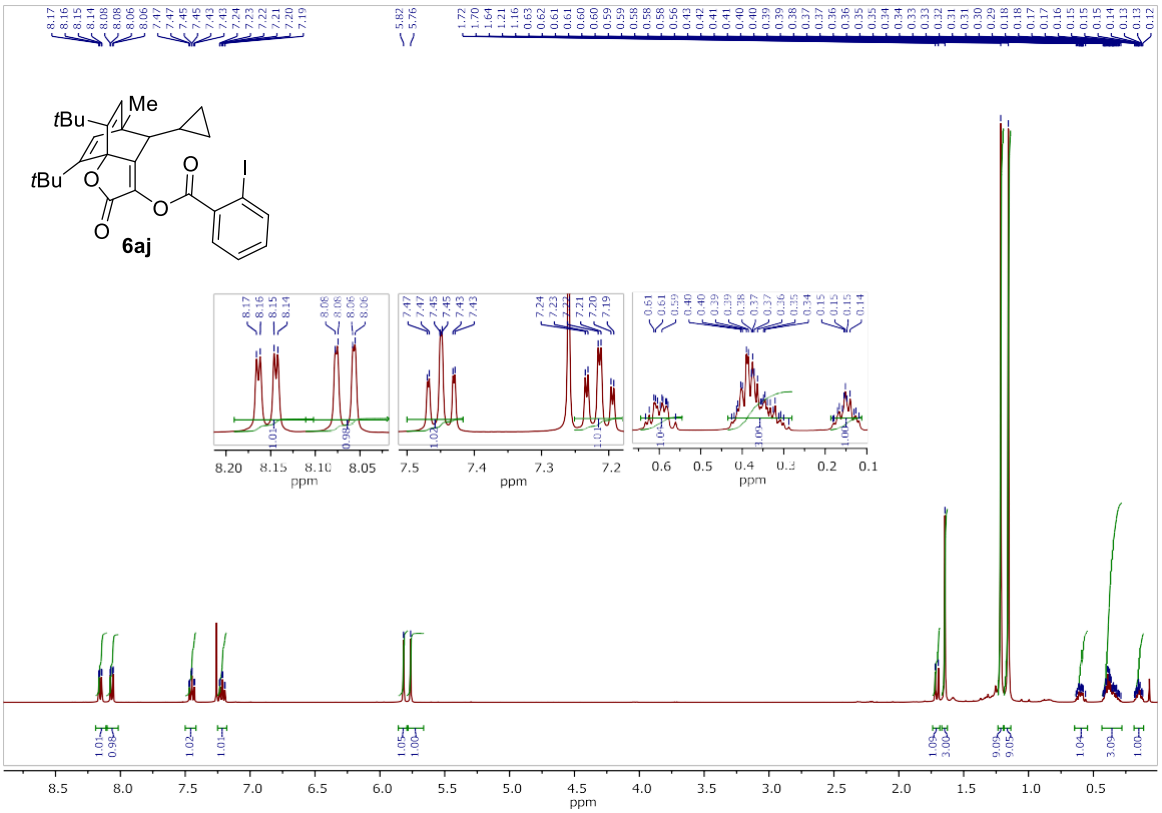
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ai**



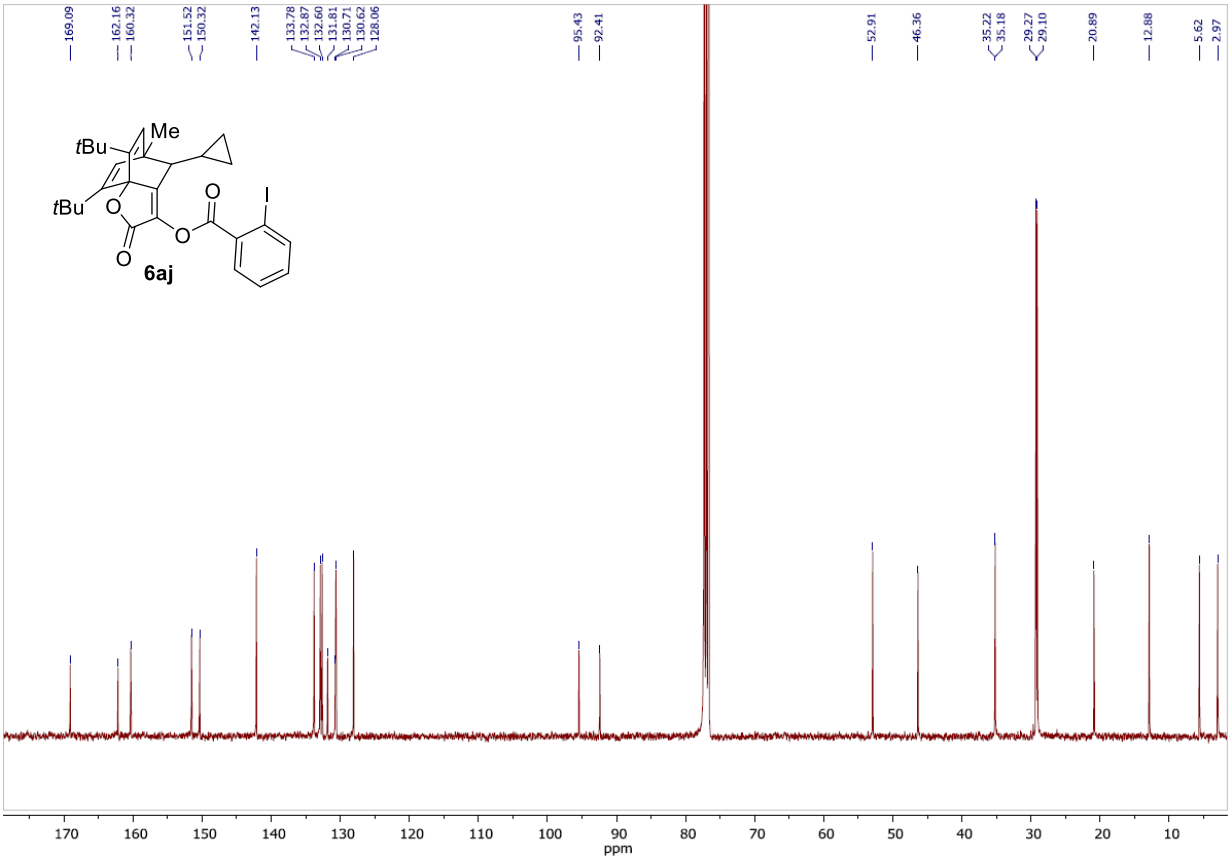
IR of compound **6ai**



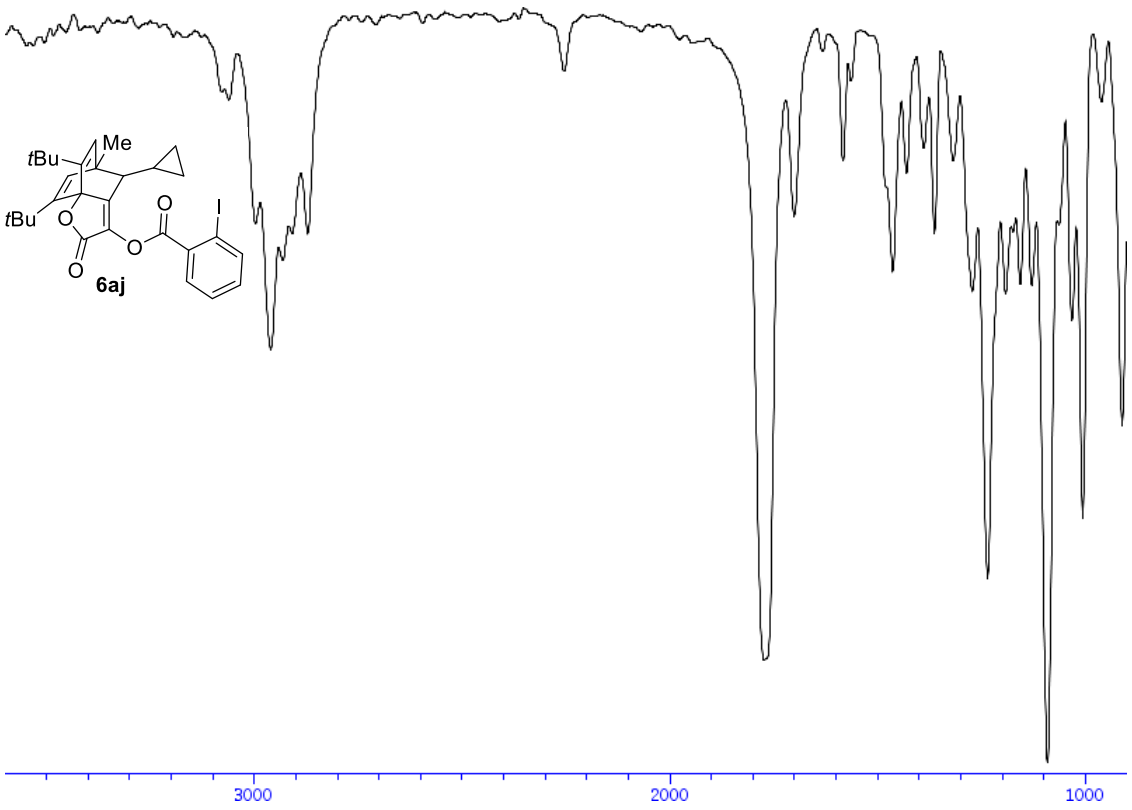
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6aj**



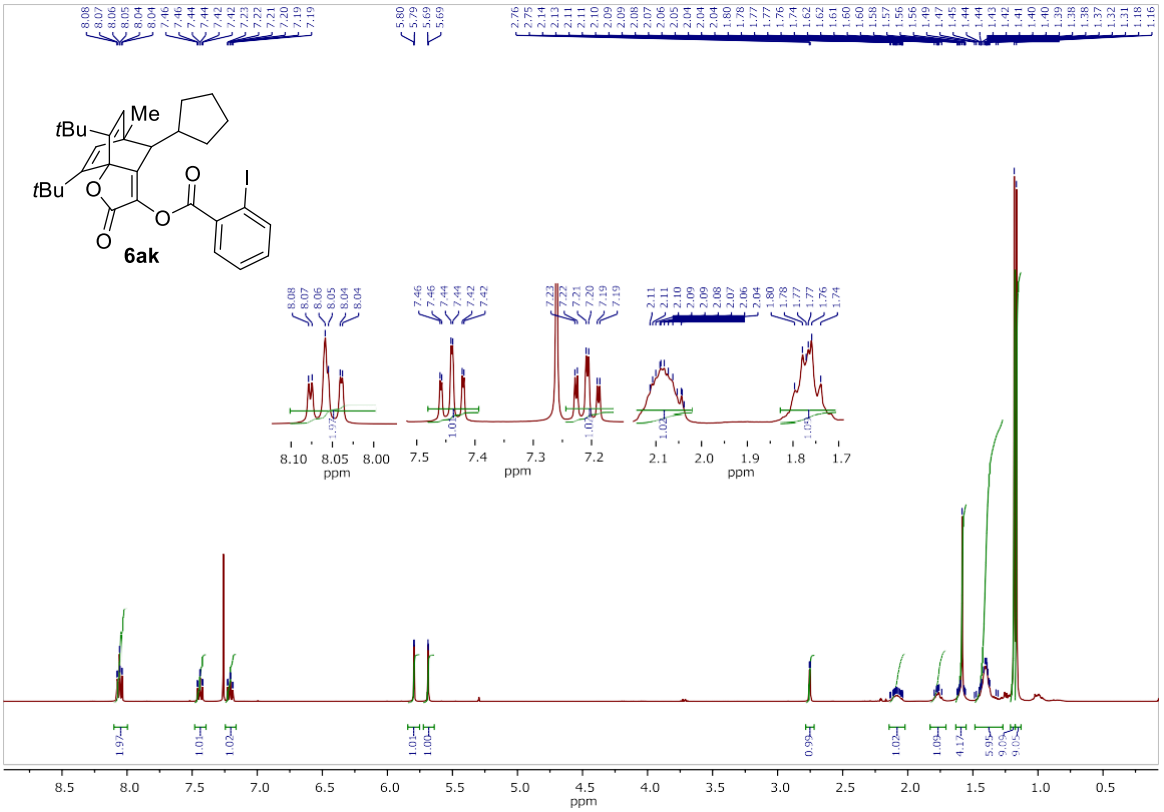
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6aj**



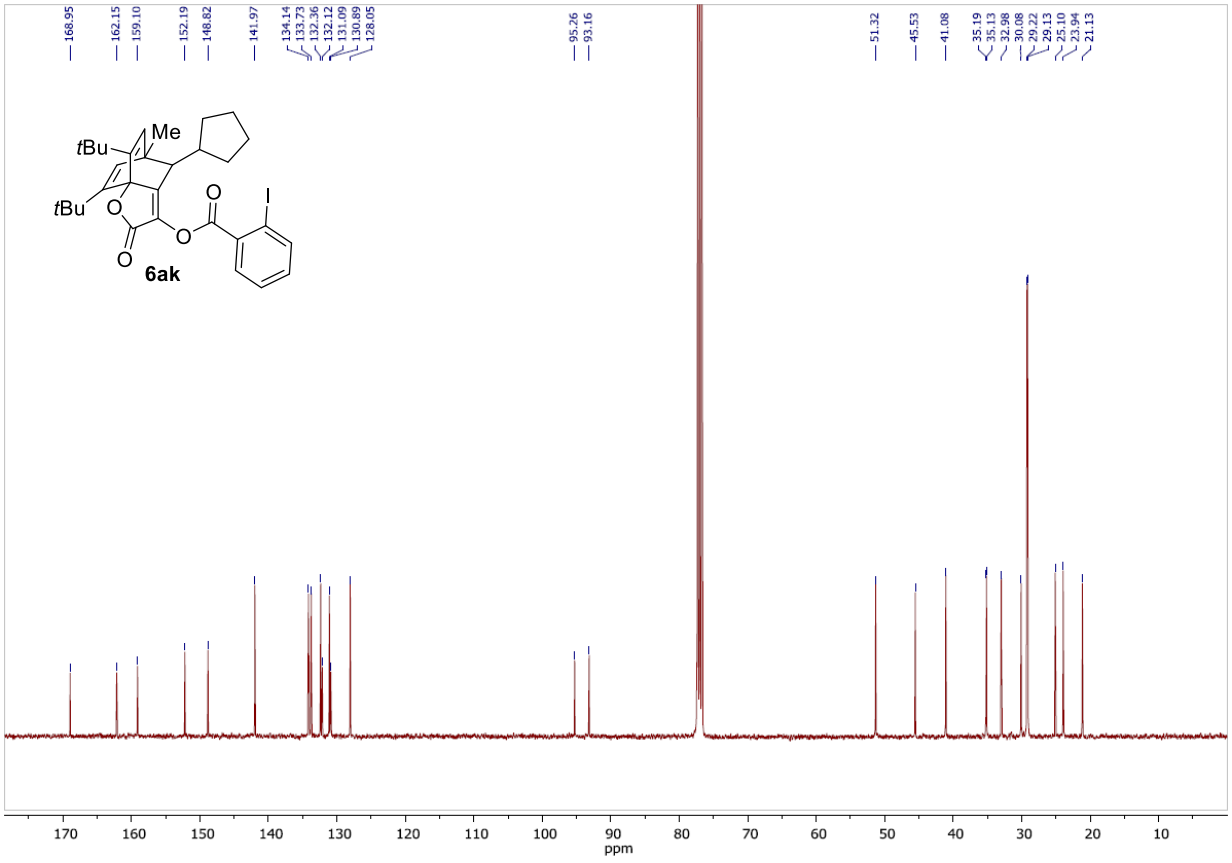
IR of compound **6aj**



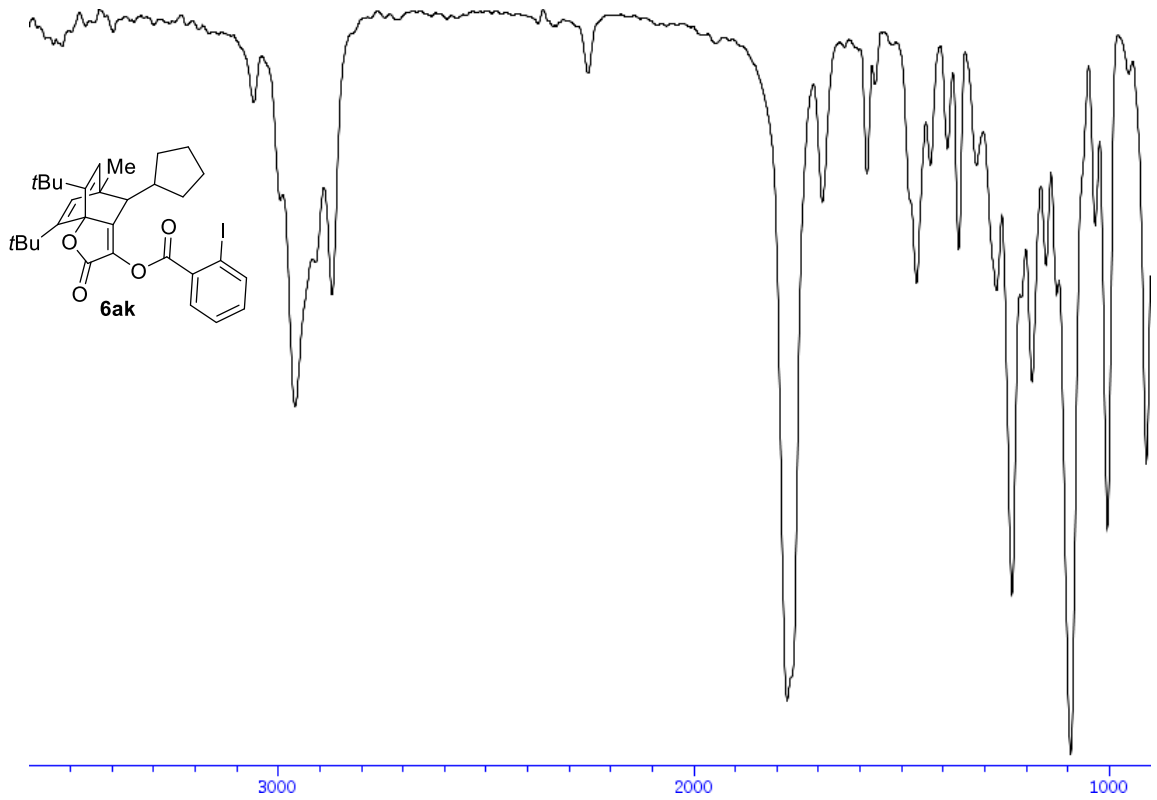
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6ak**



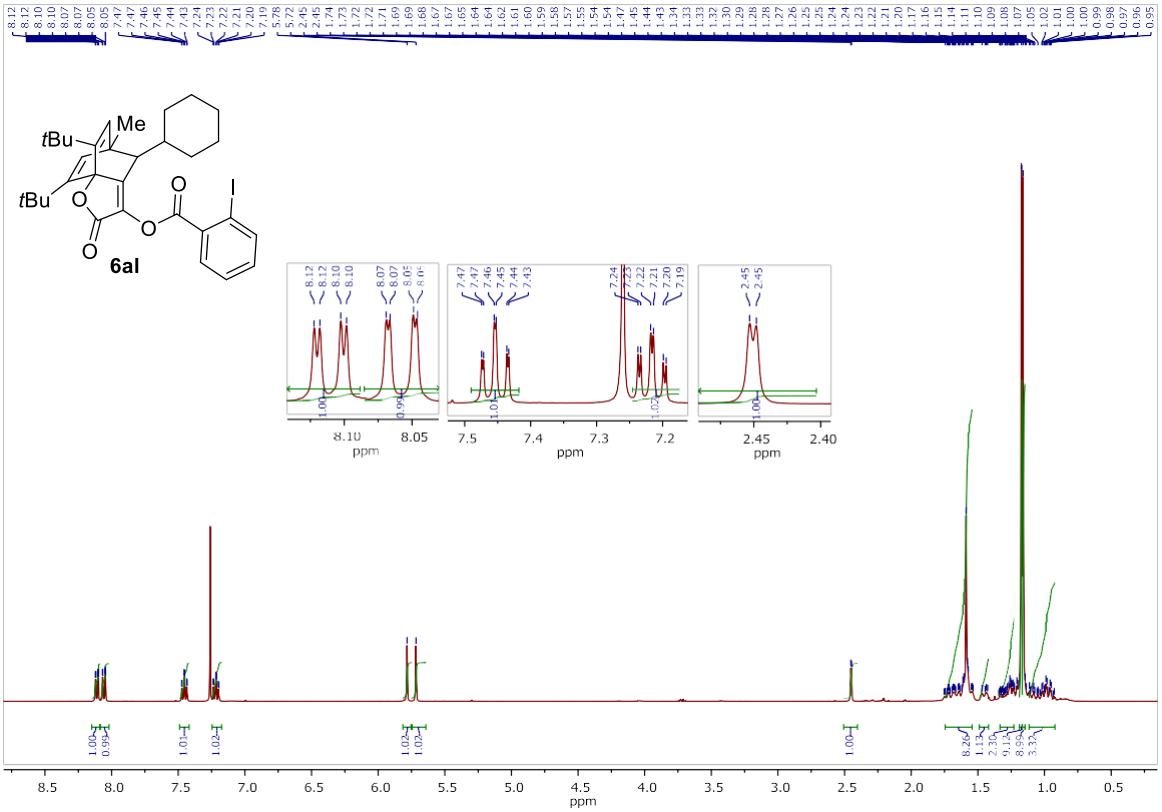
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6ak**



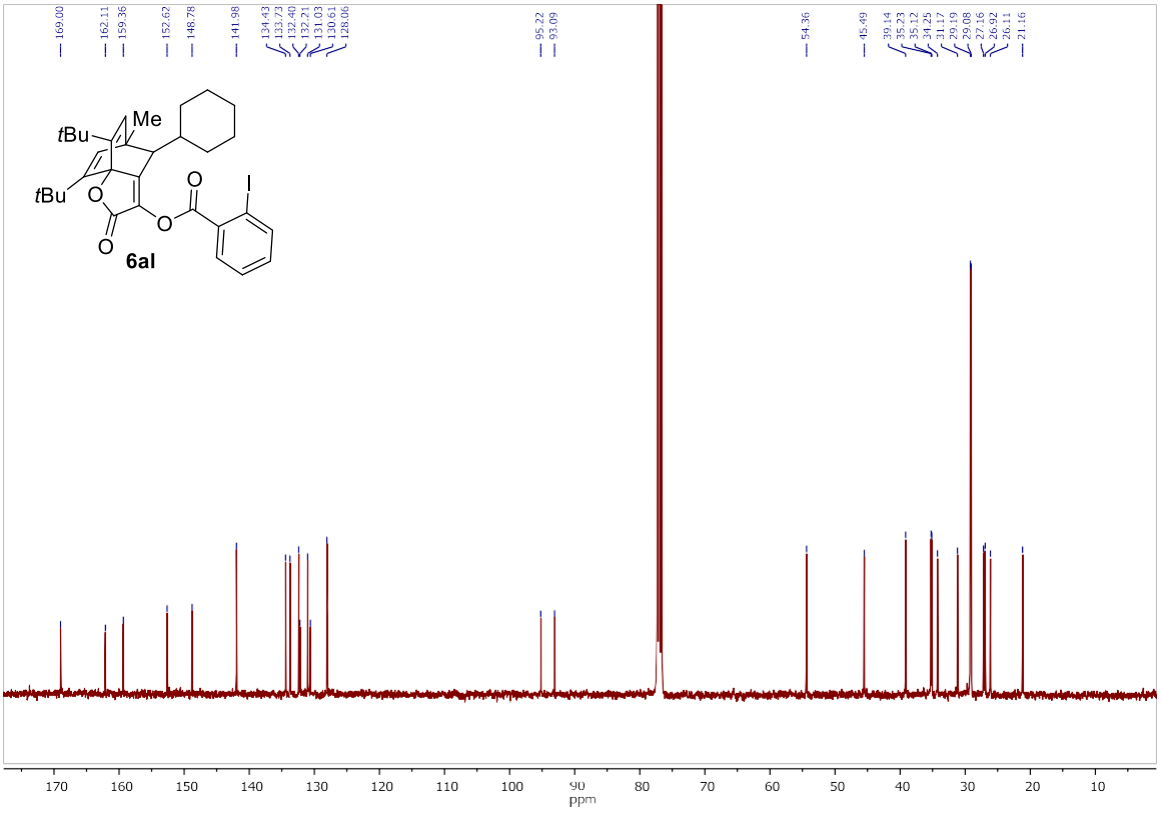
IR of compound **6ak**



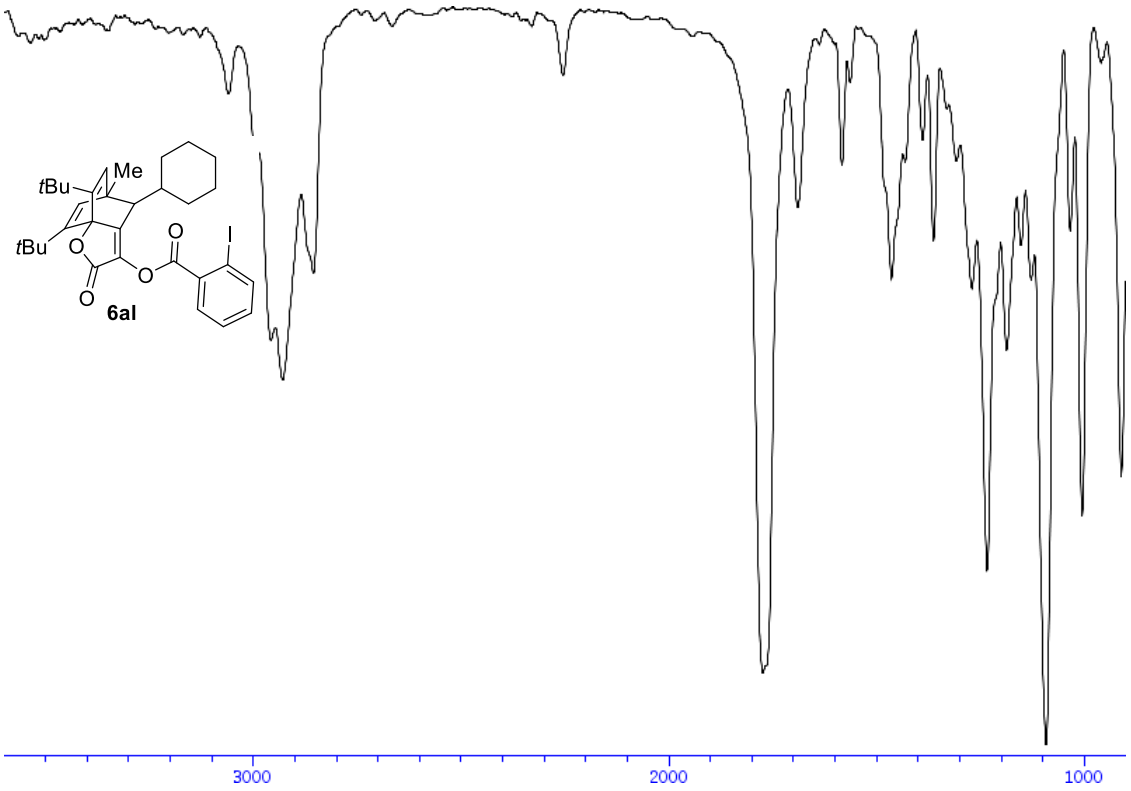
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **6al**



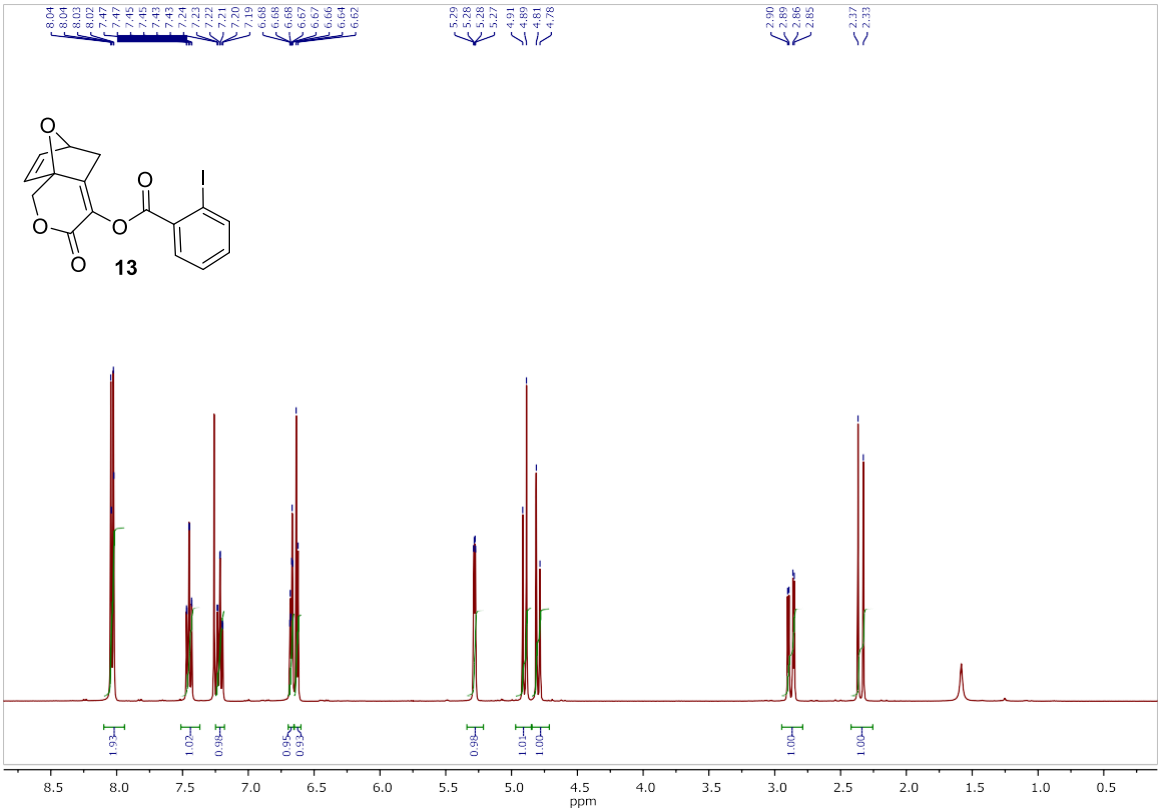
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **6al**



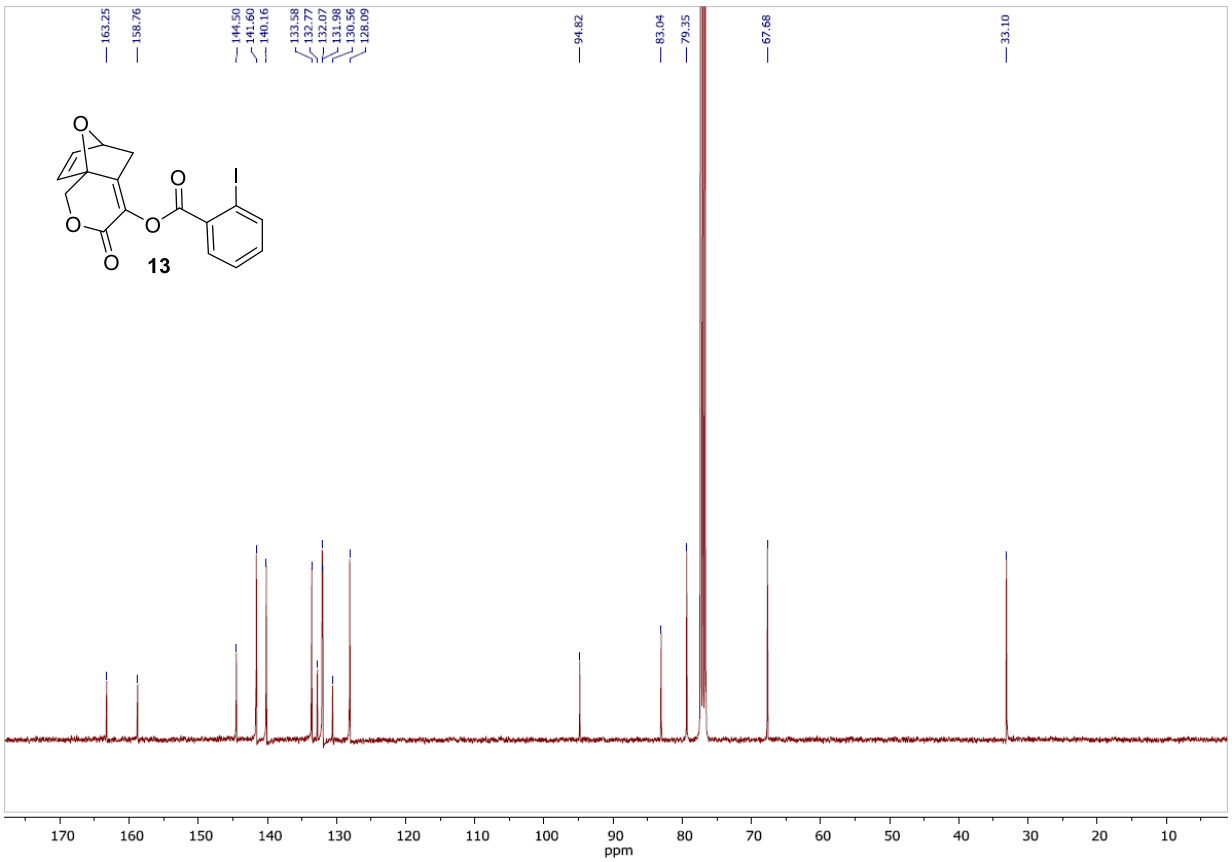
IR of compound **6al**



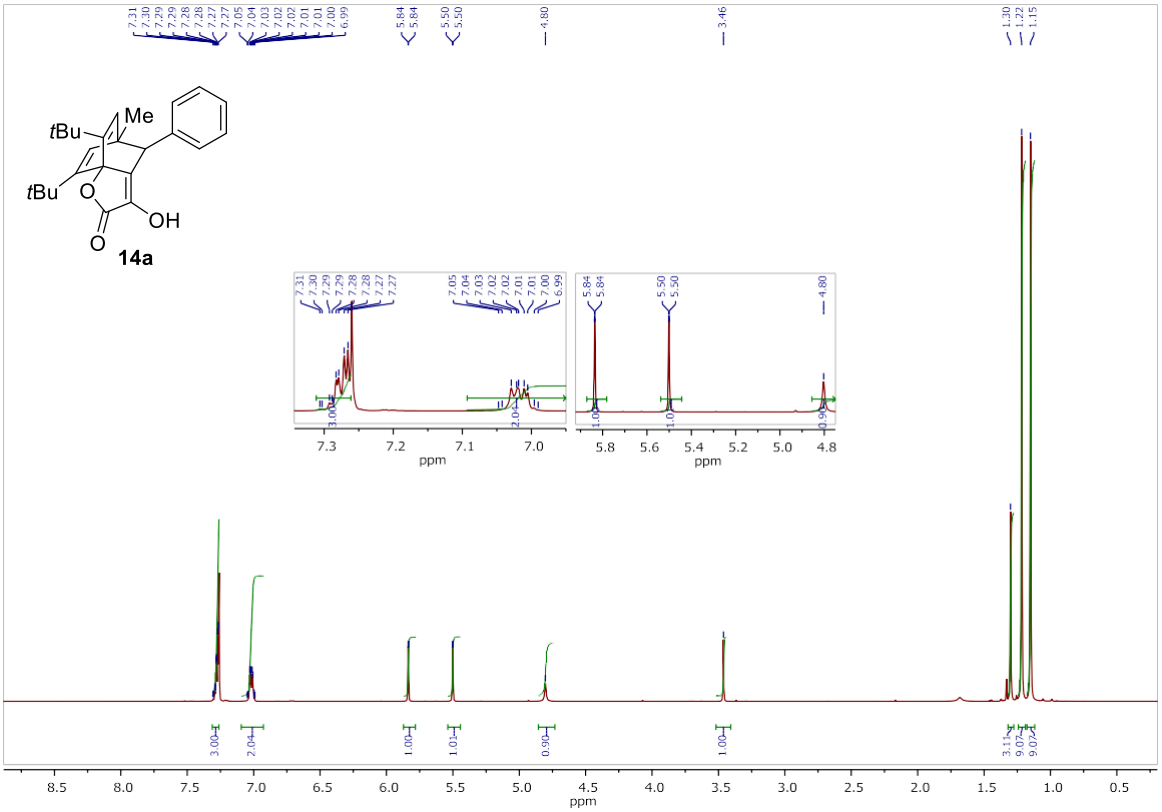
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **13**



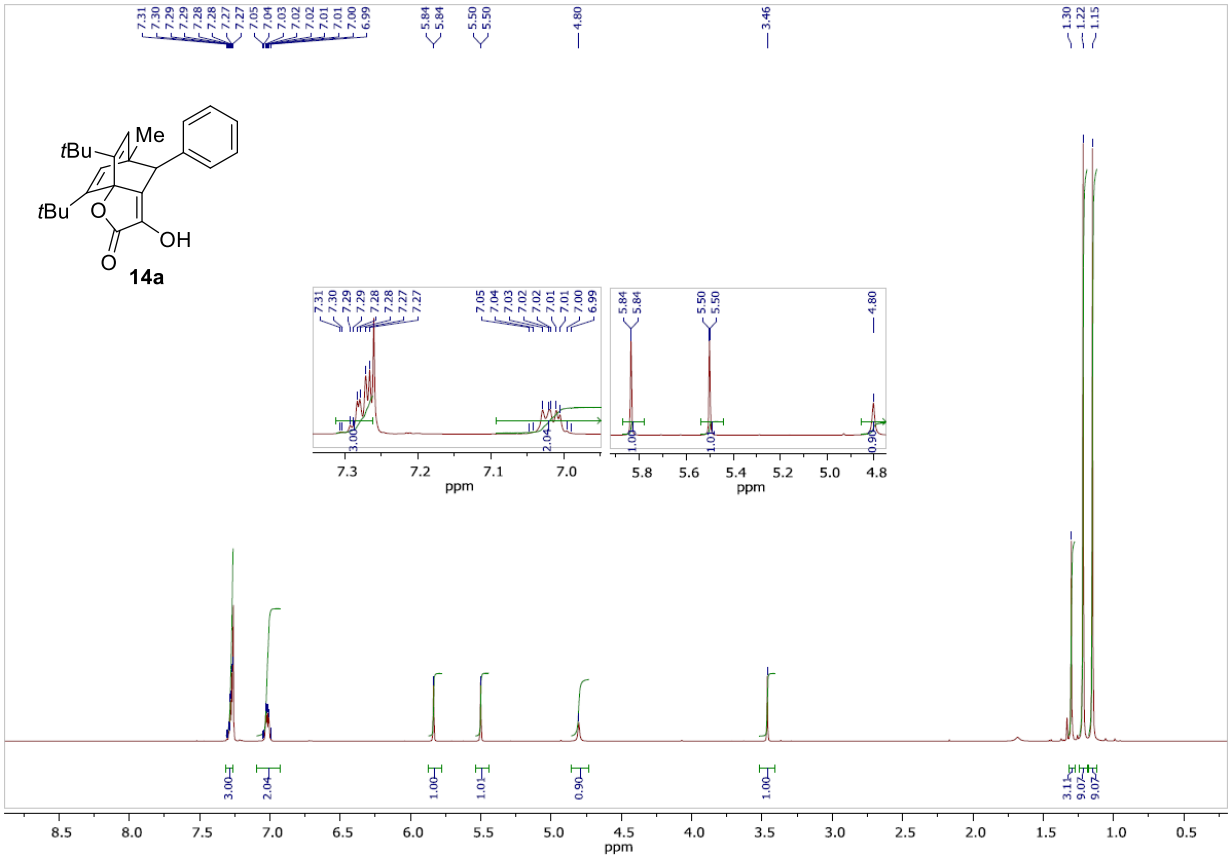
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **13**



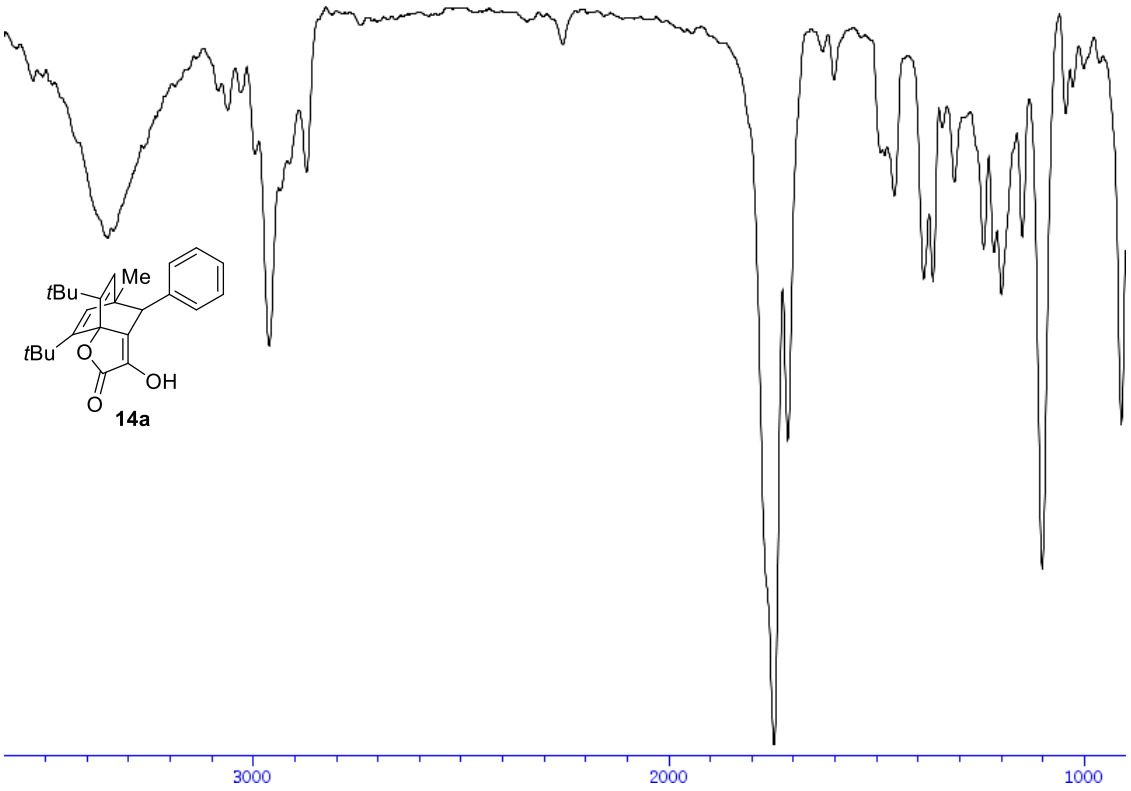
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **14a**



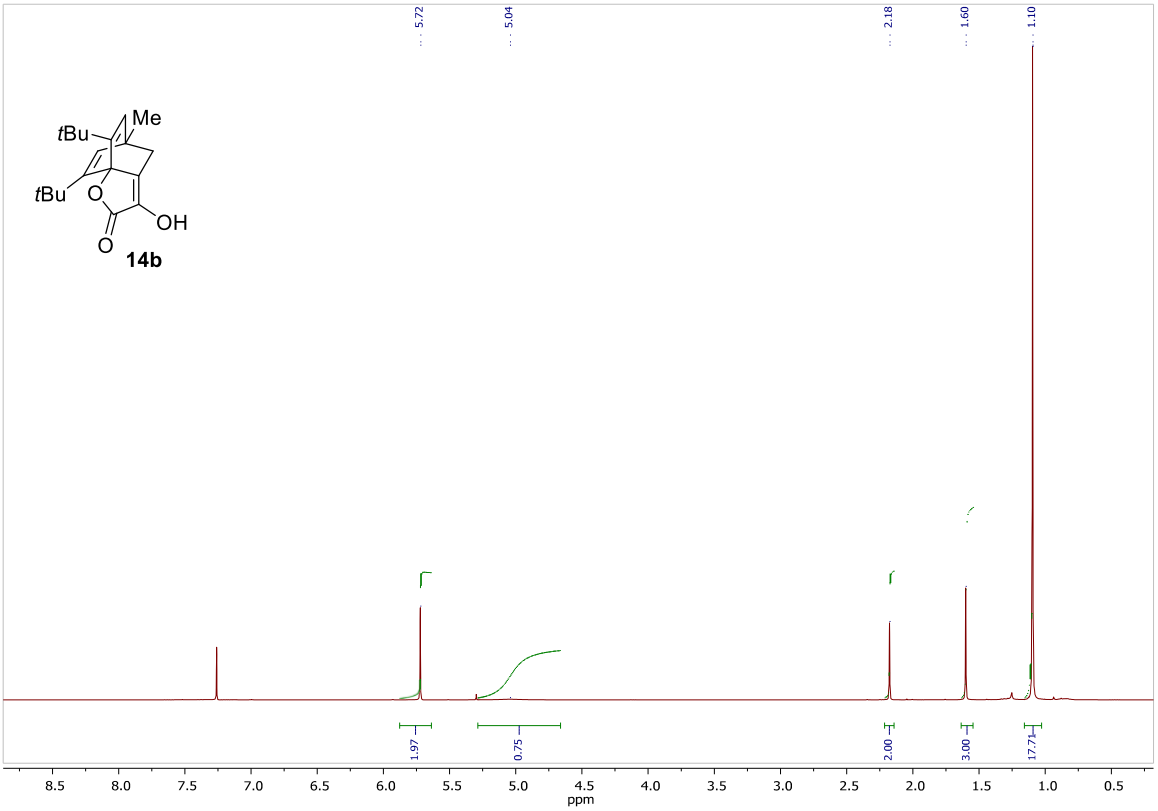
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **14a**



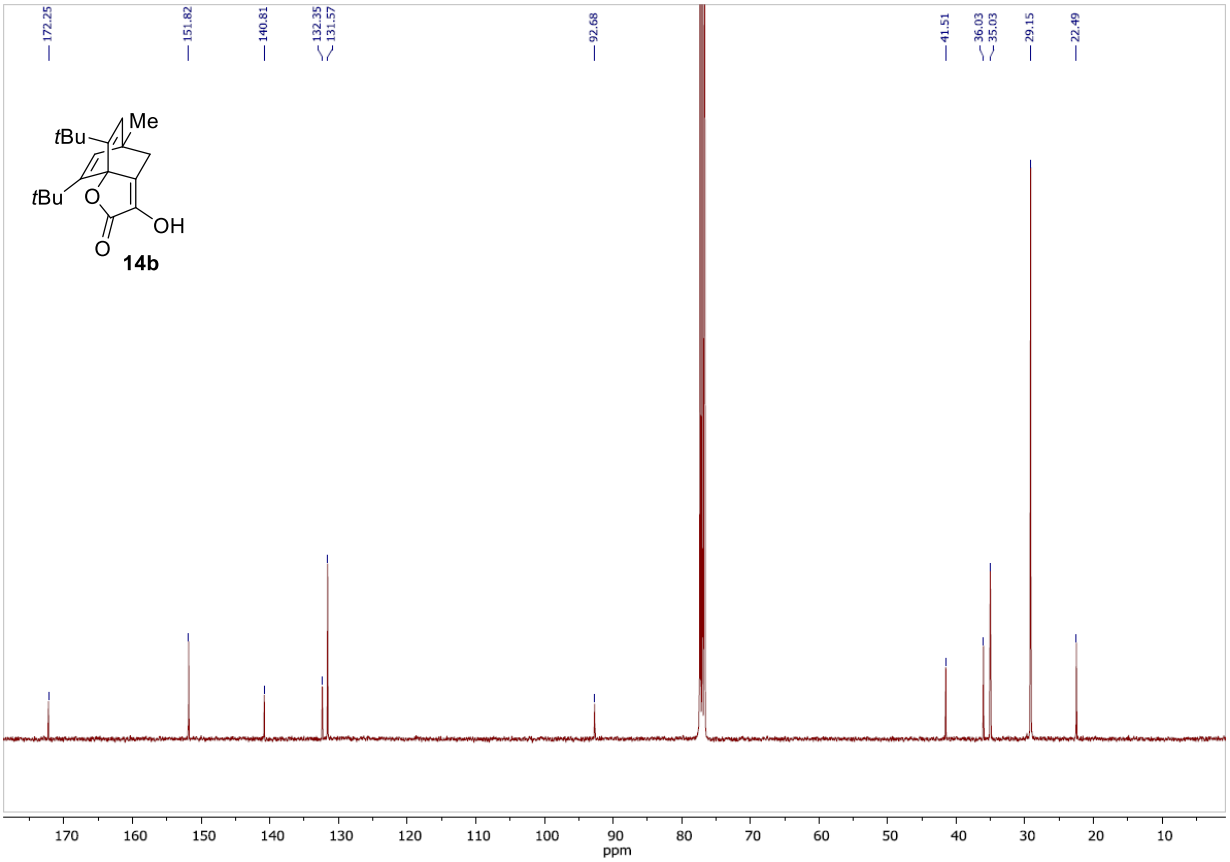
IR of compound **14a**



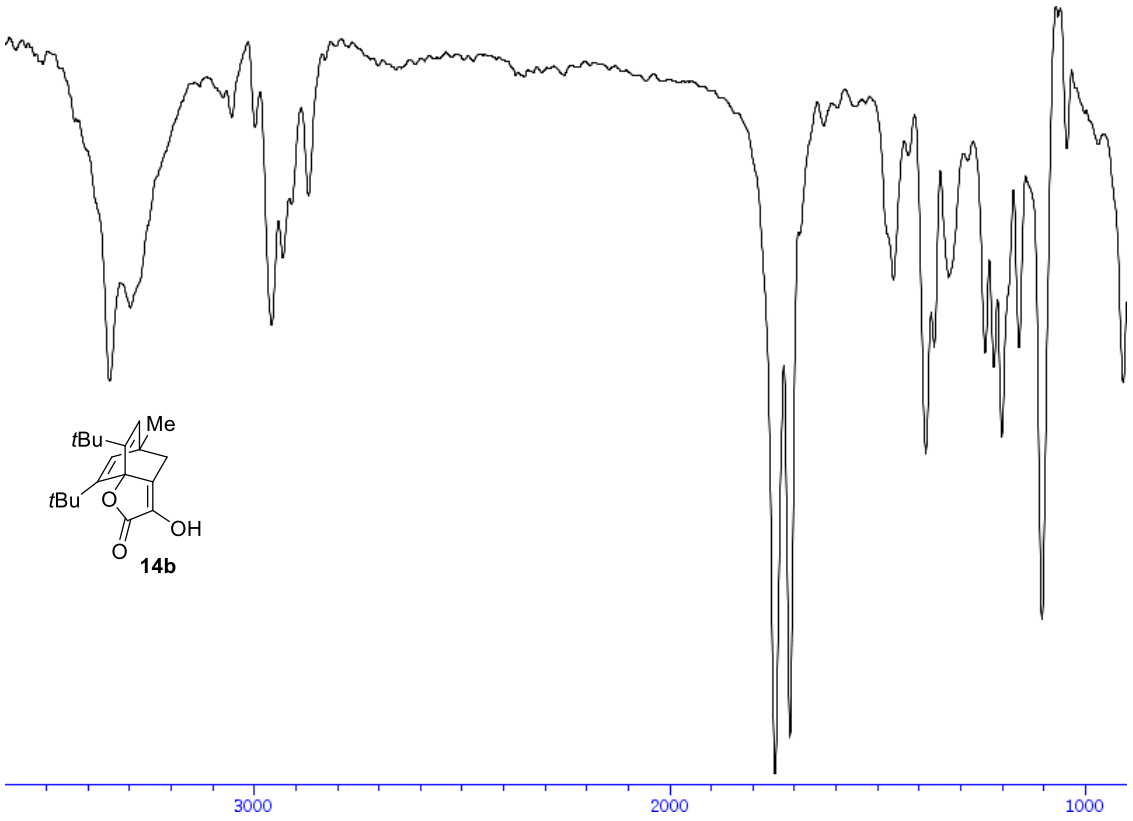
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **14b**



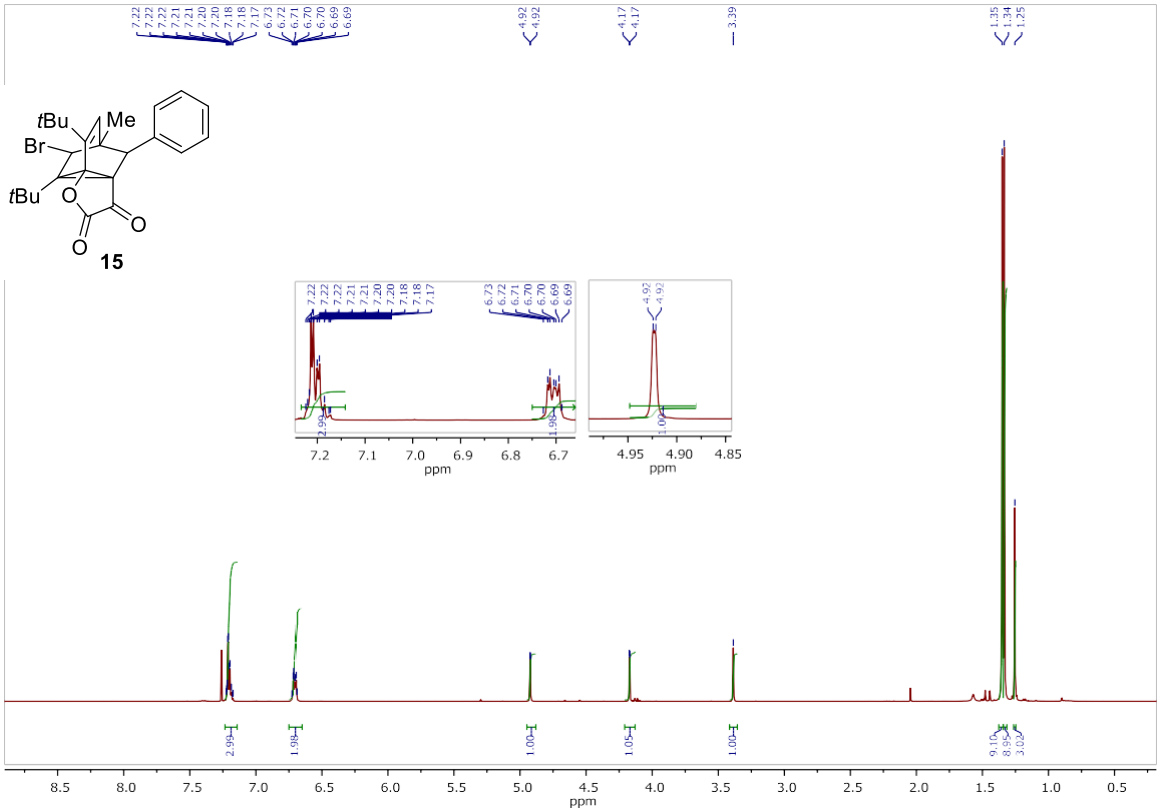
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **14b**



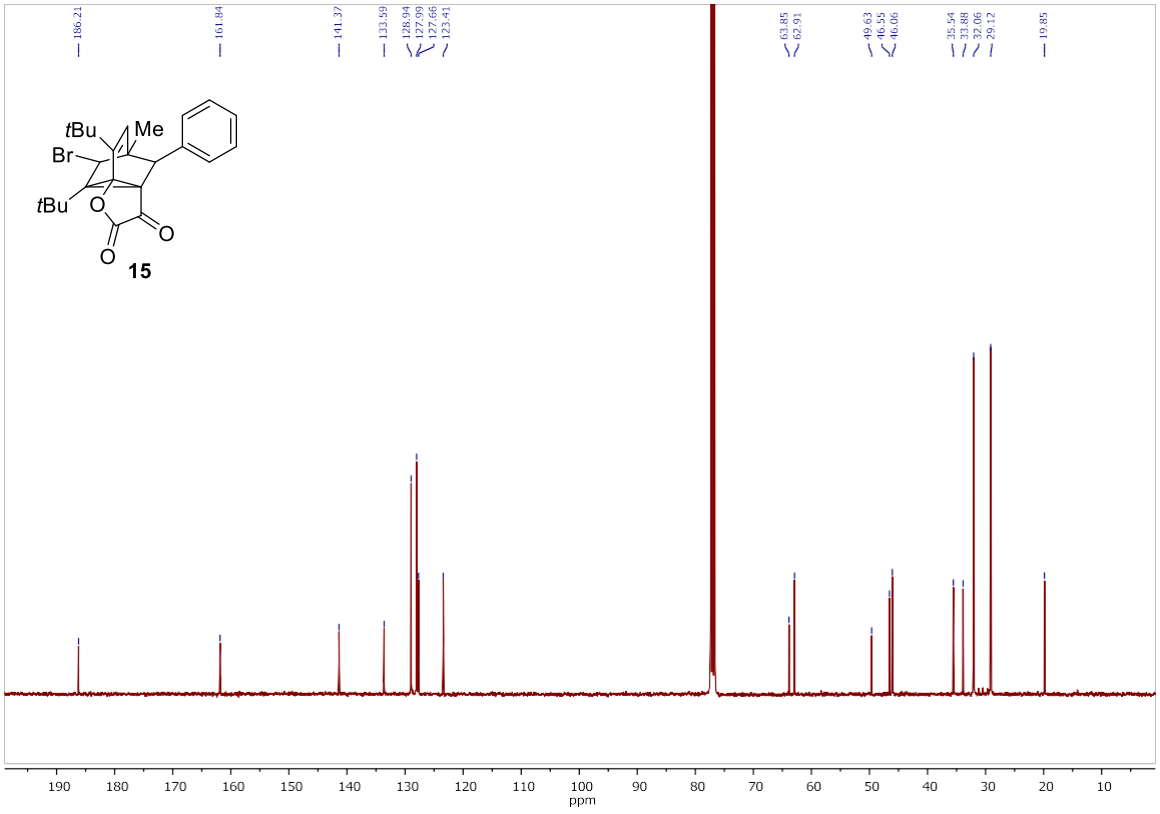
IR of compound **14b**



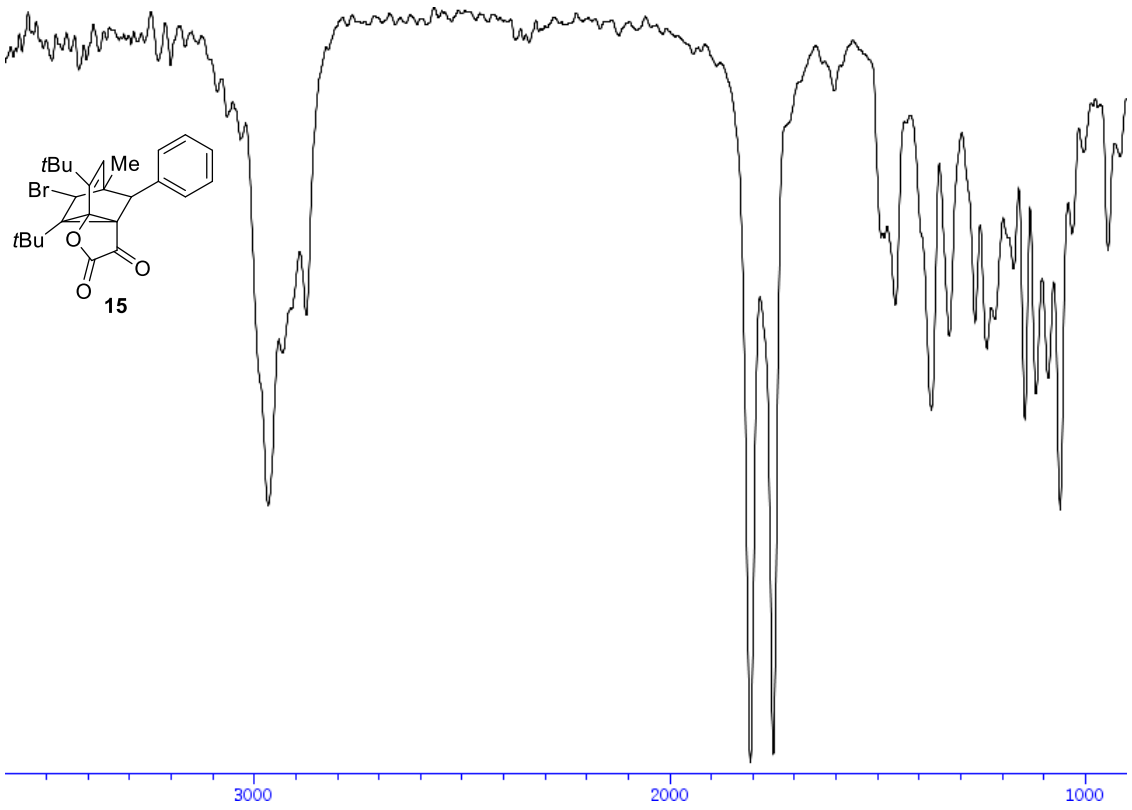
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **15**



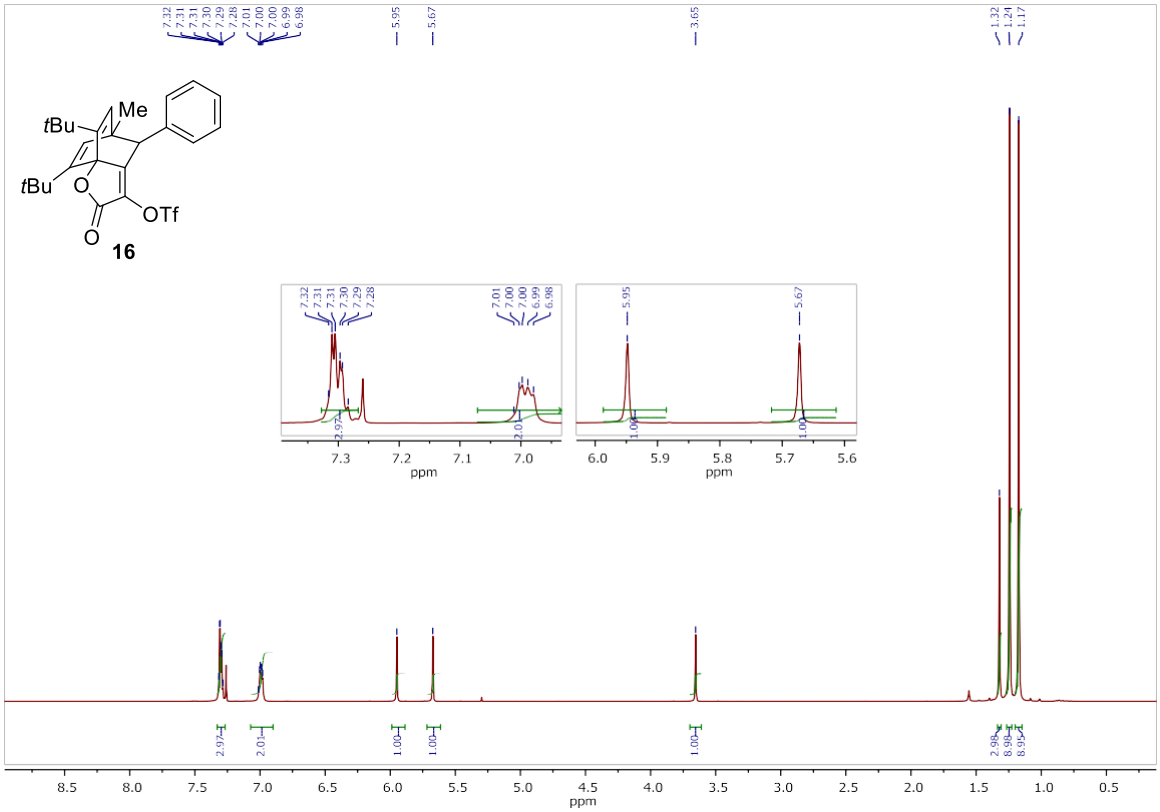
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **15**



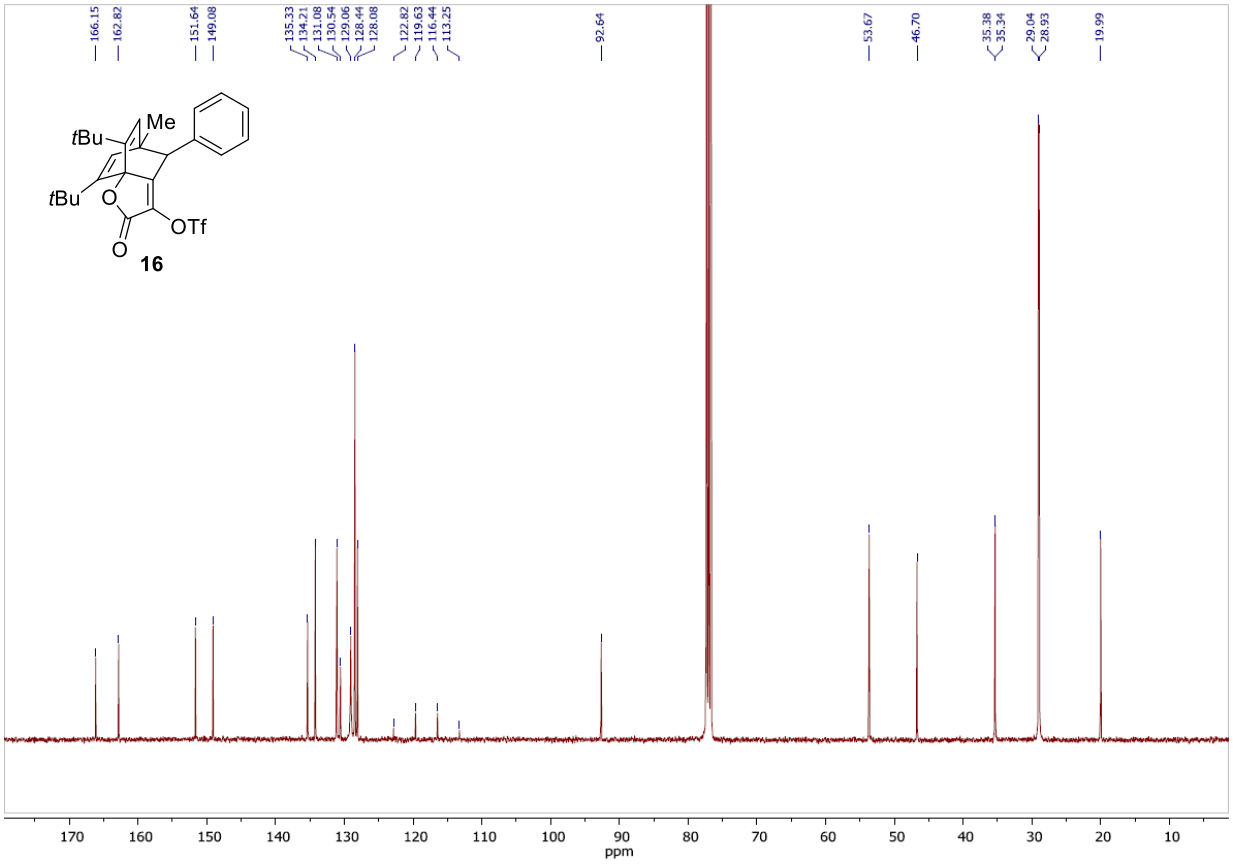
IR of compound **15**



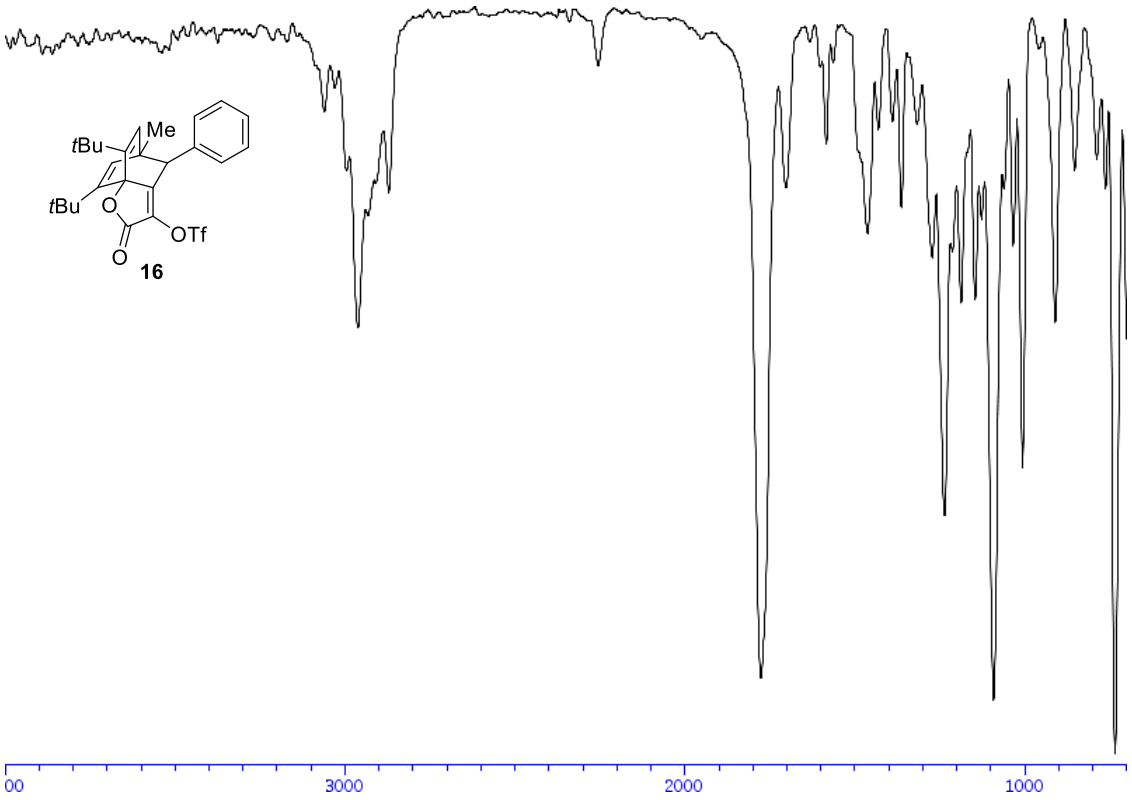
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **16**



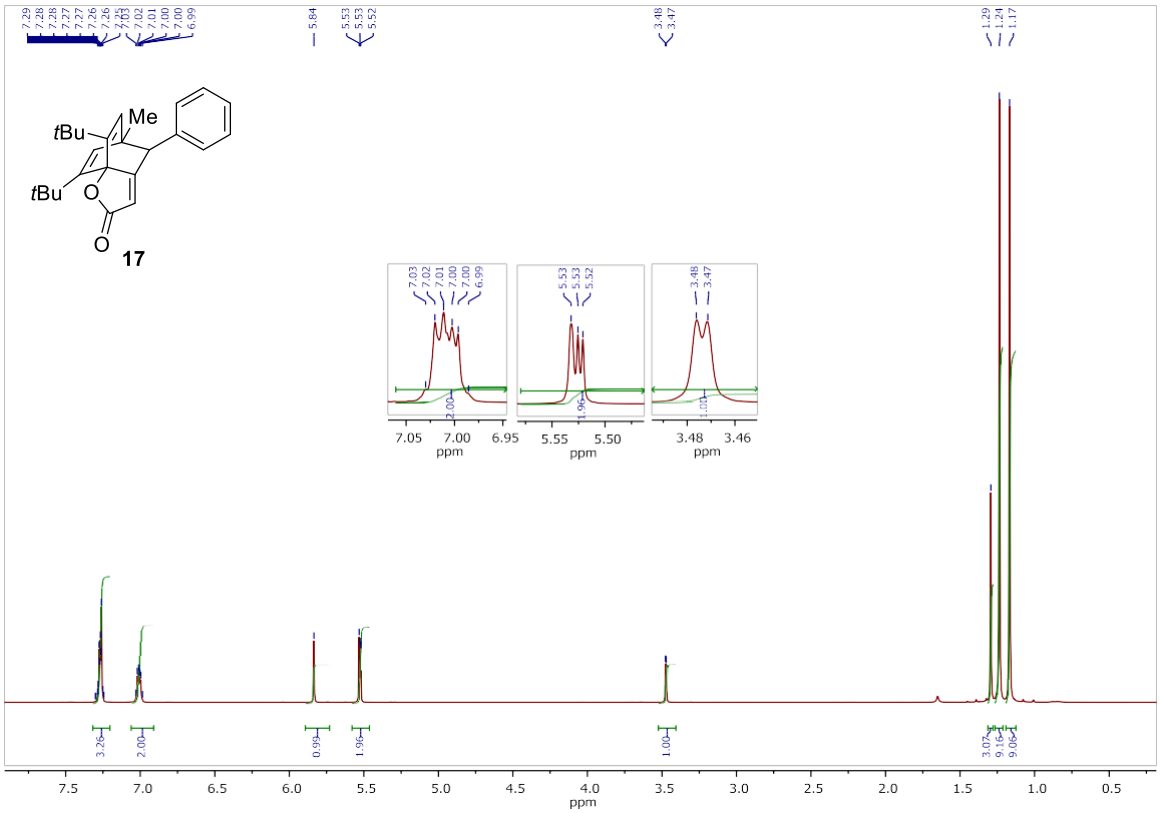
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **16**



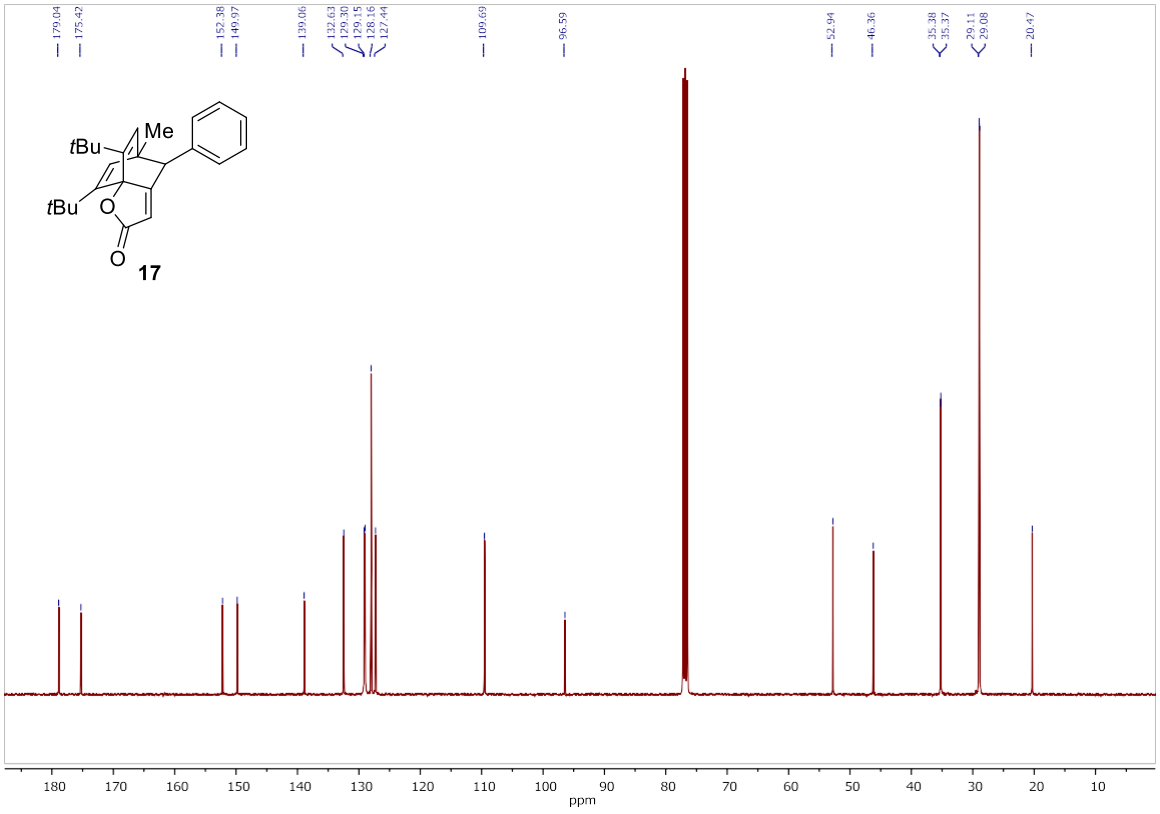
IR of compound **16**



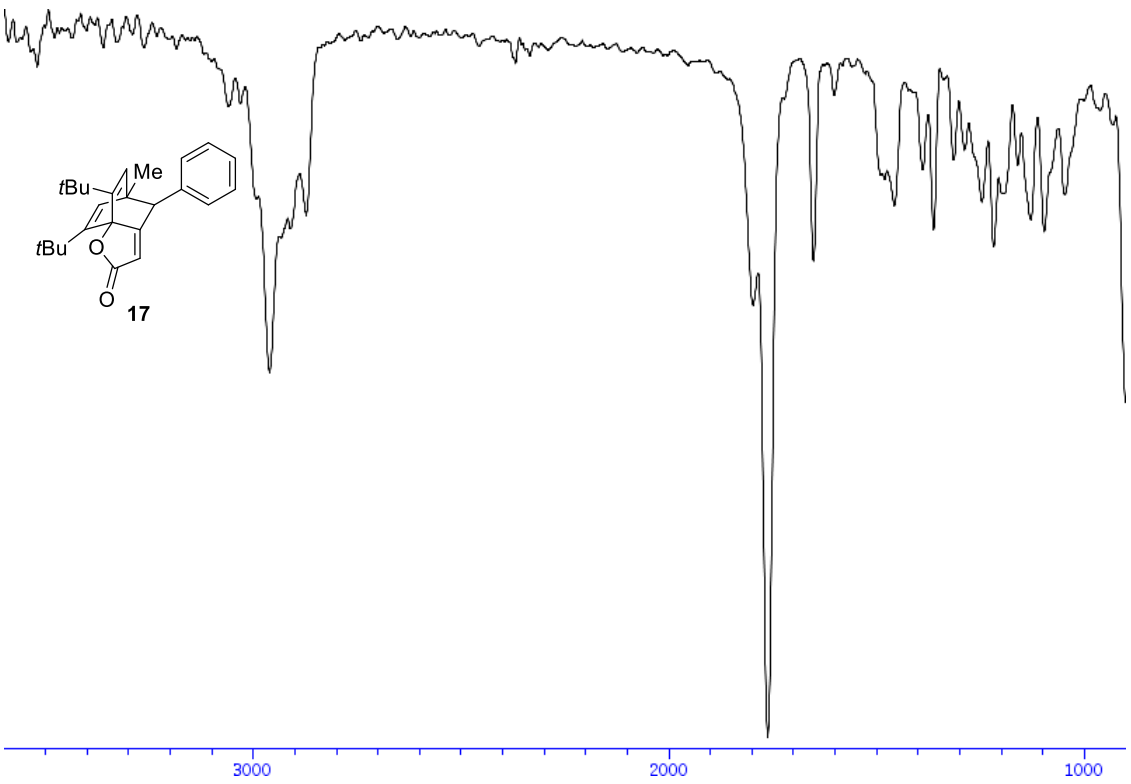
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **17**



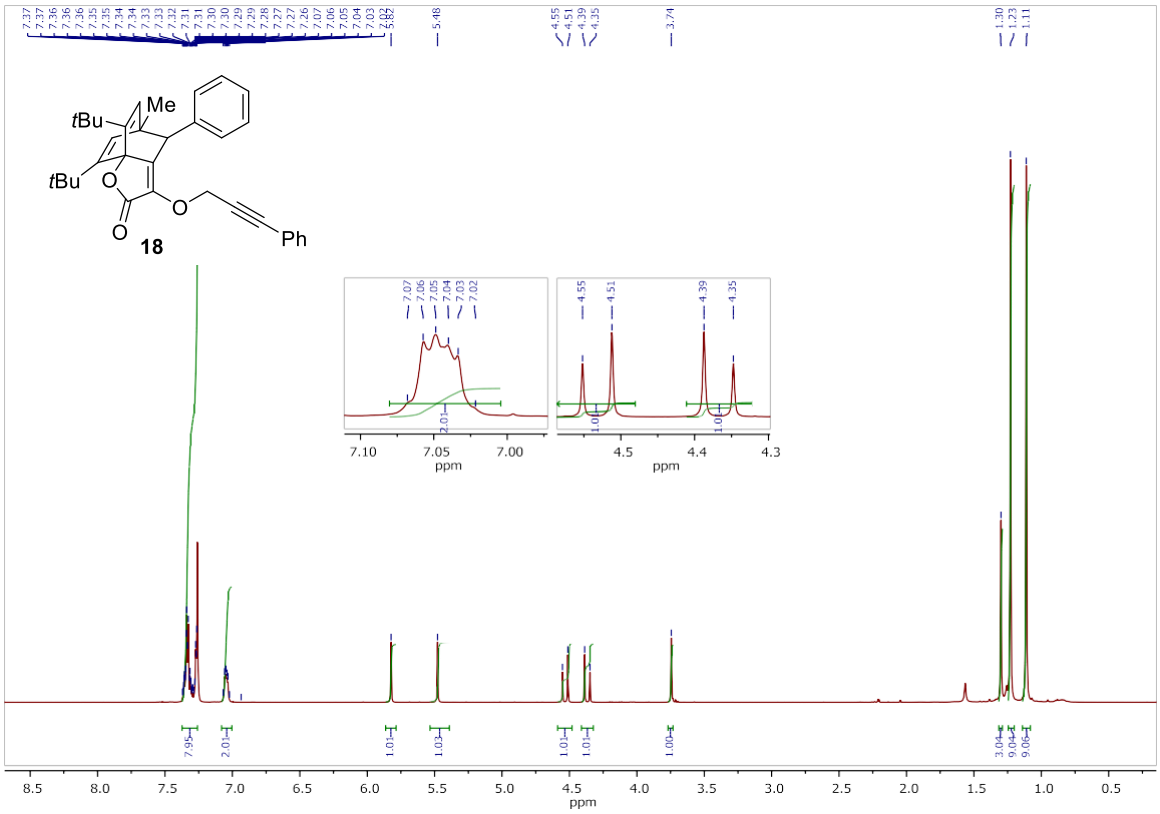
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **17**



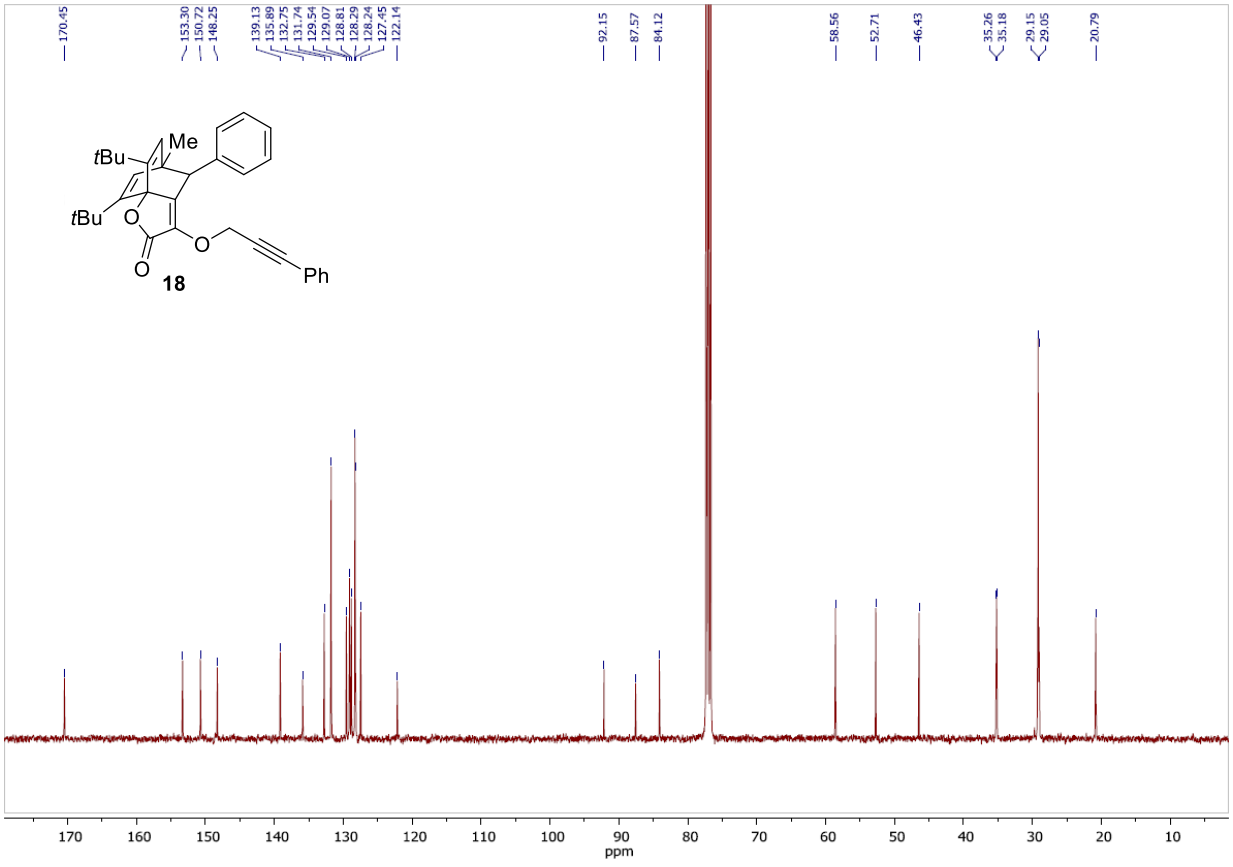
IR of compound **17**



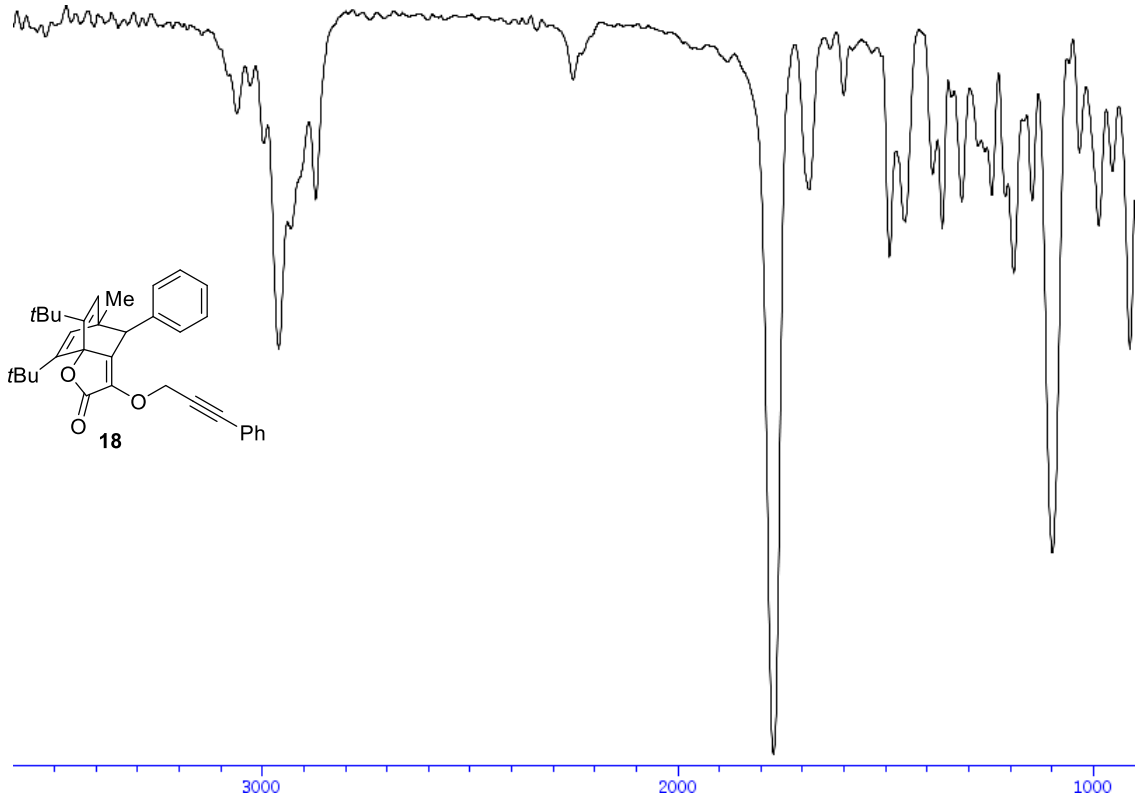
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **18**



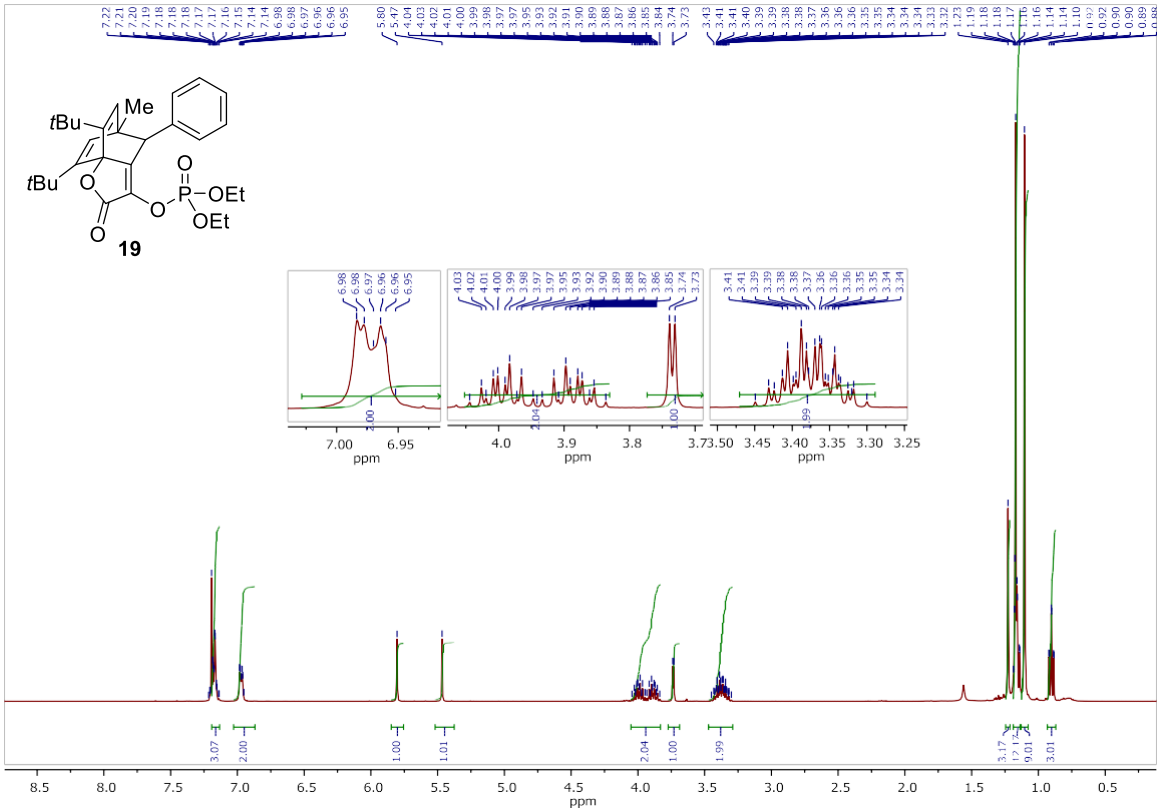
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **18**



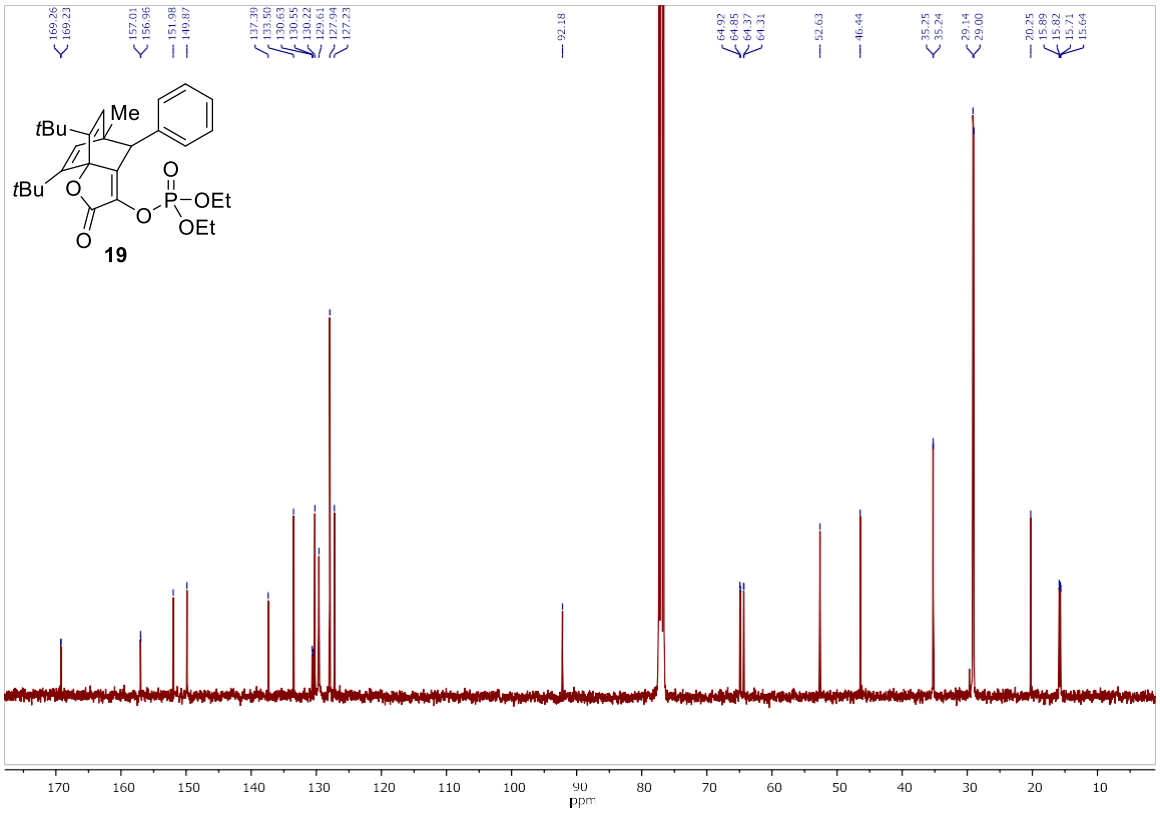
IR of compound **18**



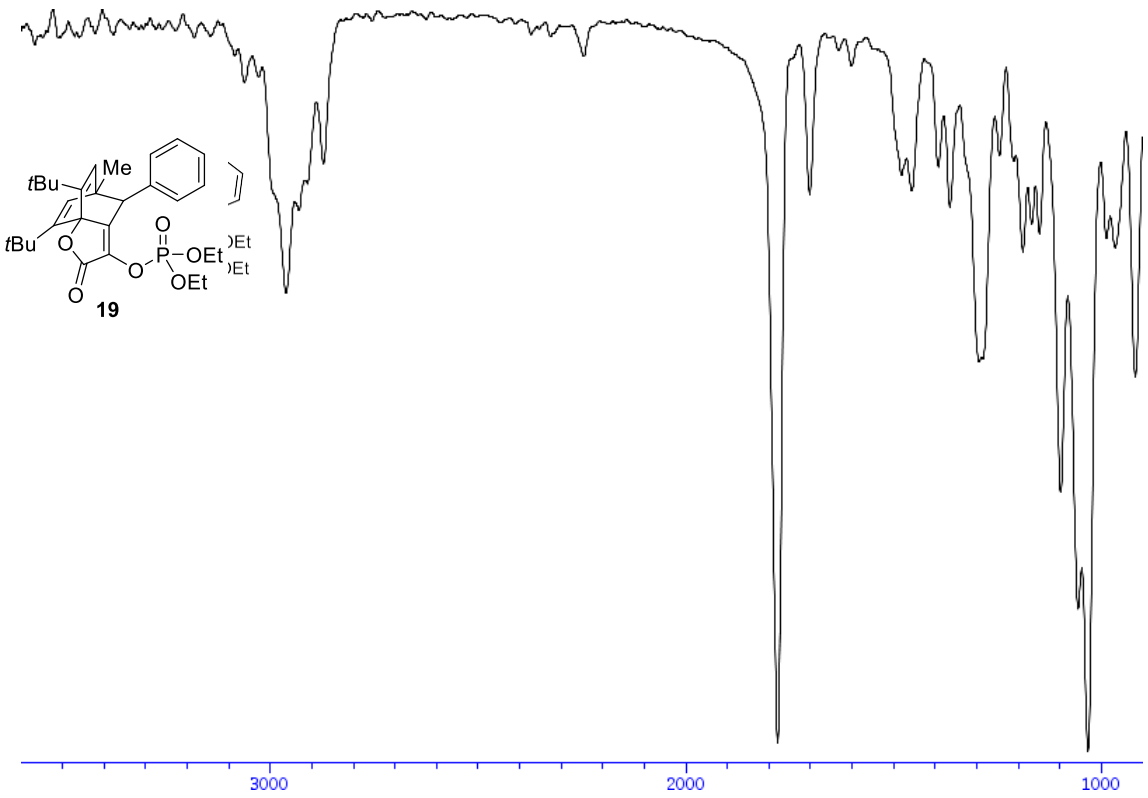
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **19**



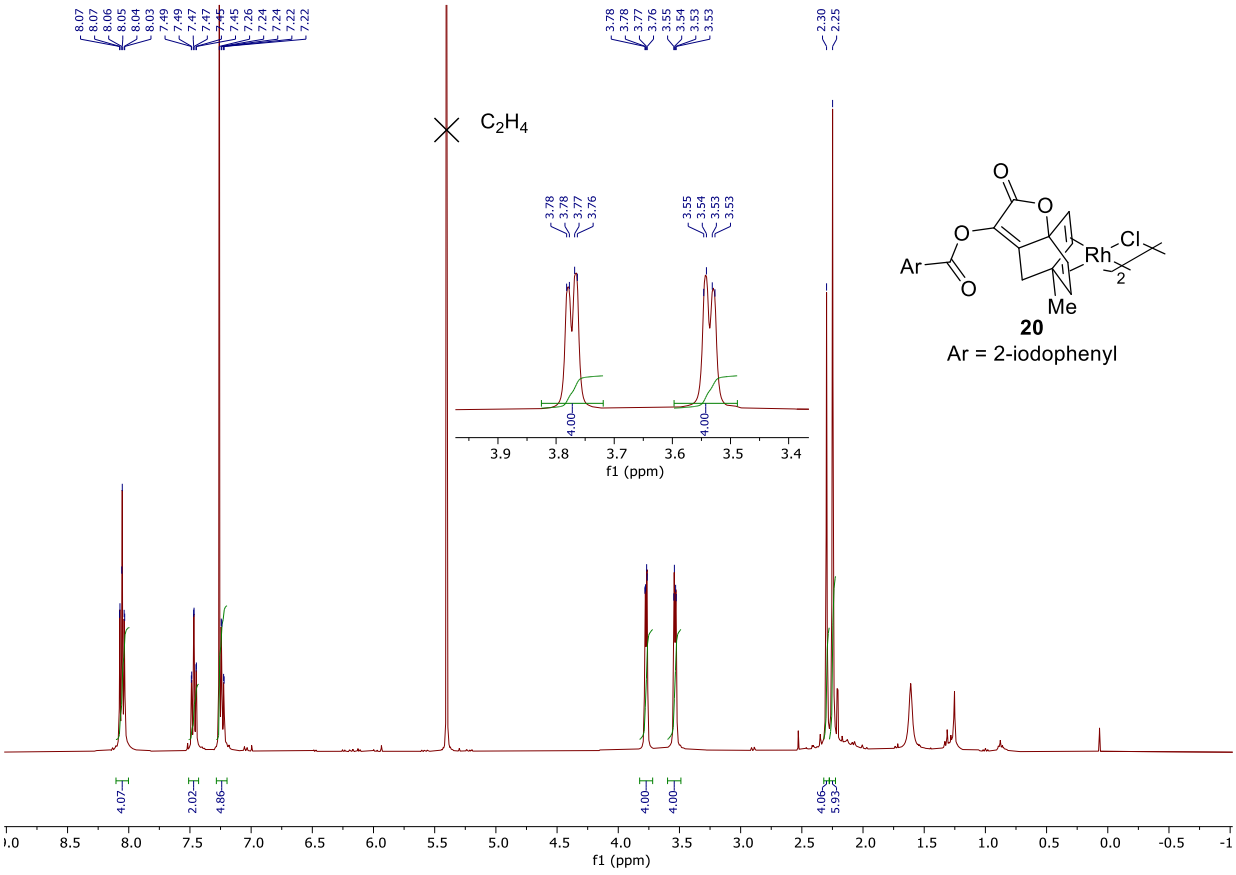
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **19**



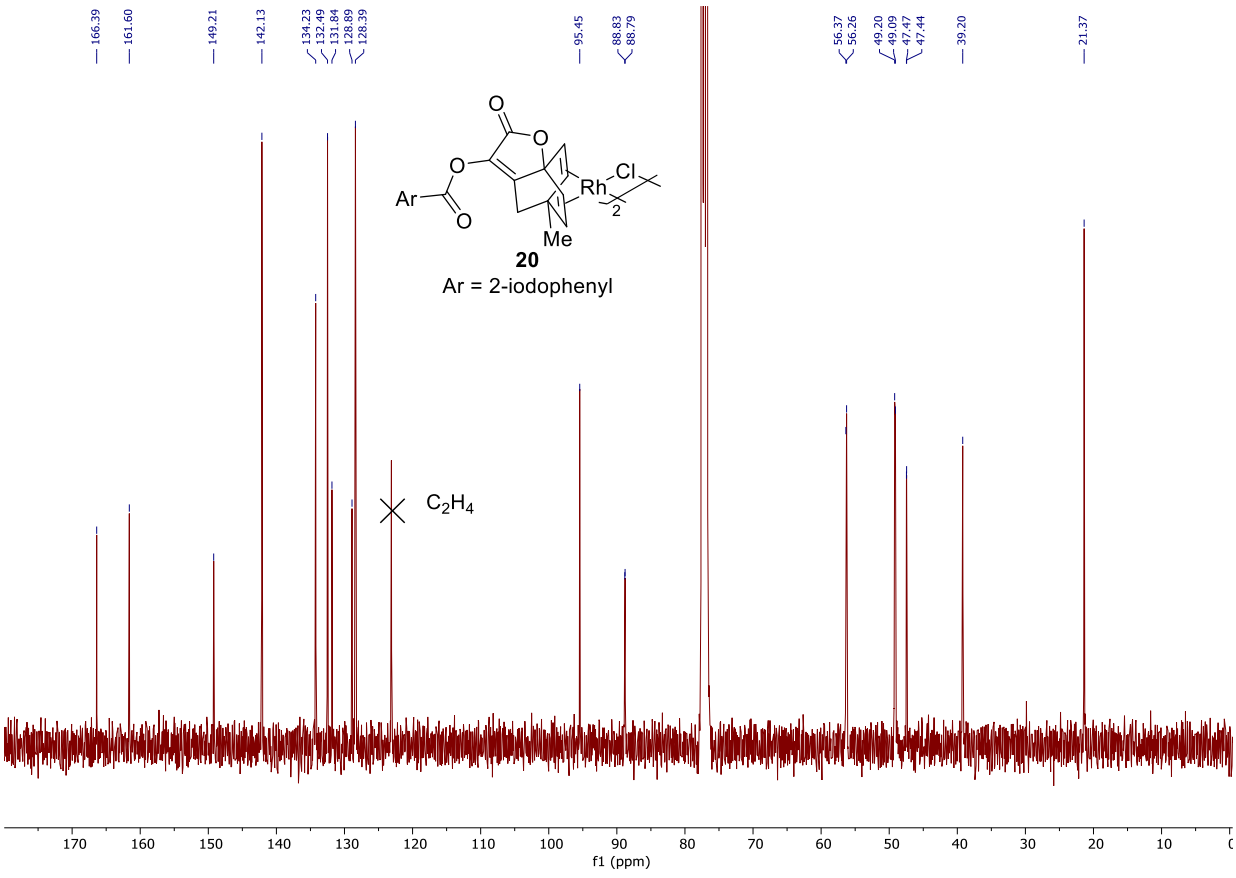
IR of compound **19**



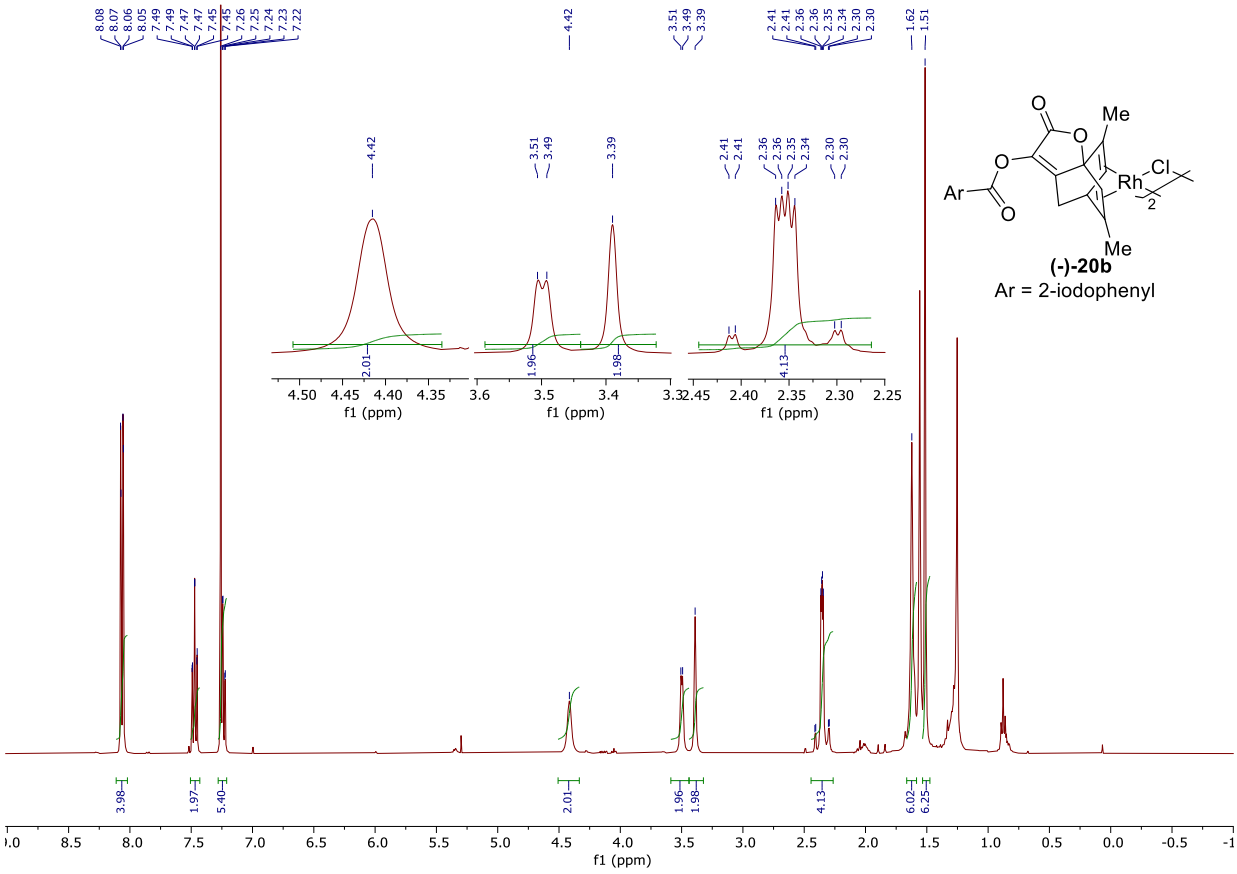
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **20a**



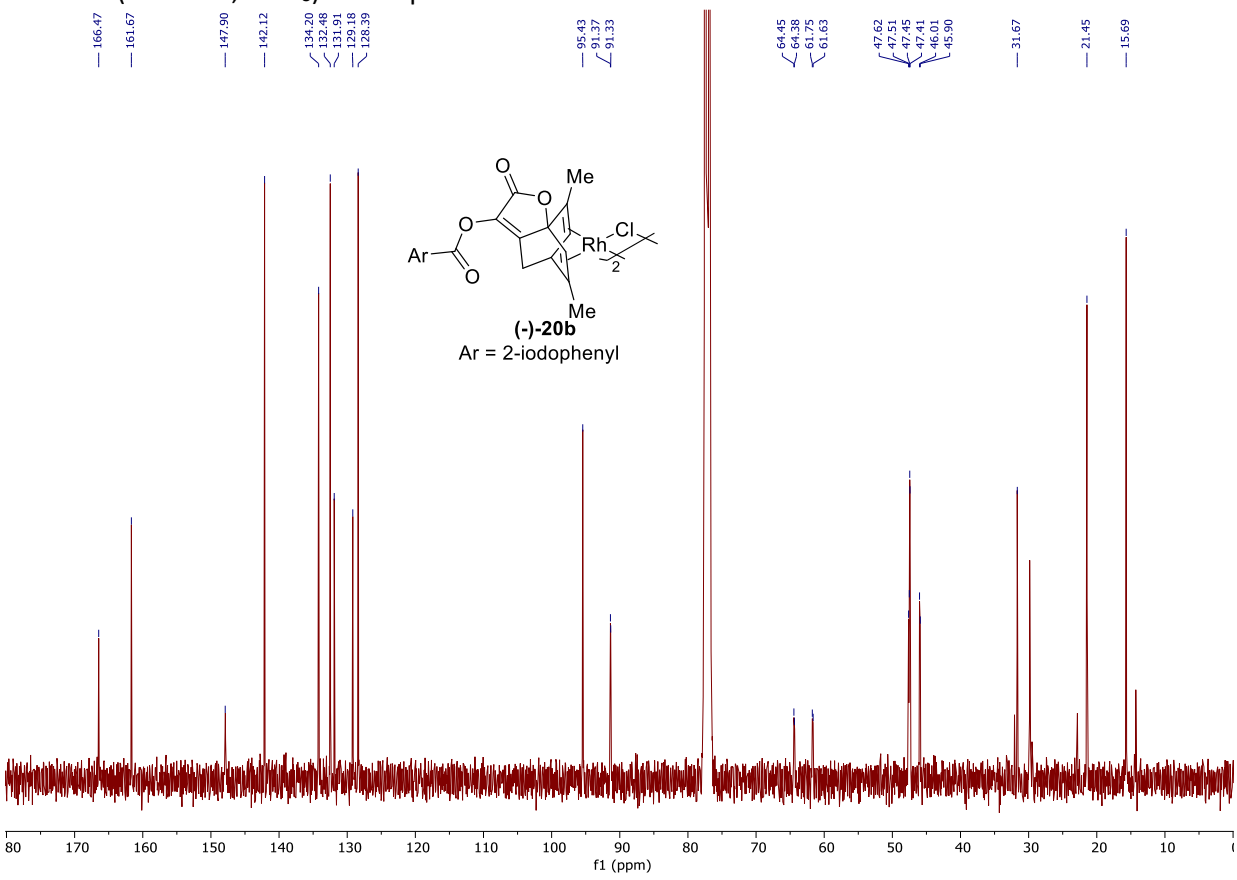
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **20a**



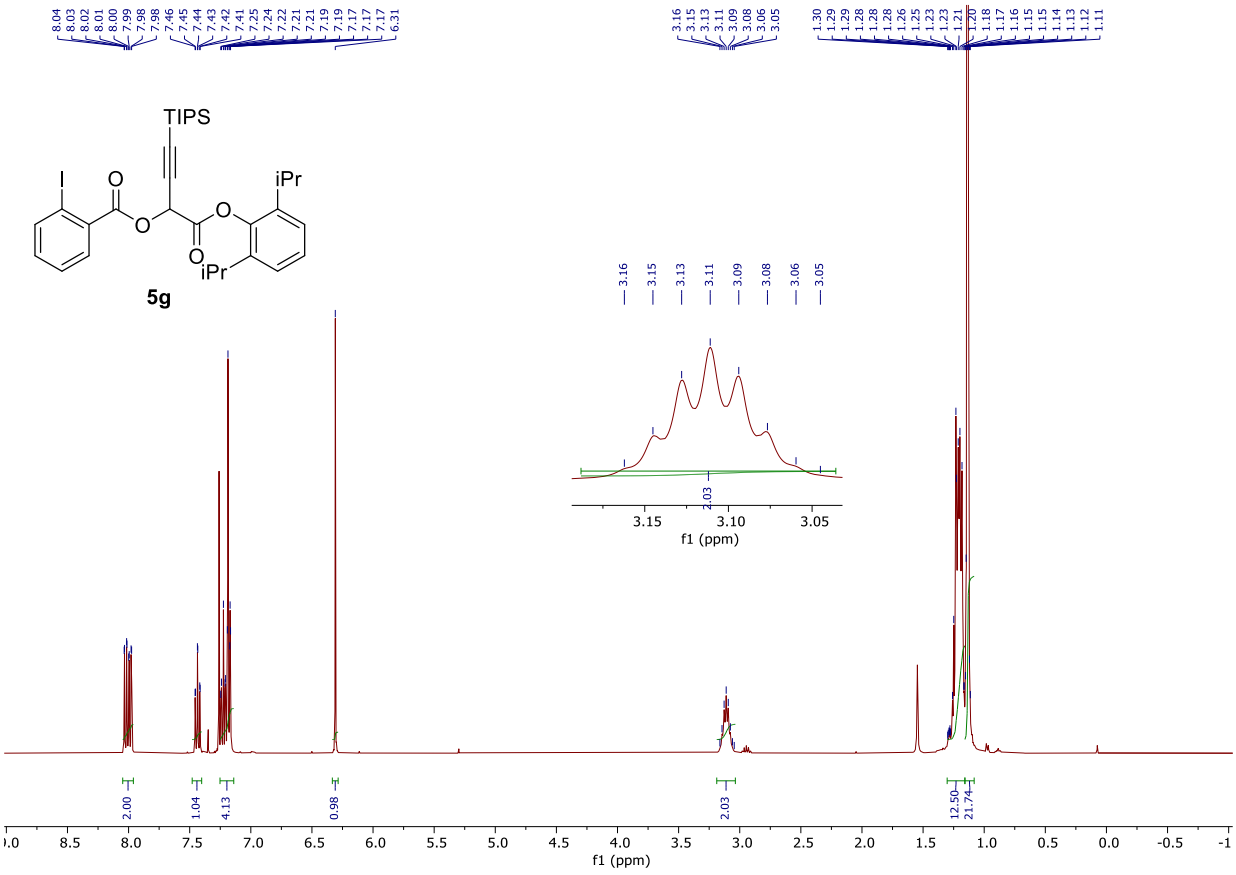
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **(-)-20b**



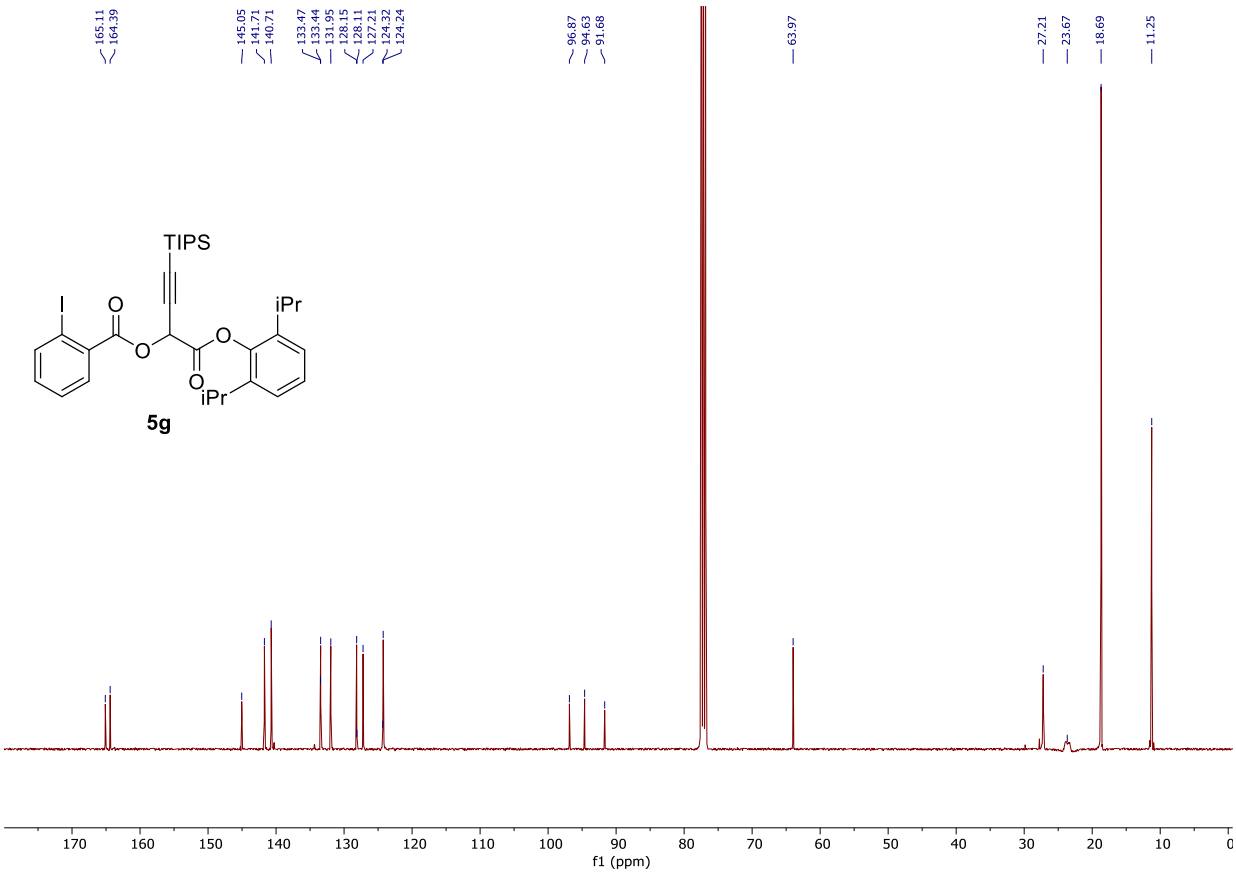
^{13}C-NMR (100 MHz, $CDCl_3$) of compound **20b**



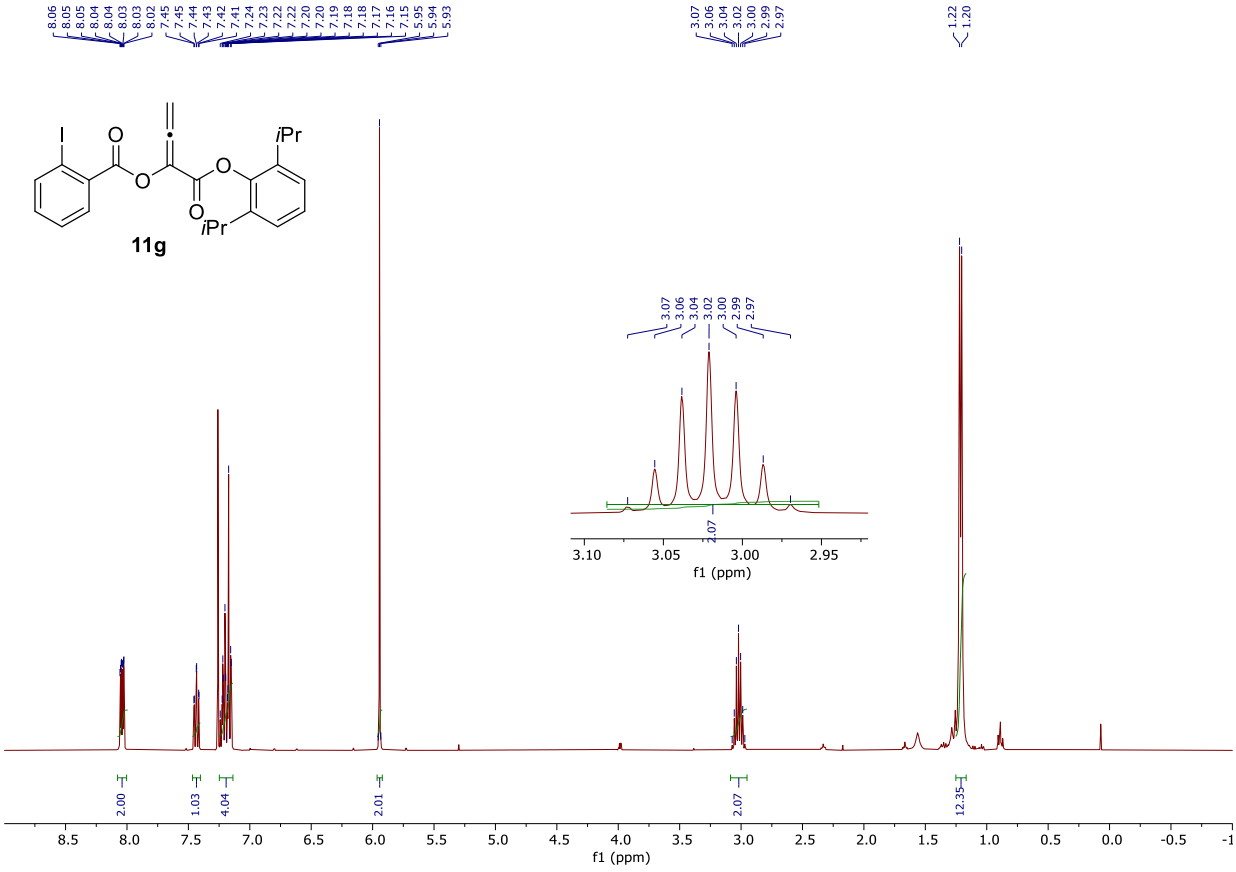
^{1}H-NMR (400 MHz, $CDCl_3$) of compound **5g**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **5g**



^{1}H-NMR (400 MHz, $CDCl_3$) of compound **11g**



^{13}C-NMR (100 MHz, $CDCl_3$) of compound **11g**