Electronic Supplementary Information


Fei Ye, Mansour Haddad,
Véronique Michelet* and Virginie Ratovelomanana-Vidal*

Contents

I. General informations ........................................................................................................................................2
II. Preparation of diynes and cyanamides .....................................................................................................3
III. Ru-catalyzed [2+2+2] cycloaddition reactions .....................................................................................5
IV. NMR spectra .............................................................................................................................................14
I. General informations

All manipulations were carried out under an argon atmosphere. $^1$H NMR and $^{13}$C NMR were recorded on Bruker AV300 or AV400 instruments. All signals are expressed as ppm (δ) and are referenced to the non-deuterated solvent peak CHCl$_3$ (7.26 ppm for $^1$H and 77.16 ppm for $^{13}$C) or Methanol-D$_4$ (3.31 ppm for $^1$H and 49.00 ppm for $^{13}$C). Coupling constants (J) are given in Hz and refer to apparent peak multiplicities. The following abbreviations are used: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet.

Melting points were determined with a Kofler Heizbank 7841 apparatus and are uncorrected.

Mass spectrometry analyses (direct introduction by chemical ionization with ammoniac or electrospray) were performed at the Ecole Nationale Supérieure de Chimie de Paris (ENSCP). High resolution mass spectra were performed at the University Pierre and Marie Curie (Paris).

Sigma-Aldrich Silica gel (high-purity grade, pore size 60 Å, 230-400 mesh particle size, 40-63 μm particle size) was employed for flash column chromatography. Analytical thin layer chromatography (TLC) was carried out using commercial silica-gel plates (Merck 60 F254), spots were detected with UV light (254 nm) and revealed with a KMnO$_4$ or para-anisaldehyde stain solution.

All reagents were used as received from commercial sources. A freshly opened bottle of ruthenium(III) trichloride hydrate was used for the [2+2+2] cycloadditions.
II. Preparation of diynes and cyanamides

1. Synthesis of diynes 1 and 19

Diynes 1a-h\(^1\) and 19\(^2\) were prepared according to the previously reported literatures.

Preparation of diynes, reaction conditions: a) NaH (2.4 equiv), THF, 0 °C to RT, 12 h; b) LiAlH\(_4\) (6 equiv), THF, 0 °C to RT, 1 h; c) PdCl\(_2\)(PPh\(_3\))\(_2\) (5 mol%), CuI (2.5 mol%), Iodobenzene (2.5 equiv), Et\(_3\)N/THF (1:1), 50 °C, 4 h; d) LiHMDS (2.2 equiv), TMSCl (2.5 equiv), THF, -70 °C, 2 h; e) EtN(iPr)\(_2\) (4 equiv), Ac\(_2\)O (4 equiv), DCM, 0 °C to RT, 24 h; f) NaH (2.5 equiv), nBu\(_4\)I (0.25 equiv), Benzyl bromide (2.5 equiv), THF, 0 °C to RT, 12 h; g) K\(_2\)CO\(_3\) (4 equiv), MeCN, reflux, 12 h.

Diyne 1e was prepared according to the following protocol:

To a suspension of NaH (60% in mineral oil, 2.4 equiv, 14.4 mmol, 0.58 g) in THF (30 mL) at 0 °C was added dropwise a solution of 1,3-dimethylbarbituric acid (1 equiv., 6 mmol, 0.94 g), the reaction mixture was stirred at 0 °C for 1 h, then 1-bromo-2-butyne (2.4 equiv, 14.4 mmol, 1.26 mL) in THF (10 mL) was added to the mixture. Reaction mixture was then allowed to warm up to room temperature.

---


and stirred for 12 h until completion by TLC. The mixture was finally quenched with saturated ammonium chloride and extracted with Et₂O. The combined organic layers were washed with water and brine. The solution was dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by flash chromatography (Cyclohexane/Ethyl acetate gradient from 95/5 to 85/15) to afford compound 1e (0.96 g, 62%) as a white solid. m. p.: 118-120 °C.

**1H NMR** (300 MHz, CDCl₃) δ 3.40 – 3.24 (m, 6H), 2.78 – 2.51 (m, 4H), 1.75 – 1.50 (m, 6H).

**13C NMR** (75 MHz, CDCl₃) δ 170.3, 151.4, 80.0, 72.4, 56.6, 28.8, 28.3, 3.4.

**MS** (CI, NH₃): m/z = 261 [M + H]⁺.

2. **Synthesis of cyanamides 2**

Cyanamides 2a-b and 2e-f were purchased from commercial sources. Cyanamides 2d were prepared according to the reported literature.³ Cyanamides 2c was prepared according to the following protocol:

![Chemical structure](image)

*N*-Methylenzylamine (1.55 mL, 12.0 mmol, 2 equiv) was added to a solution of cyanogen bromide (0.64 g, 6.0 mmol, 1 equiv) in Et₂O/THF (1:1, 30 mL) at 0 °C. The reaction mixture was stirred at room temperature for 3 h. Hexane (5 mL) was added, and the mixture was stirred for an additional 10 min. It was then filtered through a pad of Celite, and the filtrate was washed with water (4x25 mL) and brine (2x25 mL). The solution was dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by flash chromatography (Cyclohexane/Ethyl acetate gradient from 80/20 to 70/30) to afford compound 2c (0.75 g, 86 %) as a colorless oil.

**1H NMR** (300 MHz, CDCl₃) δ 7.46 – 7.28 (m, 5H), 4.15 (s, 2H), 2.77 (s, 3H).

**13C NMR** (75 MHz, CDCl₃) δ 134.5, 129.1, 128.8, 128.5, 119.0, 57.3, 37.9.

The **1H NMR** data obtained were in agreement with the literature.⁴

---


III. Ru-catalyzed [2+2+2] cycloaddition reactions.

General procedure: Ru-catalyzed [2+2+2] cycloaddition of diynes with cyanamides under solvent-free conditions.

A sealed tube was equipped with RuCl₃·nH₂O (5 mol %) and diyne 1 (1 mmol, 1 equiv), followed by the addition of cyanamide 2 (2.0 mmol, 2.0 equiv) under argon atmosphere. The tube was sealed and the reaction mixture was stirred vigorously at 80 or 110 °C. When the reaction was complete (TLC monitoring), the crude reaction mixture was directly purified by flash chromatography over silica gel to afford cycloadducts. The excess of cyanamide was removed by bulb to bulb distillation.

The Ru(acac)₃ catalyst was not efficient for this transformation (80 °C and 110 °C).

**Dimethyl 3-(dimethylamino)-1,4-dimethyl-5,7-dihydro-6H-cyclopenta[c]pyridine-6,6-dicarboxylate (3).**

![Chemical structure of 3](image)

This compound was prepared using diyne 1a (236 mg, 1.0 mmol), N,N-dimethylcyanamide 2a (140 mg, 2.0 mmol, 2.0 equiv) and RuCl₃·nH₂O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 80/20 to 70/30) afforded 3 (225 mg, 74%) as a white solid.

The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0×10⁻³ mbar, 70 °C for 10 minutes).

**¹H NMR** (300 MHz, CDCl₃) δ 3.74 (s, 6H), 3.48 (s, 2H), 3.47 (s, 2H), 2.75 (s, 6H), 2.31 (s, 3H), 2.14 (s, 3H).

**¹³C NMR** (75 MHz, CDCl₃) δ 172.2, 161.6, 150.3, 147.9, 127.2, 117.1, 59.9, 53.2, 42.5, 40.1, 38.7, 21.8, 14.9.

**MS** (Cl, NH₃): m/z = 307 [M + H]⁺.

The NMR data obtained were in agreement with the literature.⁵

**Dimethyl 1,4-dimethyl-3-morpholino-5,7-dihydro-6H-cyclopenta[c]pyridine-6,6-dicarboxylate (4).**

---

This compound was prepared using diyne 1a (236 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 80/20) afforded 4 (330 mg, 95%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0x10$^{-3}$ mbar, 90 °C for 10 minutes).

$^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 3.86 – 3.78 (m, 4H), 3.76 (d, $J = 4.0$ Hz, 6H), 3.50 (s, 2H), 3.48 (s, 2H), 3.12 – 2.99 (m, 4H), 2.33 (s, 3H), 2.14 (s, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 172.1, 160.2, 150.5, 148.5, 128.3, 117.9, 67.4, 59.9, 53.2, 50.8, 40.0, 38.7, 21.7, 14.4.

MS (Cl, NH$_3$): m/z = 349 [M + H]$^+$. 

The NMR data obtained were in agreement with the literature.$^5$

(1,4-Dimethyl-3-morpholino-6,7-dihydro-5H-cyclopenta[c]pyridine-6,6-diyl)dimethanol (5).

---

This compound was prepared using diyne 1b (180 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate 80/20) afforded 3c (30 mg, 10%) as a pale yellow solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0x10$^{-3}$ mbar, 90 °C for 10 minutes).

$^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 3.86 – 3.81 (m, 4H), 3.81 – 3.67 (m, 4H), 3.13 – 2.99 (m, 4H), 2.72 – 2.60 (m, 4H), 2.31 (s, 3H), 2.12 (s, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 159.8, 152.4, 149.1, 130.0, 118.6, 69.5, 67.4, 50.8, 48.7, 37.9, 36.6, 21.7, 14.4.

MS (Cl, NH$_3$): m/z = 293 [M + H]$^+$. 

The NMR data obtained were in agreement with the literature.$^6$
(1,4-Dimethyl-3-morpholino-6,7-dihydro-5H-cyclopenta[c]pyridine-6,6-diyl)bis(methylene) diacetate (6).

This compound was prepared using diyne 1c (264 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 80/20) afforded 6 (255 mg, 68%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0×10$^{-3}$ mbar, 90 °C for 10 minutes). m.p. 102 – 104 °C.

$^1$H NMR (300 MHz, CDCl$_3$) δ 4.08 (s, 4H), 3.89 – 3.73 (m, 4H), 3.16 – 2.92 (m, 4H), 2.78 – 2.70 (m, 4H), 2.31 (s, 3H), 2.12 (s, 3H), 2.07 (s, 6H).

$^{13}$C NMR (75 MHz, CDCl$_3$) δ 171.1, 160.1, 151.4, 149.1, 129.2, 118.4, 67.4, 66.9, 50.8, 46.2, 38.1, 36.8, 21.7, 21.0, 14.4.

MS (Cl, NH$_3$): m/z = 377 [M + H]$^+$.

HRMS (ESI$^+$): calcd. for C$_{20}$H$_{29}$N$_2$O$_5$ [M+H]$^+$: 377.2071, found 377.2072.

4-(6,6-Bis((benzyloxy)methyl)-1,4-dimethyl-6,7-dihydro-5H-cyclopenta[c]pyridin-3-yl)morpholine (7).

This compound was prepared using diyne 1d (360 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate 80/20) afforded 7 (390 mg, 83%) as a pale yellow oil. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0×10$^{-3}$ mbar, 90 °C for 10 minutes).

$^1$H NMR (300 MHz, CDCl$_3$) δ 7.40 – 7.18 (m, 10H), 4.53 (s, 4H), 3.96 – 3.72 (m, 4H), 3.50 (s, 4H), 3.16 – 2.94 (m, 4H), 2.79 – 2.70 (m, 4H), 2.31 (s, 3H), 2.11 (s, 3H).

---

13C NMR (75 MHz, CDCl$_3$) δ 159.7, 152.9, 148.9, 138.8, 130.7, 128.5, 127.6, 118.5, 73.7, 73.4, 67.5, 50.9, 48.1, 38.5, 37.1, 21.7, 14.4.

**MS (Cl, NH$_3$):** m/z = 473 [M + H]$^+$.  

**HRMS (ESI$^+$):** calcd. for C$_{30}$H$_{37}$N$_2$O$_3$ [M+H]$^+$: 473.2799, found 473.2790.

**1,1',3',4-Tetramethyl-3-morpholino-5,7-dihydro-2'H-spirocyclopenta[c]pyridine-6,5'-pyrimidine-2',4',6'(1'H,3'H)-trione (8).**

This compound was prepared using diyne 1e (260 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 80/20 to 50/50) afforded 8 (275 mg, 74%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0x10$^{-3}$ mbar, 90 °C for 10 minutes). m.p. 175 – 178 °C.

1H NMR (300 MHz, CDCl$_3$) δ 3.90 – 3.76 (m, 4H), 3.49 (s, 2H), 3.45 (s, 2H), 3.34 (s, 6H), 3.17 – 2.94 (m, 4H), 2.30 (s, 3H), 2.15 (s, 3H).

13C NMR (75 MHz, CDCl$_3$) δ 172.2, 160.7, 151.4, 150.6, 148.3, 127.3, 117.8, 67.4, 55.8, 50.8, 44.0, 42.6, 29.3, 21.8, 14.5.

**MS (Cl, NH$_3$):** m/z = 373 [M + H]$^+$.  

**HRMS (ESI$^+$):** calcd. for C$_{19}$H$_{25}$N$_4$O$_4$ [M+H]$^+$: 373.1870, found 373.1870.

**1,4-Dimethyl-3-morpholino-5,7-dihydrospiro[cyclopenta[c]pyridine-6,2'-indene]-1',3'-dione (9).**

This compound was prepared using diyne 1f (250 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 80/20) afforded 9 (268 mg, 74%) as a yellow solid. The excess of
cyanamide was removed by bulb to bulb distillation (conditions: 1.0x10⁻³ mbar, 90 °C for 10 minutes).
m.p. 206 – 209 °C.

¹H NMR (300 MHz, CDCl₃) δ 8.08 – 7.98 (m, 2H), 7.93 – 7.85 (m, 2H), 3.89 – 3.73 (m, 4H), 3.23 (s, 2H), 3.22 (s, 2H), 3.14 – 3.01 (m, 4H), 2.31 (s, 3H), 2.13 (s, 3H).

¹³C NMR (75 MHz, CDCl₃) δ 202.9, 160.6, 151.3, 148.4, 141.7, 136.2, 128.9, 123.9, 118.0, 67.4, 58.5, 50.8, 39.6, 21.8, 14.5.

MS (Cl, NH₃): m/z = 363 [M + H]⁺.


4,7-Dimethyl-6-morpholino-1,3-dihydrofuro[3,4-c]pyridine (10).

This compound was prepared using diyne 1g (122 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl₃·nH₂O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 80/20) afforded 10 (150 mg, 64%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0x10⁻³ mbar, 90 °C for 10 minutes).

¹H NMR (300 MHz, CDCl₃) δ 5.05 (s, 2H), 5.00 (s, 2H), 3.86 – 3.81 (m, 4H), 3.12 – 3.07 (m, 4H), 2.32 (s, 3H), 2.12 (s, 3H).

¹³C NMR (75 MHz, CDCl₃) δ 160.5, 150.1, 146.2, 127.6, 115.1, 73.2, 72.7, 67.3, 50.7, 21.9, 14.6.

MS (Cl, NH₃): m/z = 235 [M + H]⁺.

The NMR data obtained were in agreement with the literature.⁶

4-(4,7-Dimethyl-2-tosyl-2,3-dihydro-1H-pyrrolo[3,4-c]pyridin-6-yl)morpholine (11).

This compound was prepared using diyne 1h (275 mg, 1.0 mmol), 4-cyanomorpholine 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl₃·nH₂O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 80/20) afforded 11 (200 mg, 68%) as a white solid. The excess of terephthaldehyde was removed by bulb to bulb distillation (conditions: 1.0x10⁻³ mbar, 90 °C for 10 minutes).

¹H NMR (300 MHz, CDCl₃) δ 7.78 – 7.70 (m, 2H), 7.68 – 7.60 (m, 2H), 5.10 (s, 2H), 4.32 (s, 2H), 3.86 – 3.81 (m, 4H), 3.12 – 3.07 (m, 4H), 2.33 (s, 3H), 2.13 (s, 3H).

¹³C NMR (75 MHz, CDCl₃) δ 160.5, 150.1, 146.2, 127.6, 115.1, 73.2, 72.7, 67.3, 50.7, 21.9, 14.6.

MS (Cl, NH₃): m/z = 387.1617.
acetate gradient from 90/10 to 80/20) afforded 11 (280 mg, 72%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10\(^{-3}\) mbar, 90 °C for 10 minutes).

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.78 (d, \(J = 8.3\) Hz, 2H), 7.33 (d, \(J = 8.0\) Hz, 2H), 4.52 – 4.40 (m, 4H), 3.85 – 3.75 (m, 4H), 3.10 – 3.00 (m, 4H), 2.41 (s, 3H), 2.27 (s, 3H), 2.08 (s, 3H).

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 160.8, 147.7, 146.8, 144.0, 134.1, 130.1, 127.8, 124.8, 116.4, 67.3, 53.5, 52.6, 50.69, 21.7, 14.5.

**MS** (Cl, NH\(_3\)): m/z = 388 [M + H].

The NMR data obtained were in agreement with the literature.\(^6\)

**Dimethyl 3-(benzyl(methyl)amino)-1,4-dimethyl-5,7-dihydro-6\(\)H-cyclopenta[c]pyridine-6,6-dicarboxylate (15).**

\begin{center}
\includegraphics[width=0.5\textwidth]{chemical_formula.png}
\end{center}

This compound was prepared using diyne 1a (236 mg, 1.0 mmol), \(N\)-benzyl-\(N\)-methylcyanamide 2c (292 mg, 2.0 mmol, 2.0 equiv) and RuCl\(_3\)·nH\(_2\)O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 95/5 to 85/15) afforded 15 (306 mg, 81%) as a colorless oil. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10\(^{-3}\) mbar, 120 °C for 10 minutes).

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.45 – 7.38 (m, 2H), 7.32 (t, \(J = 7.3\) Hz, 2H), 7.28 – 7.16 (m, 1H), 4.26 (s, 2H), 3.77 (s, 6H), 3.55 – 3.45 (m, 4H), 2.67 (s, 3H), 2.35 (s, 3H), 2.20 (s, 3H).

\(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 172.2, 161.4, 150.4, 148.1, 140.0, 128.4, 128.2, 127.7, 126.8, 117.8, 59.9, 58.4, 53.2, 40.1, 39.8, 38.8, 21.7, 14.8.

**MS** (Cl, NH\(_3\)): m/z = 383 [M + H].

**HRMS** (ESI\(^+\)): calcd. for C\(_{22}\)H\(_{27}\)N\(_2\)O\(_4\) [M+H]: 383.1965, found 383.1963.

**Dimethyl 3-(dibenzylamino)-1,4-dimethyl-5,7-dihydro-6\(\)H-cyclopenta[c]pyridine-6,6-dicarboxylate (16).**
This compound was prepared using diyne 1a (236 mg, 1.0 mmol), dibenzylcyanamide 2d (444 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 95/5 to 90/10) afforded 16 (344 mg, 75%) as a sticky yellow oil. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10$^{-3}$ mbar, 180 °C for 20 minutes).

$^1$H NMR (300 MHz, CDCl$_3$) δ 7.39 – 7.13 (m, 10H), 4.25 (s, 4H), 3.76 (s, 6H), 3.49 (s, 4H), 2.29 (s, 3H), 2.24 (s, 3H).

$^{13}$C NMR (75 MHz, CDCl$_3$) δ 172.2, 159.9, 150.4, 148.2, 139.9, 128.6, 128.3, 128.2, 126.7, 118.9, 59.7, 55.4, 53.2, 40.1, 38.8, 21.6, 14.5.

MS (Cl, NH$_3$): m/z = 459 [M + H]$^+$. 

Dimethyl 1,4-dimethyl-3-(pyrrolidin-1-yl)-5,7-dihydro-6H-cyclopenta[c]pyridine-6,6-dicarboxylate (17).

This compound was prepared using diyne 1a (236 mg, 1.0 mmol), pyrrolidine-1-carbonitrile 2e (192 mg, 2.0 mmol, 2.0 equiv) and RuCl$_3$·nH$_2$O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 90/10 to 90/10) afforded 17 (285 mg, 86%) as a colorless oil. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10$^{-3}$ mbar, 80 °C for 10 minutes).

$^1$H NMR (300 MHz, CDCl$_3$) δ 3.75 (s, 6H), 3.44 (m, 8H), 2.29 (s, 3H), 2.15 (s, 3H), 1.87 (m, 4H).

$^{13}$C NMR (75 MHz, CDCl$_3$) δ 172.3, 158.9, 150.3, 147.4, 124.6, 113.5, 60.0, 53.1, 50.3, 40.1, 38.6, 25.6, 21.7, 15.8.
MS (Cl, NH₃): m/z = 333 [M + H]^+.

The NMR data obtained were in agreement with the literature.⁵

**Dimethyl 1,4-dimethyl-3-(piperidin-1-yl)-5,7-dihydro-6H-cyclopenta[c]pyridine-6,6-dicarboxylate (18).**

This compound was prepared using diyne 1a (236 mg, 1.0 mmol), piperidine-1-carbonitrile 2f (220 mg, 2.0 mmol, 2.0 equiv) and RuCl₃·nH₂O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 95/5 to 90/10) afforded 18 (251 mg, 73%) as a colorless oil. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10⁻³ mbar, 80 °C for 10 minutes).

¹H NMR (300 MHz, CDCl₃) δ 3.75 (s, 6H), 3.49 (s, 2H), 3.47 (s, 2H), 3.06 – 2.91 (m, 4H), 2.32 (s, 3H), 2.13 (s, 3H), 1.73 – 1.61 (m, 4H), 1.61 – 1.50 (m, 2H).

¹³C NMR (75 MHz, CDCl₃) δ 172.2, 161.7, 150.1, 148.1, 127.5, 118.1, 59.8, 53.2, 51.6, 40.01, 38.7, 26.4, 24.8, 21.7, 14.4.

MS (Cl, NH₃): m/z = 347 [M + H]^+.

The NMR data obtained were in agreement with the literature.⁶

**Dimethyl 1-methyl-3-morpholino-5,7-dihydro-6H-cyclopenta[c]pyridine-6,6-dicarboxylate (20)**

This compound was prepared using diyne 19 (222 mg, 1.0 mmol), piperidine-1-carbonitrile 2b (224 mg, 2.0 mmol, 2.0 equiv) and RuCl₃·nH₂O (10.4 mg, 0.05 mmol). Purification on silica gel (Cyclohexane/Ethyl acetate gradient from 95/5 to 90/10) afforded 20 (71 mg, 43%) as a white solid. The excess of cyanamide was removed by bulb to bulb distillation (conditions: 1.0 x 10⁻³ mbar, 90 °C for 10 minutes). m.p. 110 – 112°C.
$^1$H NMR (400 MHz, CDCl$_3$) δ 6.33 (s, 1H, H$_8$), 3.83 – 3.78 (m, 4H, H$_{13}$), 3.75 (s, 6H, H$_1$), 3.49 (s, 2H, H$_4$), 3.47 – 3.41 (m, 6H, H$_{5,12}$), 2.32 (s, 3H, H$_{11}$)

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 172.0 (C$_2$), 159.3 (C$_7$), 151.7 (C$_9$), 151.5 (C$_{10}$), 124.3 (C$_6$), 100.1 (C$_8$), 67.0 (C$_{13}$), 60.0 (C$_3$), 53.2 (C$_1$), 46.4 (C$_{12}$), 40.8 (C$_4$), 38.0 (C$_5$), 22.2 (C$_{11}$).

NOESY (400 MHz, CDCl$_3$) H$_8$ (6.33 ppm) correlates to H$_{12}$ (3.47 – 3.41 ppm), H$_5$ (3.47 – 3.41 ppm) correlates to H$_{11}$ (2.32 ppm).

HRMS (ESI$^+$): calcd. for C$_{17}$H$_{23}$N$_2$O$_5$ [M+H]$^+$: 335.1601, found 335.1603.
IV. NMR spectra

1e