Organic Syntheses

Synthesis of 1,3-Dimethyl-3-(*p*-tolyl)-1*H*-pyrrolo[3,2-*c*]pyridin-2(3*H*)-one by Cu(II)-Mediated Direct Oxidative Coupling

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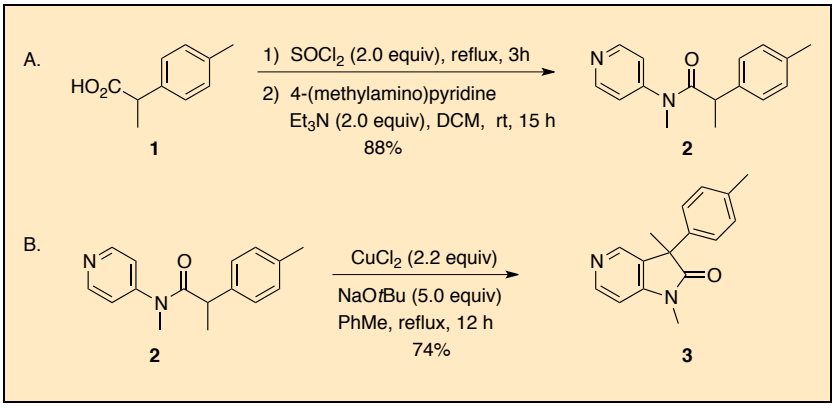
Checked by Yen-Ku Wu and Viresh H. Rawal



Procedure

Caution! Thionyl chloride reacts violently with water and releases dangerous gases.

A. *N-Methyl-N-(pyridin-4-yl)-2-(p-tolyl)propanamide* (**2**). A 50-mL two-necked, round-bottomed flask equipped with a 12 mm x 2.5 mm octagonal Teflon-coated magnetic stir bar, a reflux condenser fitted with a gas inlet with a positive pressure of N_2, and a glass stopper (Note 1) is charged with 2-(*p*-tolyl)propionic acid **1** (Note 2) (5.70 g, 34.7 mmol, 1.0 equiv) and thionyl chloride (Note 3) (5.1 mL, 69.4 mmol, 2.0 equiv). The reaction

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mixture is heated to reflux for 3 h (Note 4). After cooling to room temperature, excess thionyl chloride is removed under vacuum to give the crude acid chloride (Note 5). Separately, a dry, 250-mL two-necked, round-bottomed flask (Note 1) equipped with a 4.0 cm long, oval-shaped Teflon-coated magnetic stir bar, a nitrogen inlet having a positive pressure of N_2, and a rubber septum is charged with 4-(methylamino)pyridine (Note 6) (3.75 g, 34.7 mmol, 1.0 equiv), followed by dry dichloromethane (40 mL) (Note 7), which is added by syringe. The resulting solution is cooled to 0 °C (ice bath, external temperature) and treated with dry triethylamine (Note 8) (9.7 mL, 69.4 mmol, 2.0 equiv), which is added by syringe. The acid chloride formed earlier is diluted with 30 mL dichloromethane (Note 7) and the resulting solution is withdrawn by syringe and added dropwise (Note 9) to the flask containing 4-(methylamino)pyridine and triethylamine at 0 °C. The 50-mL round-bottomed flask is rinsed with 10 mL dichloromethane (Note 7), and the rinsate is added to the 250-mL flask. The ice bath is removed and the reaction mixture is stirred at 25 °C for 15 h and then transferred to a 250-mL separatory funnel. The 250-mL flask is rinsed with 20 mL dichloromethane and the solution is added to the separatory funnel. The organic layer is washed with water (50 mL) and the separated aqueous phase is back-extracted with dichloromethane (2 x 50 mL). The combined organic layers are dried over anhydrous $MgSO_4$ (10 g), filtered through a 150-mL medium porosity fritted glass funnel, and concentrated with a rotary evaporator (20 mmHg, 25 °C). The crude brown oil is dissolved in 10 mL EtOAc and is charged on a column (inner diameter = 6 cm, l = 15 cm) of 160 g of silica gel (Note 10) and subjected to flash chromatography (Note 11) using EtOAc as eluent. A first 170 mL fraction is collected in a conical flask, and subsequent fractions are collected in test tubes (Note 12). Product **2** is identified by TLC (EtOAc, R_f = 0.24, UV and $KMnO_4$ active) (Note 13) in test tubes 10-32. Fractions containing the product are concentrated by rotary evaporator (20 mmHg, 25 °C), and the resulting product is placed under high vacuum (1.0 mmHg, 25 °C, 2 h) to give **2** (7.77 g, 88% yield) as a white solid that is indefinitely stable at room temperature (Notes 14 and 15).

B. *1,3-Dimethyl-3-(p-tolyl)-1H-pyrrolo[3,2-c]pyridin-2(3H)-one (**3**)*. A 500-mL two-necked, round-bottomed flask equipped with an oval-shaped 4.0 cm Teflon-coated magnetic stir bar, a nitrogen inlet with a positive pressure of N_2, and a rubber septum (Note 1) is charged with amide **2** (6.36 g, 25.0 mmol, 1.0 equiv). The flask is placed under vacuum (1.0 mmHg) for 5 min and then back-filled with nitrogen. This sequence of vacuum and back-filling is repeated two times. Anhydrous $CuCl_2$ (Note 16)

(7.4 g, 55.0 mmol, 2.2 equiv) and NaO*t*Bu (Note 17) (12.0 g, 125.0 mmol, 5.0 equiv) are sequentially added to the flask containing amide **2** (Note 18). Dry toluene (250 mL) (Note 19) is added by syringe under nitrogen atmosphere while stirring (Note 20), then the rubber septum is replaced with a dry reflux condenser. The nitrogen inlet in the second neck of the flask is transferred to the top of the reflux condenser and the flask opening is sealed with a glass stopper. The reaction mixture is heated to a gentle reflux for 12 h (Note 21), after which no starting material is evident (Note 22). After cooling to room temperature, the reaction mixture is diluted with 150 mL EtOAc and passed through a pad of Celite (Note 23). The flask is rinsed several times with EtOAc (6 x 150 mL) and the washings are also passed through the Celite pad (Note 24). The combined filtrate (ca. 1300 mL) is divided into two equal parts. The first half of the filtrate (ca. 650 mL) is transferred to a 1-L separatory funnel, to which brine (200 mL) and EtOAc (100 mL) are added. After extraction, the organic layer is collected and the aqueous layer is back-extracted with EtOAc (3 x 200 mL). The organic layers are combined. This sequence of extraction is repeated with the second half of the filtrate. The combined organic layers are concentrated with a rotary evaporator (20 mmHg, 25 °C) to afford a brown oil. The crude product is dissolved in 10 mL of EtOAc and charged on a column (inner diameter = 6 cm, l = 16.5 cm) of 170 g of silica gel (Note 10) and subjected to flash chromatography (Note 11) using EtOAc as the eluent. The first 180 mL of eluent is collected in a conical flask. Subsequent fractions are collected in test tubes (Note 12). Product **3** is found in test tubes 25-86 (Note 13). Fractions containing the product are concentrated by rotary evaporation (20 mmHg, 25 °C), and the resulting product placed under high vacuum (1.0 mmHg, 25 °C, 3 h) to afford **3** (4.67 g, 74% yield) as a pale yellow solid that is indefinitely stable at room temperature (Notes 25, 26 and 27).

Notes

1. All reaction vessels were dried under vacuum (1.0 mmHg) with the aid of a heat-gun for 3-4 min and maintained under nitrogen atmosphere during the course of the reaction.
2. 2-(*p*-Tolyl)propionic acid (97%) was purchased from Sigma-Aldrich and was used as received.

3. Thionyl chloride (>99%) was purchased from Sigma-Aldrich and was used as received.
4. The temperature of the oil bath was kept at 84 °C.
5. Initially, the vacuum (1.0 mmHg) was applied slowly to the stirred, crude mixture at 0 °C for 5–10 min to avoid bumping and then the flask was kept at room temperature for 1.5 h under vacuum (1.0 mmHg).
6. 4-(Methylamino)pyridine (99%) was purchased from Alfa Aesar and was used as received.
7. Methylene chloride (Optima grade) was purchased from Fisher Scientific and was dried using an alumina column-based system (Innovative Technologies PureSolv).
8. Triethylamine (Sigma-Aldrich, >99%) was distilled over KOH prior to use.
9. If the acid chloride solution was added too fast, strong fuming occurred. Normally, 0.5 mL/min was a reasonable rate of addition.
10. SiliCycle Silia*Flash*® P60 silica gel, 40-63 μm (230-400 mesh).
11. Flash chromatography was performed using 1.3-1.4 bar air pressure. Caution: a thick walled column and protective shield should be used.
12. Fractions were collected in 150 x 20 mm test tubes, allowing the collection of 28–30 mL in each test tube.
13. TLC was performed on TLC Silica gel 60 F_{254} plates.
14. Analytical data for **2**: ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.40 (d, J = 7.0 Hz, 3 H), 2.30 (s, 3 H), 3.25 (s, 3 H), 3.71 (q, J = 6.5 Hz, 1 H), 6.95 (d, J = 7.5 Hz, 2 H), 7.00 (br d, J = 5.4 Hz, 2 H), 7.05 (d, J = 8.0 Hz, 2 H), 8.57–8.58 (m, 2 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 20.4, 20.8, 36.9, 43.1, 121.5, 126.9, 129.2, 136.3, 138.0, 150.9, 151.0, 173.3; IR (cast, cm^{-1}): 2975, 2930, 1668, 1587, 1513, 1496, 1375, 1274, 1126, 1063, 1024, 826; HRMS (ESI): calcd. for $C_{16}H_{19}N_2O$ ($[M+H]^+$): 255.1492, found: 255.1488; mp 91–92 °C; Anal. calcd. for $C_{16}H_{18}N_2O$: C, 75.56; H, 7.13; N, 11.01, found: C, 75.47; H, 7.21; N, 11.03.
15. On half scale, the checkers obtained **2** in 87% yield. The submitters reported 83% yield for the full-scale reaction.
16. Anhydrous $CuCl_2$ (98%) was purchased from Strem Chemicals and used as received. It was stored in a desiccator between uses. The color of anhydrous $CuCl_2$ is dark brown. The submitters note that if the reagent becomes hydrated due to exposure to moisture and the color turns greenish, it can be dehydrated again by heating at 80 °C under vacuum (0.07 mmHg) for 12 h.

17. The checkers purchased sodium *tert*-butoxide (99.9%) from Sigma Aldrich and used as received; it was stored in a desiccator between uses. The submitter purchased sodium *tert*-butoxide (98%) from Acros Organics, sublimed it at 190 °C under vacuum (0.007 mmHg), and stored in a glove box (N_2 atmosphere) for use in this step.
18. The checkers carried out this step without a glove box. $CuCl_2$ and NaO*t*Bu were weighed under air atmosphere and quickly added to the round-bottomed flask under a positive flow of nitrogen. The submitters carried out this step as follows: The round-bottomed flask was transferred to a glove box (N_2 atmosphere). After adding $CuCl_2$ and NaO*t*Bu (sublimed), the round-bottomed flask was taken from the glove box and was connected to the Schlenk line.
19. Toluene (Optima grade) was purchased from Fisher Scientific and was dried by using an alumina column-based system (Innovative Technologies PureSolv).
20. The pale brown reaction mixture was stirred for 10 min at rt before heating was started.
21. After stirring at room temperature, the round-bottomed flask was placed in an oil bath and the temperature was set to 118 °C. It took 20–25 min for the oil to reach the preset temperature.
22. Consumption of the starting material can be checked by either TLC or ^{1}H NMR. In case of TLC, both the starting material and reaction mixture was spotted on a TLC plate and developed two times with EtOAc to get separation (TLC: EtOAc, Rf_{SM} = 0.24, $Rf_{product}$ = 0.16, both UV and $KMnO_4$ active). For NMR analysis, a 0.2 mL aliquot of the reaction mixture was withdrawn under a positive flow of nitrogen and was passed through a small pad of Celite, followed by removal of solvent under vacuum (1.0 mmHg). ^{1}H NMR showed the disappearance of the resonance (quartet) at 3.71 ppm. This indicated complete consumption of the starting material. The color of the reaction mixture was deep brown. The submitters found the reaction is complete in 7 h.
23. Celite (inner diameter = 6.2 cm, l = 3 cm) was tightly packed on a glass frit (P3). The reaction mixture was added slowly to the Celite pad. Due to the presence of large amounts of inorganic salts, the upper layer of Celite needed gentle scratching for smooth filtration.
24. The Celite was washed until the filtrate became colorless and TLC showed no further product to be present.
25. Analytical data for **3**: ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.80 (s, 3 H), 2.29 (s, 3 H), 3.21 (s, 3 H), 6.88 (d, *J* = 5.5 Hz, 1 H), 7.12 (d, *J* = 8.0 Hz, 2 H),

7.21–7.19 (m, 2 H), 8.35 (s, 1 H), 8.52 (d, J = 5.0 Hz, 1 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 20.7, 23.7, 26.2, 50.3, 103.8, 126.1, 129.2, 130.1, 136.4, 137.2, 144.3, 149.7, 150.2, 179.0; IR (cast, cm^{-1}): 3028, 2972, 2931, 1728, 1603, 1512, 1496, 1373, 1338, 1110, 1018, 818; HRMS (ESI): calcd. for $C_{16}H_{17}N_2O$ ($[M+H]^+$): 253.1335, found: 253.1333; mp 103–104 °C; Anal. calcd. for $C_{16}H_{16}N_2O$: C, 76.16; H, 6.39; N, 11.10, found: C, 76.09; H, 6.39; N, 11.11.

26. On half scale, the checkers obtained **3** in 75% yield.
27. The submitters, who had stored the reagents in a glove box and set up the reaction there (Note 18), reported 87% yield for the full-scale reaction.

Handling and Disposal of Hazardous Chemicals

The procedures in this article are intended for use only by persons with prior training in experimental organic chemistry. All hazardous materials should be handled using the standard procedures for work with chemicals described in references such as "Prudent Practices in the Laboratory" (The National Academies Press, Washington, D.C., 2011 www.nap.edu). All chemical waste should be disposed of in accordance with local regulations. For general guidelines for the management of chemical waste, see Chapter 8 of Prudent Practices.

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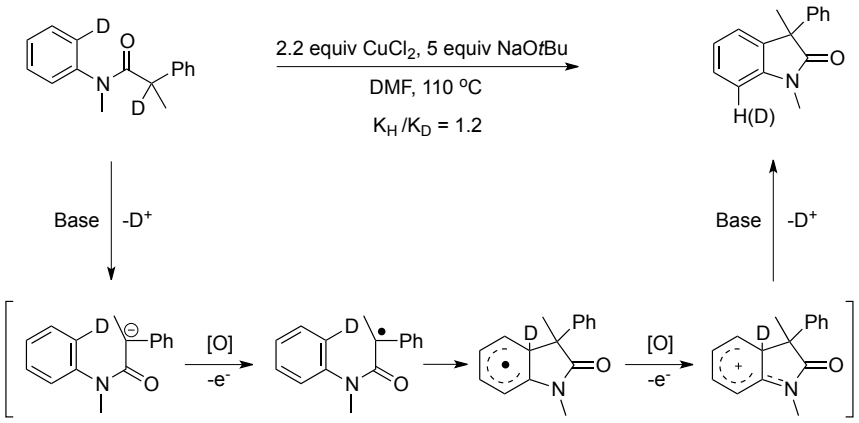
Discussion

In 2009, this group reported a novel, efficient, and high atom economic protocol for the synthesis of 3,3-disubstituted oxindoles, which relied on the direct oxidative coupling of an aromatic Csp^2–H and a Csp^3–H centers.[2] The reactions were carried out with readily synthesized anilides in the presence of $CuCl_2$ as the oxidant and NaO*t*Bu as a base in DMF at 110 °C. Shortly following this report, Taylor and coworkers published a similar protocol

leading to oxindoles with ester, nitrile and phosphonate functions in the 3-position.[3]

A likely mechanism of this reaction is shown in Scheme 1. The amidyl radical formed by one electron oxidation of the amide enolate cyclizes onto the aromatic ring. The resulting cyclohexadienyl radical is oxidized to form a σ-complex which readily aromatizes to the oxindole product.[2,3] Secondary isotope effect measurements indicates that Csp^2–H bond breaking is not involved in the rate-determining step and a radical pathway is also indicated by the finding that a cyclopropyl-substituted substrate furnished a conjugated diene as the only product.[2,3a] An intramolecular radical cyclization reaction is the key step of this transformation. The base/oxidant procedure captivates by its simplicity.



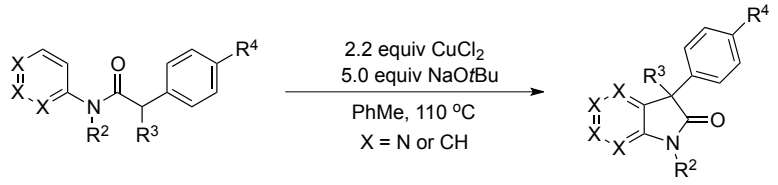
Scheme 1. Proposed pathway for the direct C–H coupling reaction

The $CuCl_2$-mediated protocol was extended to the synthesis of 3,3-disubstituted aza-oxindoles.[4] Compounds containing the aza-oxindole structural motif exhibit biological activities such as oral anti-inflammatory activity, and potent TrkA kinase and JAK 3 kinase inhibition.[5] Unlike the synthesis of oxindole, there are fewer protocols available in the literature for this class of compounds. Examples include the oxidation of azaindoles,[6a,b] radical cyclization reactions,[6c] Pauson-Khand type [2+2+1] cycloadditions,[6d] Pd-catalyzed intramolecular α-pyridination of amides,[6e] photo cyclizations,[6f,g] and cyclization of aminopyridineacetic acids.[6h] All the aforementioned methods require a specifically functionalized precursor; for

instance the presence of an *ortho*-pyridyl halogen, an α-xanthate group or an α-hydroxy group, or a preexisting bicyclic ring system. The $CuCl_2$-mediated oxidative radical coupling protocol[4] for aza-oxindole synthesis does not entail such structural specificity. The reactions with the pyridyl amides were carried out in the presence of $CuCl_2$ and NaO*t*Bu in toluene at 110 °C.[4] The key step of this transformation is a Minisci reaction, an intramolecular radical cyclization on the pyridine ring. Substrates with varying the position of nitrogen in the pyridine ring afforded aza-oxindoles in fair to excellent yields (Entry 1-11, Table 1). In general, yields with *para*-pyridyl substrates were considerably higher than with *ortho*-pyridyl substrates (Entry 1-3 *vs* 4-7, Table 1). The oxidative coupling reaction of *meta*-pyridyl amide substrate afforded two regioisomeric products (Entry 8-11, Table 1). The regioisomer resulting from the addition at *ortho* to the pyridyl N is largely favored (Entry 8, Table 1) or is the exclusive product (Entry 9-11, Table 1).[4] In the synthetic protocol for aza-oxindole detailed here, the concentration of the reaction was raised by a factor of two compared to the small scale preparation previously reported (0.1M *vs* 0.05M).[4]

In the course of these studies, a new route to aza-oxindoles, proceeding *via* a base promoted Truce-Smiles rearrangement, was found.[7]

Table 1. Selected examples of $CuCl_2$ mediated aza-oxindole synthesis[a]



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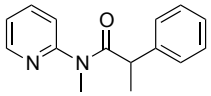
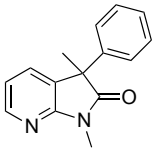
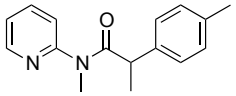
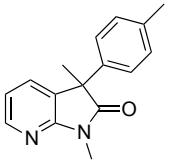
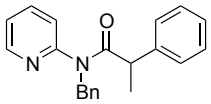
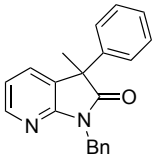
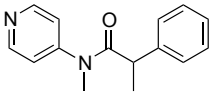
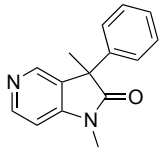
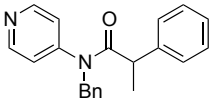
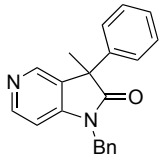
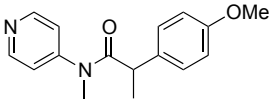
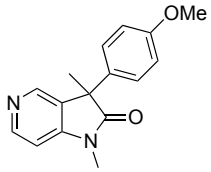
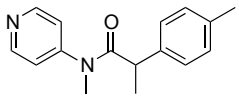
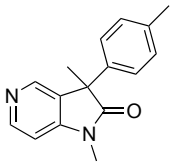
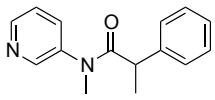
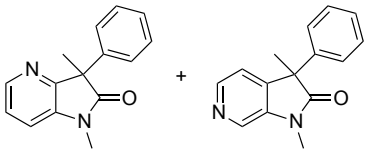
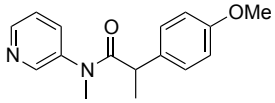
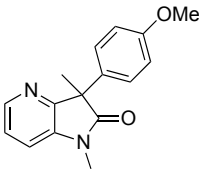
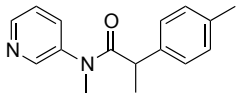
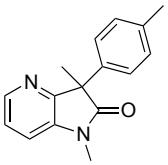
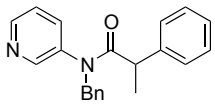
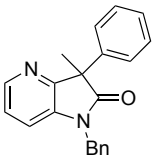
1			68
2			57
3			64
4			94
5			79
6			99

Entry	Substrate	Product	Yield(%)
7			99
8		 84:16	95
9			82
10			88
11			71

[a] 0.4-0.8 mmol scale in PhMe (0.05M). Yields given are those of isolated pure products.[4]

References

1. Department of Organic Chemistry, University of Geneva, 30 Quai Ernest Ansermet, 1211 Geneva 4, Switzerland. We thank the Swiss National Science Foundation and the University of Geneva for financial support.
2. Jia, Y. X.; Kündig, E. P. *Angew. Chem. Int. Ed.* **2009**, *48*, 1636.
3. (a) Perry, A.; Taylor, R. J. K. *Chem. Commun.* **2009**, 3249. (b) Pugh, D. S.; Klein, J. E. M. N.; Perry, A. Taylor, R. J. K. *Synlett* **2010**, 934. (c) Klein, J.

E. M. N.; Perry, A.; Pugh, D. S.; Taylor, R. J. K. *Org. Lett.* **2010**, *12*, 3446. (d) Pugh, D. S.; Taylor, R. J. K. *Org. Synth.* **2012**, *89*, 438.
4. Dey, C.; Kündig, E. P. *Chem. Commun.* **2012**, *48*, 3064.
5. (a) Ting, P. C.; Kaminski, J. J.; Sherlock, M. H.; Tom, W. C.; Lee, J. F.; Bryant, R. W.; Watnick, A. S.; Mcphail, A. T. *J. Med. Chem.* **1990**, *33*, 2697. (b) Kumar, V.; Dority, J. A.; Bacon, E. R.; Singh, B.; Lesher, G. Y. *J. Org. Chem.* **1992**, *57*, 6995. (c) Cheung, M.; Hunter, R. N.; Peel, M. R.; Lackey, K. E. *Heterocycles* **2001**, *55*, 1583. (d) Adams, C.; Aldous, D. J.; Amendola, S.; Bamborough, P.; Bright, C.; Crowe, S.; Eastwood, P.; Fenton, G.; Foster, M.; Harrison, T. K. P.; King, S.; Lai, J.; Lawrence, C.; Letallec, J. P.; McCarthy, C.; Moorcroft, N.; Page, K.; Rao, S.; Redford, J.; Sadiq, S.; Smith, K.; Souness, J. E.; Thurairatnam, S.; Vine, M.; Wyman, B. *Bioorg. Med. Chem. Lett.* **2003**, *13*, 3105. (e) Wood, E. R.; Kuyper, L.; Petrov, K. G.; Hunter, R. N.; Harris, P. A.; Lackey, K. *Bioorg. Med. Chem. Lett.* **2004**, *14*, 953.
6. (a) Marfat, A.; Carta, M. P. *Tetrahedron Lett.* **1987**, *28*, 4027. (b) Robinson, R. P.; Donahue, K. M. *J. Org. Chem.* **1991**, *56*, 4805. (c) Bacqué, E.; Qacemi, M. E.; Zard, S. Z. *Org. Lett.* **2004**, *6*, 3671. (d) Saito, T.; Furukawa, N.; Otani, T. *Org. Biomol. Chem.* **2010**, *8*, 1126. (e) Ackermann, L.; Vicente, R.; Hofmann, N. *Org. Lett.* **2009**, *11*, 4274. (f) Goehring, R. R.; Sachdeva, Y. P.; Pisipati, J. S.; Sleevi, M. C.; Wolfe, J. F. *J. Am. Chem. Soc.* **1985**, *107*, 435. (g) Wolfe, J. F.; Sleevi, M. C.; Goehring, R. R. *J. Am. Chem. Soc.* **1980**, *102*, 3646. (h) Okuda, S.; Robison, M. M. *J. Am. Chem. Soc.* **1959**, *81*, 740.
7. Dey, C.; Katayev, D.; Ylijoki, K. E. O.; Kündig, E. P. *Chem. Commun.* **2012**, *48*, 10957.

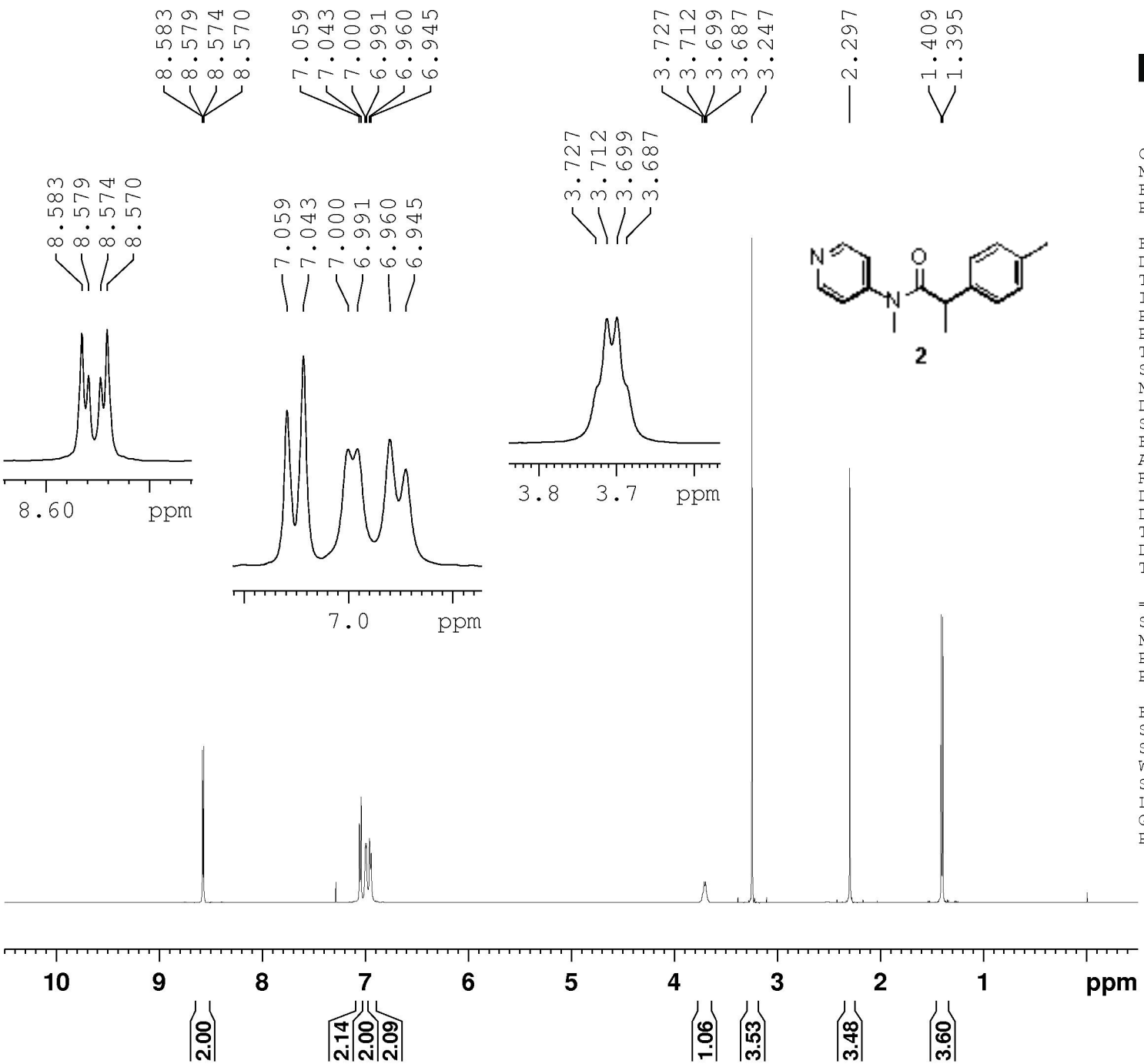
Appendix
Chemical Abstracts Nomenclature (Registry Number)

2-(*p*-Tolyl)propionic acid; (938-94-3)
Thionyl chloride, (7719-09-7)
4-(Methylamino)pyridine; (1121-58-0)
N-Methyl-*N*-(pyridin-4-yl)-2-(*p*-tolyl)propanamide, (1364651-81-9)
Copper (II) chloride; (7447-39-4)
Sodium *tert*-butoxide; (865-48-5)
1,3-Dimethyl-3-(*p*-tolyl)-1*H*-pyrrolo[3,2-*c*]pyridin-2(3*H*)-one; (1364652-24-3)

Peter Kündig graduated from the Federal Institute of Technology (ETH) in Zurich and then moved to the University of Toronto where he obtained his Ph.D. (G.A.S. Ozin). Following a postdoctoral stay at the University of Bristol (P. Timms), he started his own research at the University of Geneva, focusing on synthetic and mechanistic organometallic chemistry and on metal mediated and catalyzed reactions in organic synthesis. He held from 1990-2012 a Chair in Organic Chemistry. His awards include the Werner Prize of the Swiss Chemical Society (1986) and the EUCHEMS award (2007). Kündig was chair of the ChemComm Editorial Board (2007-11) and presently is President of the Swiss Chemical Society.

Chandan Dey was born in Midnapore, West Bengal, India in 1984. He obtained a B.Sc. (Hons.) degree in Chemistry from Midnapore college, India in 2006. In 2008, he received a M.Sc. degree from Indian Institute of Technology-Bombay, India. He joined the group of Prof. E. Peter Kündig at University of Geneva, Switzerland where he completed his doctoral study in 2012.

Yen-Ku Wu was born in Taipei, Taiwan. He received his B.Sc. in chemistry in 2004 and M.Sc. with Professor Hsing-Jang Liu in 2006 from National Tsing Hua University. In 2008, he started his Ph.D. studies working on non-conventional Nazarov chemistry under the supervision of Professor F. G. West at the University of Alberta. After obtaining his Ph.D. in 2013, he moved to the University of Chicago, where he is currently a postdoctoral scholar in the laboratories of Professor Viresh H. Rawal.



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DW 50.000 usec
DE 10.00 usec
TE 296.1 K
D1 2.00000000 sec
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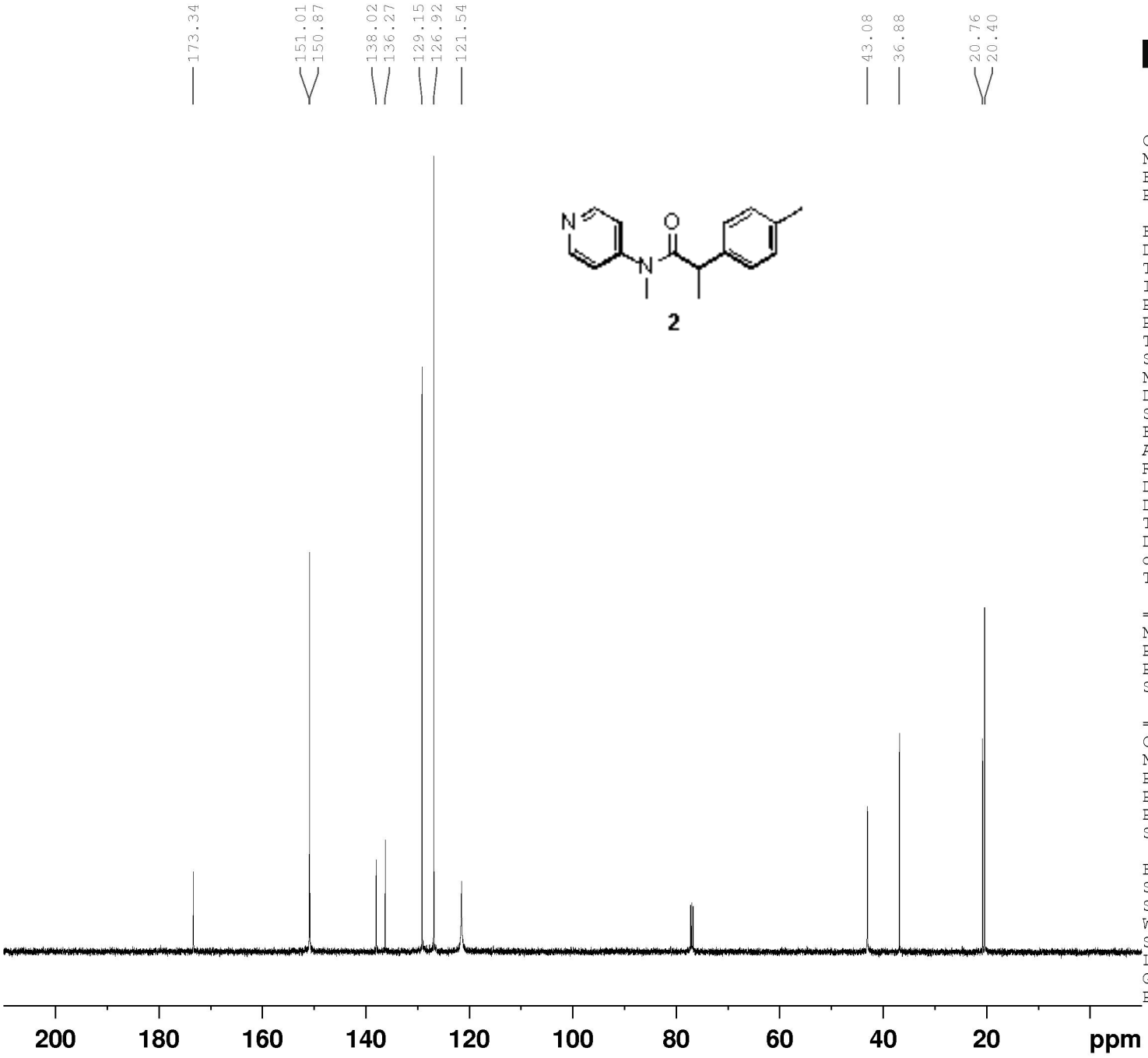


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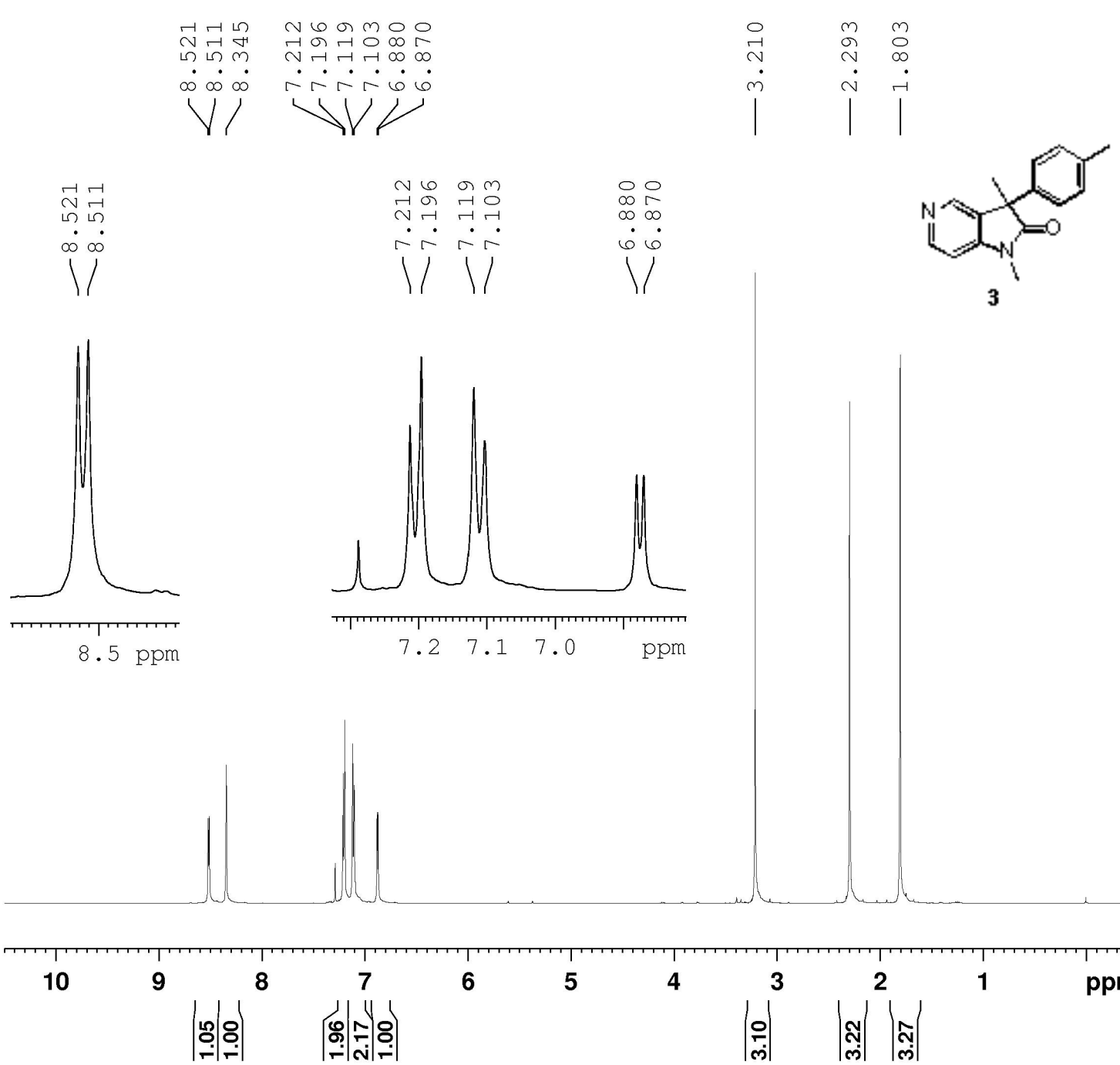

3

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TE                 297.1 K
D1              3.00000000 sec
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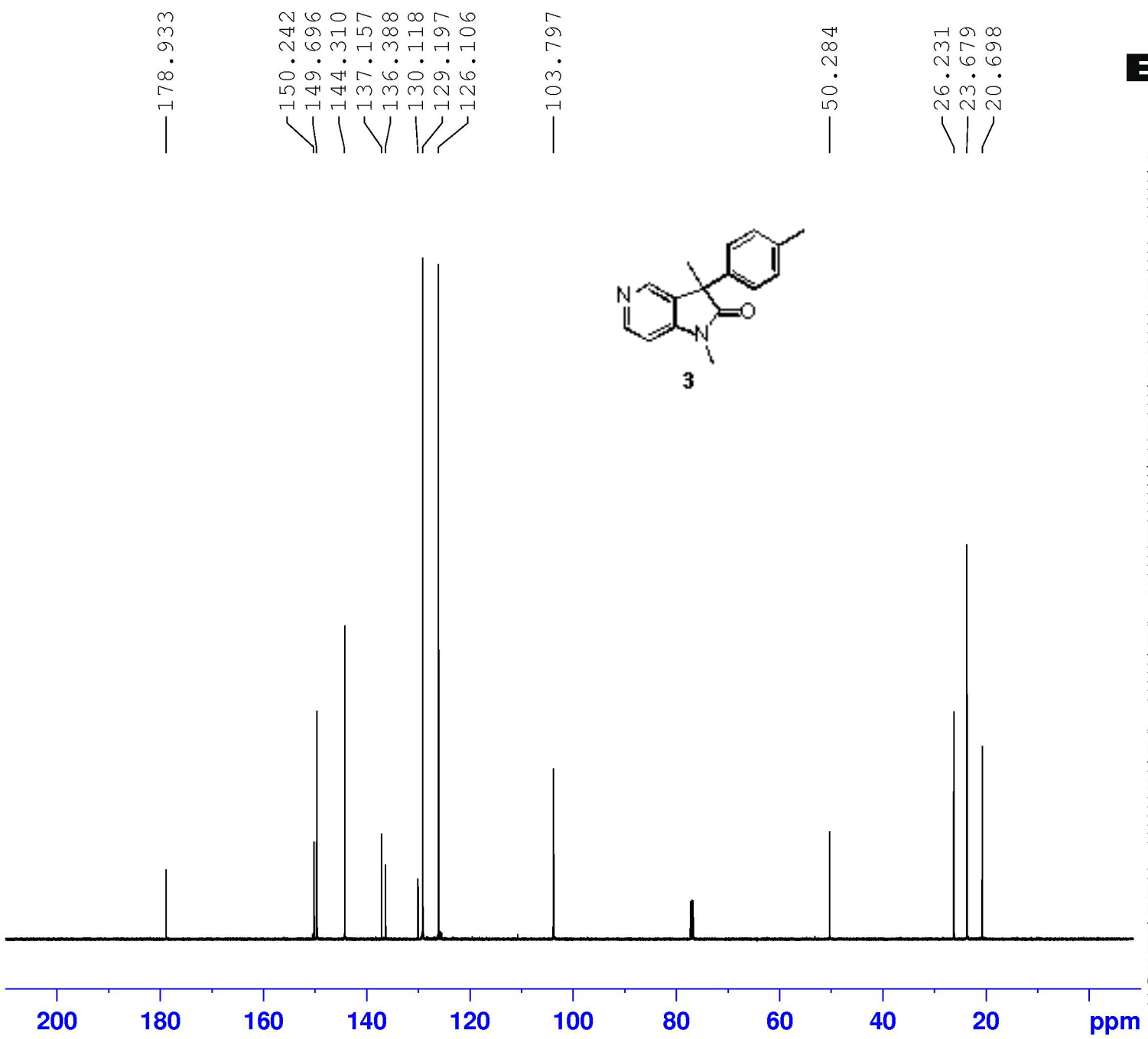

BRUKER

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FIDRES 0.158734 Hz
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DW 16.800 usec
DE 6.50 usec
TE 297.2 K
D1 3.00000000 sec
D11 0.03000000 sec
TD0 1

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NUC1 13C
P1 10.00 usec
PLW1 72.83999634 W

======== CHANNEL f2 ========
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NUC2 1H
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PCPD2 80.00 usec
PLW2 19.00000000 W
PLW12 0.29688001 W

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