Palladium-Catalyzed C–H Bond Acetoxylation via Electrochemical Oxidation

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I. Materials and Methods

Bulk electrolysis experiments were performed in an H-cell with two compartments divided by an ultra-fine glass frit (10 mM P5 frit from Adams and Chittenden Scientific Glass). Each reaction utilized three electrodes: anode (working), cathode (counter), and reference. The two compartments in the H-cell were equipped with a graphite rod (anode and cathode), and a stir bar. The reference electrode on the working side of the cell consisted of a Ag wire in a fritted chamber containing a solution of $AgBF_4$ (0.01 M) and NBu_4PF_6 (0.1 M) in acetonitrile. A multi-channel potentiostat from Bio-Logic Instruments (model VSP-CHAS) was used for all the electrochemical studies.

NMR spectra were recorded on a Varian vnmrs 700 (700 MHz for ^{1}H; 176 MHz for ^{13}C) or a Varian vnmrs 500 (500 MHz for ^{1}H; 126 MHz for ^{13}C) spectrometer with the residual solvent peak ($CDCl_3$; ^{1}H: δ = 7.26 ppm, ^{13}C: δ = 77.16 ppm; CD_3CN; ^{1}H: δ = 1.94 ppm, 13C: δ = 1.32 ppm) as the internal reference unless otherwise noted. Chemical shifts are reported in parts per million (ppm, δ) relative to tetramethylsilane. Multiplicities are reported as follows: s (singlet), d (doublet), t (triplet), q (quartet), and m (multiplet). Coupling constants (*J*) are reported in Hz. High-resolution mass spectra were recorded on a Micromass AutoSpec Ultima Magnetic Sector mass spectrometer.

All commercial reagents and solvents were used as received unless otherwise indicated. Tetramethylammonium acetate (TMAOAc) and 8-methylquinoline were purchased from TCI America and used without further purification. Benzoquinone, purchased from Sigma Aldrich, was purified by sublimation before use. Anhydrous acetonitrile and acetic acid were purchased from Sigma Aldrich. Other chemicals were purchased from commercial sources (Alfa Aeser, Sigma Aldrich, TCI, Acros, Astatech, and Ark Pharm) and used without further purification. Thin layer chromatography (TLC) was performed on Macherey-Nagel SIL G-25 TLC plates pre-coated with silica gel UV254. Biotage® SNAP Ultra column cartridges were used for flash column chromatography. $CDCl_3$ and CD_3CN were purchased from Cambridge Isotope Laboratories, Inc. All reagents were weighed out under ambient conditions.

The substrates 8-methyl-5-nitroquinoline,[i] 5-bromo-8-methylquinoline,[i] 5-methoxy-8-methylquinoline,[i] 8-methylquinoline-5-carbonitrile,[ii] methyl 8-methylquinoline-5-carboxylate[ii] and 8-methyl-5-phenylquinoline[iii] were prepared according to literature procedures.

II. Experimental Procedure for Cyclic Voltammetry

Cyclic voltammetry was performed in a three-electrode cell with a 3 mM glassy carbon disc as the working electrode, a Pt wire counter electrode, and a reference electrode consisting of a Ag wire in a fritted chamber containing a solution of $AgBF_4$ (0.01 M) and NBu_4PF_6 (0.1 M) in acetonitrile. A solution of the palladacycle **2** (0.02 M) and supporting electrolyte TMAOAc or tetramethylammonium hexafluorophosphate ($TMAPF_6$) (0.1 M) in a mixture of acetic acid and acetonitrile was added to the cell. The potential was swept from 0 to 1.5 V at a 100 mV/s scan rate.

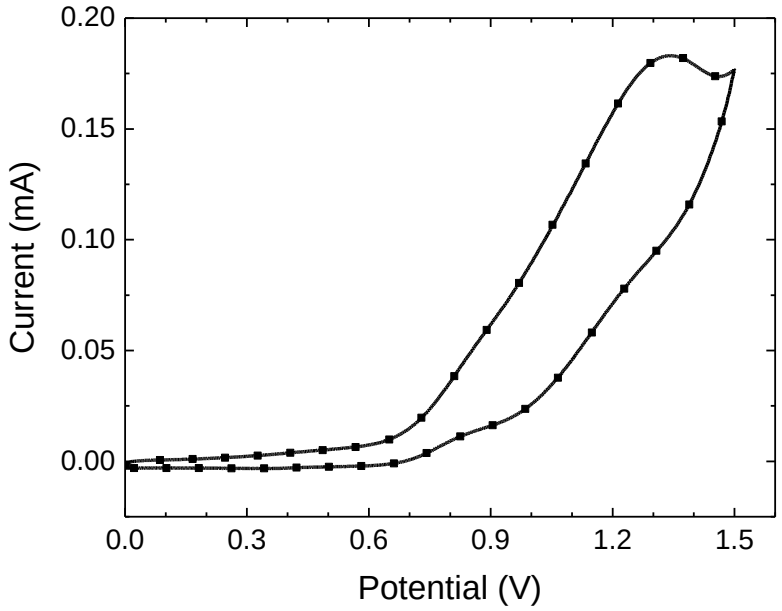
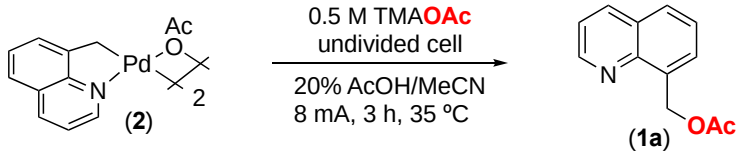


Figure 1. Cyclic Voltammogram of palladacycle **2** in 20% AcOH/MeCN and TMAOAc

A CV of the preformed palladium complex **2** in the reaction mixture is shown above. Compared to the CV of the same complex in absence of AcOH, a significant shift to higher potential was observed. The reason for this is still unclear.

III. Experimental Procedure for Stoichiometric Bulk Electrolysis



The electrochemical oxidation was conducted in an undivided three port cell. The cell was equipped with a stir bar, two graphite rod electrodes, and a Ag/Ag^+ reference electrode. A stock solution of TMAOAc (0.5 M) in either MeCN or in 20% acetic acid in MeCN was prepared (0.33 g of TMAOAc in 5 mL of solution). The palladacycle **2** (0.2 mmol,123 mg) was dissolved in the electrolyte solution (4 mL). This mixture was added to the three port cell and bulk electrolysis was conducted at 35 ºC under constant current settings with 8 mA passed through the solution over 6 h. The yield was determined by ^{1}H NMR spectroscopic analysis using trimethoxybenzene (0.2 mmol, 33.6 mg) as a standard. In MeCN, **1a** was formed in 23% yield (with 0.4 mmol of **1a** representing 100% yield based on the dimeric nature of **2**). In 20% AcOH in MeCN, **1a** was formed in 52% yield.

IV. General Procedures

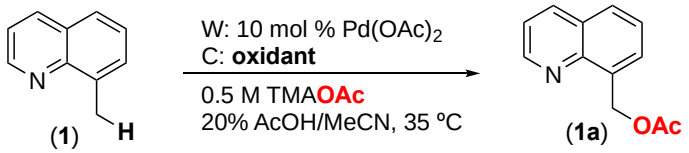
A. General procedure for optimization reactions with 8-methylquinoline

A stock solution of TMAOAc (0.5 M, 0.67 g) in acetic acid (2 mL) and acetonitrile (8 mL) was prepared.

When an undivided, three port cell was used: 8-Methylquinoline (0.4 mmol, 54 µL) and $Pd(OAc)_2$ (0.04 mmol, 8.9 mg) were dissolved in electrolyte solution (4 mL). This mixture was transferred to the cell and subjected to electrolysis at 35 ºC under constant current settings with 8 mA passed through the solution over 6 h.

When a divided H-cell was used: 8-Methylquinoline (0.4 mmol, 54 µL) and $Pd(OAc)_2$ (0.04 mmol, 8.9 mg) were dissolved in electrolyte solution (4 mL). This mixture was transferred to the anodic chamber of the H-cell. The cathodic chamber was loaded with either electrolyte solution or quinone dissolved in electrolyte, as appropriate. The bulk electrolysis was conducted at 35 ºC.

To quantify the yield of the reaction: The yield was determined by ^{1}H NMR spectroscopic analysis, using trimethoxybenzene (0.2 mmol, 33.6 mg) as a standard. The standard was added to the working (anodic) chamber after electrolysis was complete.



Entry	mA or V	Time/h	1a (%)	Modifications
1	8 mA	6	<1%	Undivided cell
2	8 mA	6	54	Divided cell, no oxidant
3	8 mA	6	32	Pt electrode on the counter side
4	8 mA	6	70	5 equiv. BQ on the counter side
5	8 mA	6	73	1 equiv. BQ on the counter side
6	8 mA	6	70	2,6-dichloro-1,4-benzoquinone on the counter side
7	8 mA	6	68	2,6-diphenyl-1,4-benzoquinone on the counter side
8	8 mA	6	70	2-methyl-1,4-benzoquinone on the counter side
9	8 mA	6	66	7% AcOH
10	8 mA	6	23	100% AcOH
11	4 mA	12	57	
12	6 mA	6	51	
13	6 mA	8	71	
14	12 mA	4	58	
15	1.2 V	12	30 ± 16	
16	1.2 V	12	17	RVC electrodes appended to Cu wire[a]
17	1.2 V	3.18	34 (35 SM)	Same mmol of e^- as 8 mA/6h

[a]AcOH dissolved Cu and the reaction got contaminated with Cu.

B. General procedure for obtaining isolated yields

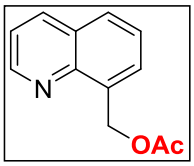
The electrochemical oxidation was conducted in an H-cell divided by an ultra-fine glass frit. Both chambers of this cell were equipped with a stir bar and graphite rod electrodes. A stock solution was prepared of TMAOAc (0.5 M) in 20% acetic acid in acetonitrile. Substrate (0.4 mmol) and $Pd(OAc)_2$ (0.04 mmol, 8.9 mg) were dissolved in electrolyte solution (4 mL) and transferred to the anodic chamber of the H-cell. The cathodic chamber was loaded with benzoquinone (0.4 mmol, 43 mg) dissolved in electrolyte. A Ag/Ag^+ reference electrode was attached to the anodic chamber. The bulk electrolysis was conducted at 35-100 ºC under constant current settings with 8 mA being passed through the solution over 6 h. The solution was removed from the working (anodic) side of the cell, and this solution was passed through a silica plug and washed with acetonitrile (3 x 10 mL). The resulting solution and washings were combined and concentrated under vacuum, and the organic products were purified by column chromatography.

C. General procedure for isolation of oximes and oxime ethers

Optimization studies showed that these reactions afforded higher yields using a slightly different solvent system (a 2 : 1 : 7 mixture of acetic anhydride (Ac_2O), acetic acid, and acetonitrile). After the bulk electrolysis, the reaction was concentrated, re-dissolved in DCM, and washed with $NaHCO_3$. The product was extracted into dichloromethane (DCM) (3 X 5 mL), dried with Na_2SO_4, filtered, concentrated, and purified by column chromatography.

IV. Synthesis and Isolation of Products from C–H Functionalization

Quinolin-8-ylmethyl acetate (1a)

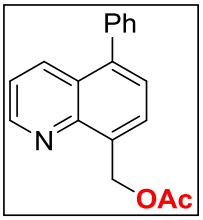


The product was formed from bulk electrolysis of 8-methylquinoline following general procedure B at 35 ºC. The product was isolated as a white powder in 73% yield (58.8 mg) via flash chromatography (gradient of 0-30% EtOAc in hexanes). The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[iv]

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{12}H_{11}NO_2$: 202.0863; found: 202.0860.

Scale-up:
8-Methylquinoline (1 mmol, 136 µL) and $Pd(OAc)_2$ (0.1 mmol, 22.4 mg) were dissolved in electrolyte solution (10 mL) and transferred to the anodic chamber of the H-cell. The cathodic chamber was loaded with benzoquinone (1 mmol, 108 mg) dissolved in electrolyte. A Ag/Ag^{+} reference electrode was attached to the anodic chamber. The bulk electrolysis was conducted at 35 ºC under constant current settings with 8 mA being passed through the solution over 18 h. The solution was removed from the working (anodic) side of the cell, was passed through a silica plug and washed with acetonitrile (3 x 10 mL). The resulting solution and washings were combined and concentrated under vacuum, and the organic products were purified by column chromatography to yield product as a white powder in 66% yield (133 mg).

(5-phenylquinolin-8-yl)-methyl acetate (3a)



The product was formed from bulk electrolysis of 5-phenyl-8-methylquinoline following general procedure B at 65 ºC. The product was isolated as a white solid in 65% yield (72.1 mg) via flash chromatography (gradient of 0-45% EtOAc in hexanes).

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{18}H_{15}NO_2$: 278.1176; found: 278.1180.

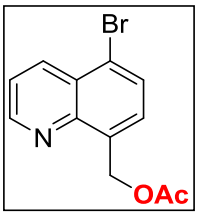
^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.97 (dd, *J* = 4.2, 1.7 Hz, 1H), 8.25 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.81 (d, *J* = 7.2 Hz, 1H), 7.51 (t, *J* = 7.3 Hz, 3H), 7.48-7.43 (multiple peaks, 3H), 7.39 (dd, *J* = 8.5, 4.1 Hz, 1H), 5.90 (s, 2H), 2.18 (s, 3H).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 171.09, 149.66, 146.26, 140.79, 139.18, 134.62, 133.43, 129.99, 128.49, 128.28, 127.74, 126.79, 126.62, 121.20, 62.96, 21.21.

IR (cm^{-1}): 1725, 1446, 1241, 1047, 843.

mp: 58-59 ºC

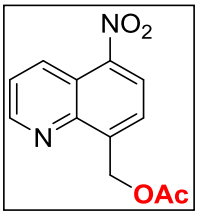
(5-bromoquinolin-8-yl)methyl acetate (4a)



The product was formed from bulk electrolysis of 5-bromo-8-methylquinoline following general procedure B at 65 ºC. The product was isolated as a white solid in 75% yield (84.1 mg) via flash chromatography (gradient of 0-45% EtOAc in hexanes). The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[v]

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{12}H_{10}BrNO_2$: 279.9968; found: 279.9970.

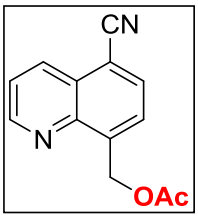
(5-nitroquinolin-8-yl)methyl acetate (5a)



The product was formed from bulk electrolysis of 5-nitro-8-methylquinoline following general procedure B at 75 ºC. The product was isolated as a pale yellow solid in 71% yield (69.9 mg) via a flash chromatography (gradient of 0-45% EtOAc in hexanes). The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[v]

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{12}H_{10}N_2O_4$: 247.0713; found: 247.0718.

5-cyanoquinolin-8-yl)methyl acetate (6a)



The product was formed from bulk electrolysis of 5-cyano-8-methylquinoline following general procedure B at 75 ºC. The product was isolated as a white solid in 75% yield (67.9 mg) via flash chromatography (gradient of 0-45% EtOAc in hexanes).

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{13}H_{10}N_2O_2$: 227.0815; found: 227.0818.

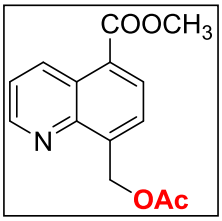
^{1}H NMR ($CDCl_3$, 700 MHz): δ 9.05 (d, *J* = 3.2 Hz, 1H), 8.56 (d, *J* = 8.4 Hz, 1H), 7.98 (d, *J* = 7.4 Hz, 1H), 7.81 (d, *J* = 7.4 Hz, 1H), 7.66 (dd, *J* = 8.5, 3.9 Hz, 1H), 5.90 (s, 2H), 2.21 (s, 3H).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 170.65, 151.21, 145.07, 140.87, 133.55, 132.72, 127.59, 126.49, 123.41, 116.63, 109.96, 62.31, 21.01.

IR (cm^{-1}): 3029, 2218, 1744, 1732, 1230, 1054, 826.

mp: 109-111 ºC

Methyl 8-(acetoxymethyl)quinoline-5-carboxylate (7a)



The product was formed from bulk electrolysis of methyl 8-methylquinoline-5-carboxylate following general procedure B at 75 ºC. The product was isolated as a white solid in 73% yield (75.7 mg) via flash chromatography (gradient of 0-45% EtOAc in hexanes).

HRMS: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_{13}H_{14}NO_4$: 260.0917; found: 260.0925.

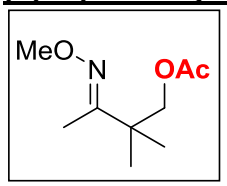
^{1}H NMR ($CDCl_3$, 700 MHz): δ 9.39 (d, *J* = 8.7 Hz, 1H), 8.98 (d, *J* = 3.8 Hz, 1H), 8.29 (d, *J* = 7.5 Hz, 1H), 7.78 (d, *J* = 7.6 Hz, 1H), 7.57 (dd, *J* = 8.8, 4.1 Hz, 1H), 5.91 (s, 2H), 4.01 (s, 3H), 2.20 (s, 3H).

^{13}C NMR ($CDCl_3$, 126 MHz): δ 170.79, 166.76, 149.66, 139.79, 134.88, 130.51, 126.85, 126.47, 126.29, 122.60, 62.83, 52.36, 21.08.

IR (cm^{-1}): 1742, 1706, 1247, 1218, 1055, 767.

mp: 81-82 ºC

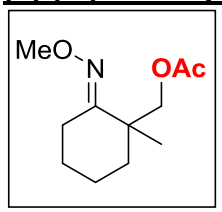
(E)-3-(methoxyimino)-2,2-dimethylbutyl acetate (8a)



The product was formed from bulk electrolysis of (*E*)-3,3-dimethylbutan-2-one O-methyl oxime following general procedure C at 100 ºC. The product was isolated via flash chromatography (gradient of 0-10% EtOAc in hexanes) in 26% yield (19.7 mg) as a colorless oil. The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[vi]

HRMS: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_9H_{18}NO_3$: 188.1281; found: 188.1280.

(E)-(2-(methoxyimino)-1-methylcyclohexyl)methyl acetate (9a)



The product was formed from bulk electrolysis of (*E*)-2,2-dimethylcyclohexan-1-one O-methyl oxime following general procedure C at 100 ºC. The product was isolated via flash chromatography (gradient of 0-10% EtOAc in hexanes) in 33% yield (28.0 mg) as a colorless oil.

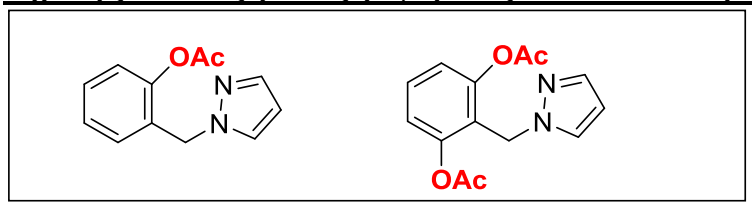
HRMS: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_{11}H_{20}NO_3$: 214.1438; found: 214.1442.

^{1}H NMR ($CDCl_3$, 700 MHz): δ 4.29 (d, *J* = 10.5 Hz, 1H), 4.10 (d, *J* = 10.5 Hz, 1H), 3.79 (s, 3H), 2.61 (m, 1H), 2.34 (m, 1H), 2.05 (s, 3H), 1.55 (multiple peaks, 6H), 1.49 (s, 3H).

^{13}C NMR ($CDCl_3$, 176 MHz): δ 171.28, 161.23, 69.87, 61.37, 40.61, 36.13, 25.71, 22.10, 21.42, 21.29, 21.09.

IR (cm^{-1}): 2935, 1740, 1228,1046, 888.

2-((1H-pyrazol-1-yl)methyl)phenyl acetate (10a)
2-((1H-pyrazol-1-yl)methyl)-1,3-phenylene diacetate (10b)



The products were formed from bulk electrolysis of 1-benzyl-1H-pyrazole following general procedure B at 100 ºC. The products were isolated via flash chromatography (gradient of 0-100% EtOAc in hexanes) in 47% yield (40.5 mg) of **10a** as a colorless oil and 11% yield (12.3 mg) of **10b** as a light yellow solid.

^{1}H NMR **10a** ($CDCl_3$, 700 MHz): δ 7.53 (apparent s, 1H), 7.34 (t, *J* = 7.7 Hz, 1H), 7.32 (d, *J* = 2.1 Hz, 1H), 7.21 (t, *J* = 7.7 Hz, 1H), 7.12 (d, *J* = 7.7 Hz, 1H), 7.11 (d, *J* = 7.7 Hz, 1H), 6.26 (t, *J* = 2.1 Hz, 1H), 5.28 (s, 2H), 2.28 (s, 3H).

^{13}C NMR **10a** ($CDCl_3$, 176 MHz): δ 169.15, 148.68, 139.49, 129.75, 129.52, 129.37, 128.71, 126.57, 122.84, 106.21, 51.15, 20.96.

IR **10a** (cm^{-1}): 1762, 1368, 1200, 1086, 745.

HRMS **10a**: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_{12}H_{13}N_2O_2$: 217.0972; found: 217.0973.

^{1}H NMR **10b** ($CDCl_3$, 700 MHz): δ 7.45 (apparent s, 1H), 7.40 (t, *J* = 8.4 Hz, 1H), 7.22 (d, *J* = 2.1 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.20 (t, *J* = 2.1 Hz, 1H), 5.25 (s, 2H), 2.27 (s, 6H).

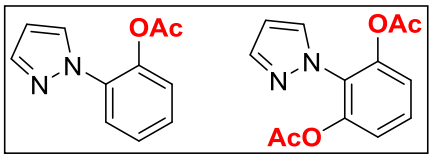
^{13}C NMR **10b** ($CDCl_3$, 176 MHz): δ 169.02, 150.39, 138.91, 129.85, 128.78, 121.24, 120.88, 106.37, 45.48, 20.96.

IR **10b** (cm^{-1}): 1751, 1464, 1366, 1168, 1033, 760.

mp **10b**: 62-64 ºC

HRMS **10b**: ESI^+ (m/z): $[M+H^+]$ calcd for $C_{14}H_{15}N_2O_4$: 275.1026; found: 275.1026.

2-(1H-pyrazol-1-yl)phenyl acetate (11a)
2-(1H-pyrazol-1-yl)-1,3-phenylene diacetate (11b)

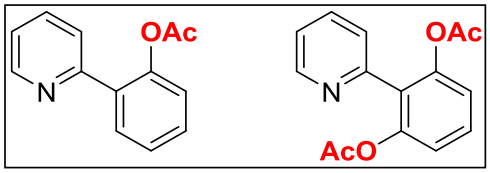


The products were formed from bulk electrolysis of 1-phenylpyrazole following general procedure B at 100 ºC. The products were isolated via flash chromatography (gradient of 0-70% EtOAc in hexanes) in 60% yield (48.5 mg) of **11a** as a yellow oil and 12% yield (12.5 mg) of **11b** as a yellow oil. The ^1H and ^{13}C NMR spectra of the products matched reported values.[iv]

HRMS of **11a**: ESI^+ (m/z): $[M+H^+]$ calcd for $C_{13}H_{11}NO_2$: 203.0815; found: 203.0812.

HRMS of **11b**: ESI^+ (m/z): $[M+H^+]$ calcd for $C_{15}H_{13}NO_4$: 261.0870; found: 261.0870.

2-(pyridin-2-yl)phenyl acetate (12a)
2-(pyridin-2-yl)-1,3-phenylene diacetate (12b)

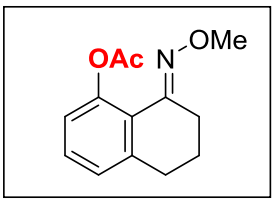


The products were formed from bulk electrolysis of 2-phenylpyridine following general procedure B at 100 ºC. The products were isolated via a flash chromatography (gradient of 0-70% EtOAc in hexanes) in 41% yield (35.0 mg) of **12a** as a yellow oil and 30% yield (32.6 mg) of **12b** as a yellow oil. The ^1H and ^{13}C NMR spectra of the products matched reported values.[iv]

HRMS of **12a**: ESI^+ (m/z): $[M+H^+]$ calcd for $C_{13}H_{11}NO_2$: 214.0863; found: 214.0860.

HRMS of **12b**: ESI^+ (m/z): $[M+H^+]$ calcd for $C_{15}H_{13}NO_4$: 272.0917; found: 272.0917.

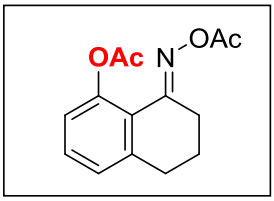
(*E*)-8-(methoxyimino)-5,6,7,8-tetrahydronaphthalen-1-yl acetate (13a)



The product was formed from bulk electrolysis of (*E*)-3,4-dihydronaphthalen-1(2H)-one O-methyl oxime following general procedure C at 100 ºC. The product was isolated via flash chromatography (gradient of 0-70% EtOAc in hexanes) in 63% yield (58.6 mg) as a pink oil. The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[vii]

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{13}H_{16}NO_3$: 234.1125; found: 234.1129.

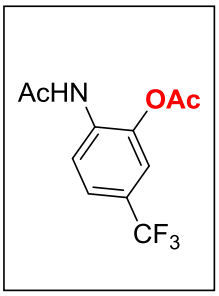
(*E*)-8-(acetoxyimino)-5,6,7,8-tetrahydronaphthalen-1-yl acetate (14a)



The product was formed from bulk electrolysis of (*E*)-3,4-dihydronaphthalen-1(2H)-one O-methyl oxime following general procedure C at 100 ºC. The product was isolated via flash chromatography (gradient of 0-100% EtOAc in hexanes) in 39% yield (40.3 mg) as an off-white solid. The ^{1}H and ^{13}C NMR spectra of the product matched reported values.[viii]

HRMS: ESI^{+} (m/z): [M+H^{+}] calcd for $C_{14}H_{16}NO_4$: 262.1074; found: 262.1075.

2-acetamido-5-(trifluoromethyl)phenyl acetate (15a)



The product was isolated from a chemical oxidation with $PhI(OAc)_2$. A 4 mL vial was charged with a stir bar, N-(4-(trifluoromethyl)phenyl)acetamide (0.20 mmol, 40.6 mg), $Pd(OAc)_2$ (0.02 mmol, 4.5 mg), and $PhI(OAc)_2$ (0.40 mmol, 128.8 mg). A mixture of 9:1 AcOH:Ac_2O (2.0 mL) was added and the resulting solution was stirred at 100 ºC for 48 h. The reaction was diluted with dichloromethane, the organic layer was washed with aqueous Na_2CO_3, and the organic layer was separated and dried over sodium sulfate. The organic extracts were concentrated and the product was isolated via a flash chromatography (gradient of 0-100% EtOAc in hexanes) as a light pink solid in 30% yield (15.8 mg).

^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.42 (d, *J* = 8.4 Hz, 1H), 7.48 (d, *J* = 8.4, 1H), 7.43 (s, 1H), 7.34 (br s, 1H), 2.43 (s, 3H), 2.26 (s, 3H).

^{13}C NMR ($CDCl_3$, 176 MHz): δ 168.19, 168.04, 139.27, 132.86, 126.12 (q, $J_{C\text{-}F}$ = 32.7 Hz), 123.44 (q, $J_{C\text{-}F}$ = 272.1 Hz), 123.54 (q, $J_{C\text{-}F}$ = 14.7 Hz), 121.92, 119.45, 24.82, 21.05.

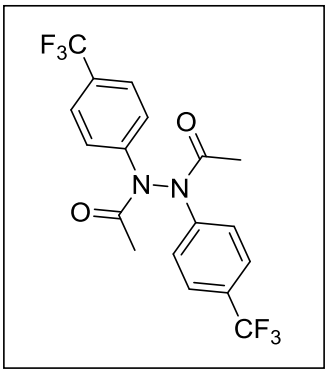
^{19}F NMR ($CDCl_3$, 376 MHz): –62.2.

IR (cm^{-1}): 1762, 1690, 1326, 1200, 1166, 1107.

mp: 104-106 ºC

HRMS: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_{11}H_{10}F_3NO_3$: 262.0686; found: 262.0688.

N'-acetyl-N,N'-bis(4-(trifluoromethyl)phenyl)acetohydrazide (16)



The product was formed from bulk electrolysis of N-(4-(trifluoromethyl)phenyl)acetamide following general procedure B at 100 ºC. The product was isolated via a flash chromatography (gradient of 0-100% EtOAc in hexanes) as a light yellow oil in 52% yield (41.9 mg).

^{1}H NMR (d_6-DMSO, 700 MHz, 100 ºC): δ 7.74 (d, *J* = 8.4 Hz, 4H), 7.63 (d, *J* = 8.4 Hz, 4H), 2.20 (s, 6H).

^{13}C NMR (d_6-DMSO, 176 MHz, 100 ºC): δ 169.23, 142.90, 127.18 (q, $J_{C\text{-}F}$ = 31.7 Hz), 125.84, 124.50, 123.34 (q, $J_{C\text{-}F}$ = 272.8 Hz), 21.47.

^{19}F NMR (d_6-DMSO, 376 MHz, 100 ºC): 61.21.

IR (cm^{-1}): 1704, 1613, 1319, 1165, 1116, 1066.

HRMS: ESI$^+$ (m/z): [M+H$^+$] calcd for $C_{18}H_{15}F_6N_2O_2$: 405.1032; found: 405.1030.

V. The Four-Electrode Experiment

This electrochemical experiment was conducted to understand the impact of benzoquinone (the sacrificial oxidant added on the counter-side) on the overall reaction. The potentials at both the working (anodic) and the counter (cathodic) electrode were monitored during the reaction as detailed below. This allowed the potential to be directly compared in presence and absence of benzoquinone without being impacted by the resistance of the frit.

The electrochemical oxidation was conducted in an H-cell divided by ultra-fine glass frit. Both chambers of this cell were equipped with a stir bar and graphite rod electrodes. An electrolyte stock solution was prepared, consisting of TMAOAc (0.5 M) dissolved in 20% acetic acid in acetonitrile. 8-Methylquinoline (0.4 mmol, 57 mg) and 10 mol% $Pd(OAc)_2$ were dissolved in electrolyte solution (4 mL) and transferred into the working chamber of the H-cell. Separately, benzoquinone (0.4 mmol, 43 mg) was dissolved in electrolyte solution (4 mL)and transferred to the counter chamber of the H-cell. A Ag/Ag^+ reference electrode was attached to both working and counter chambers. Two channels from the potentiostat were utilized, with the first channel passing a current of 8 mA between the anode and cathode. The second channel recorded the open circuit potential of the cathode. In line with our hypothesis, the cathodic potential in presence of benzoquinone was lower compared to the cathodic potential in the absence of sacrificial oxidant. The observed cathodic potentials are consistent with the relative potentials for reduction of BQ versus protons. A slight increase in the anodic potential was observed, potentially indicating overpotential in the reaction.

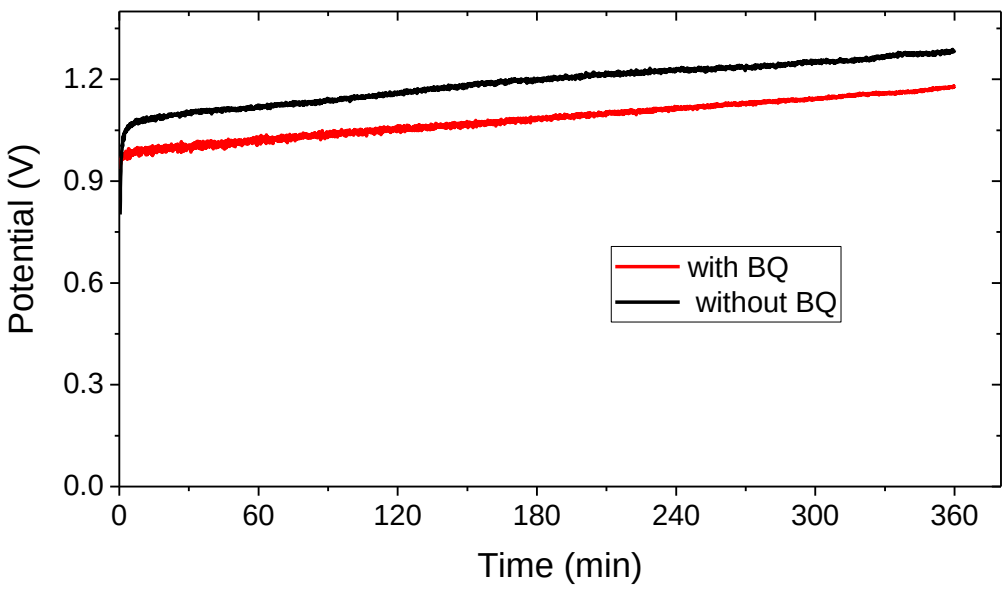


Figure 2. Working side potential through the reaction in presence and absence of benzoquinone

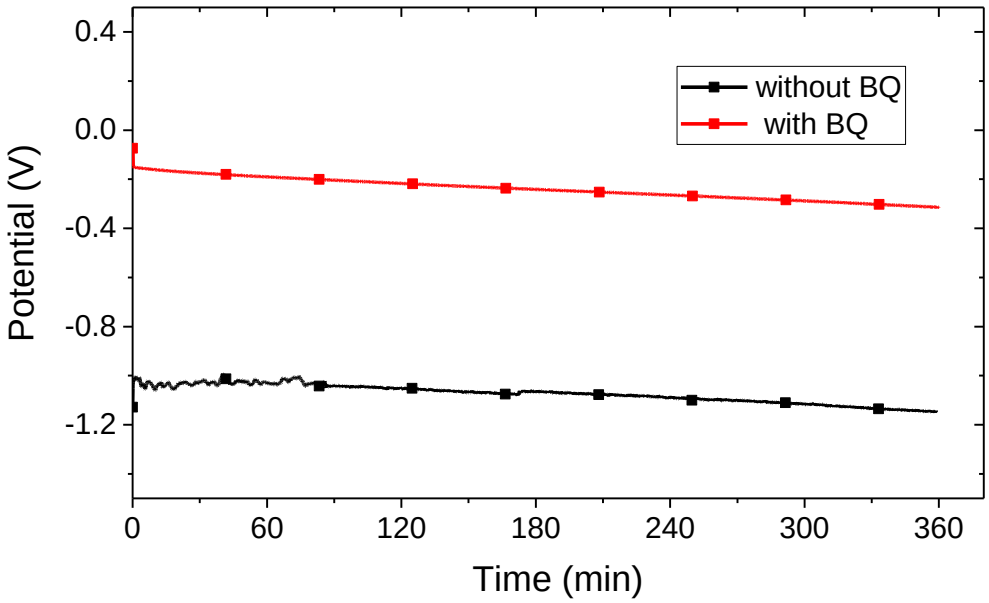


Figure 3. Counter side potential through the reaction in presence and absence of benzoquinone

VI. References

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[viii] Sanford, M. S. et al. *Org. Lett.* **2010**, *12*, 532.