Supporting Information for

Cationic Ruthenium Alkylidene Catalysts Bearing Phosphine Ligands

Koji Endo and Robert H. Grubbs*

Arnold and Mabel Beckman Laboratory of Chemical Synthesis, Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125, United States

List of Figures and Tables

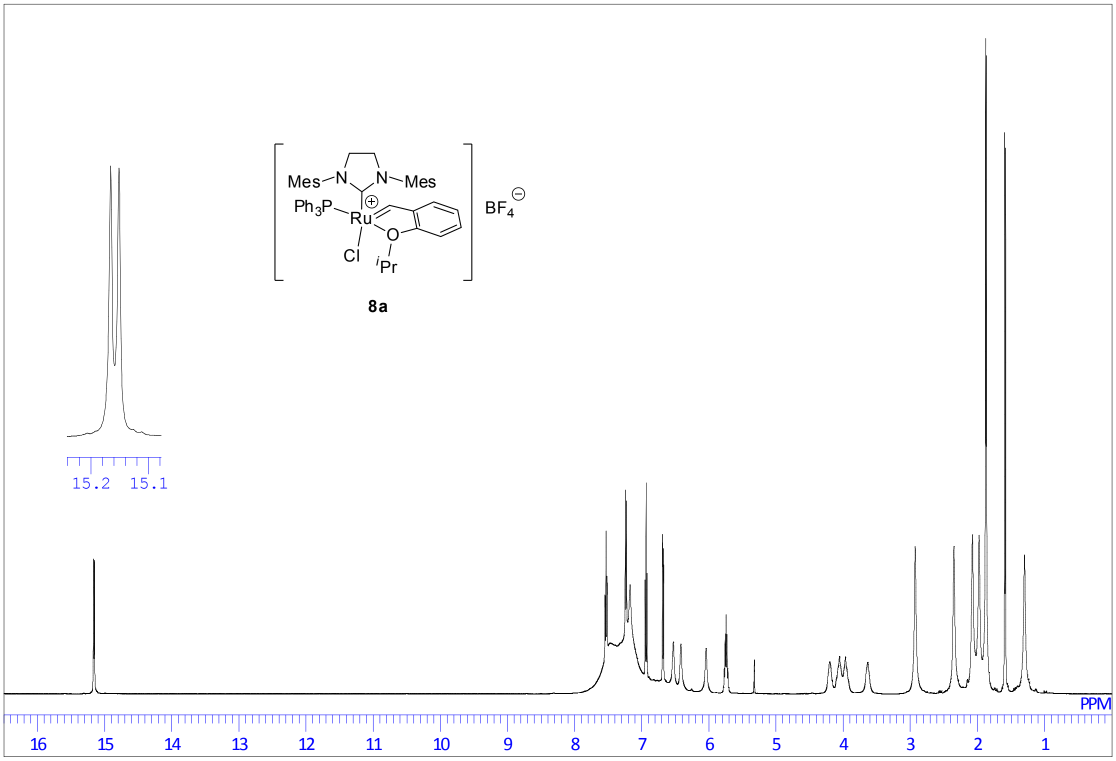

Figure S1. ^{1}H NMR spectrum of **8a** (CD_2Cl_2, 500 MHz).

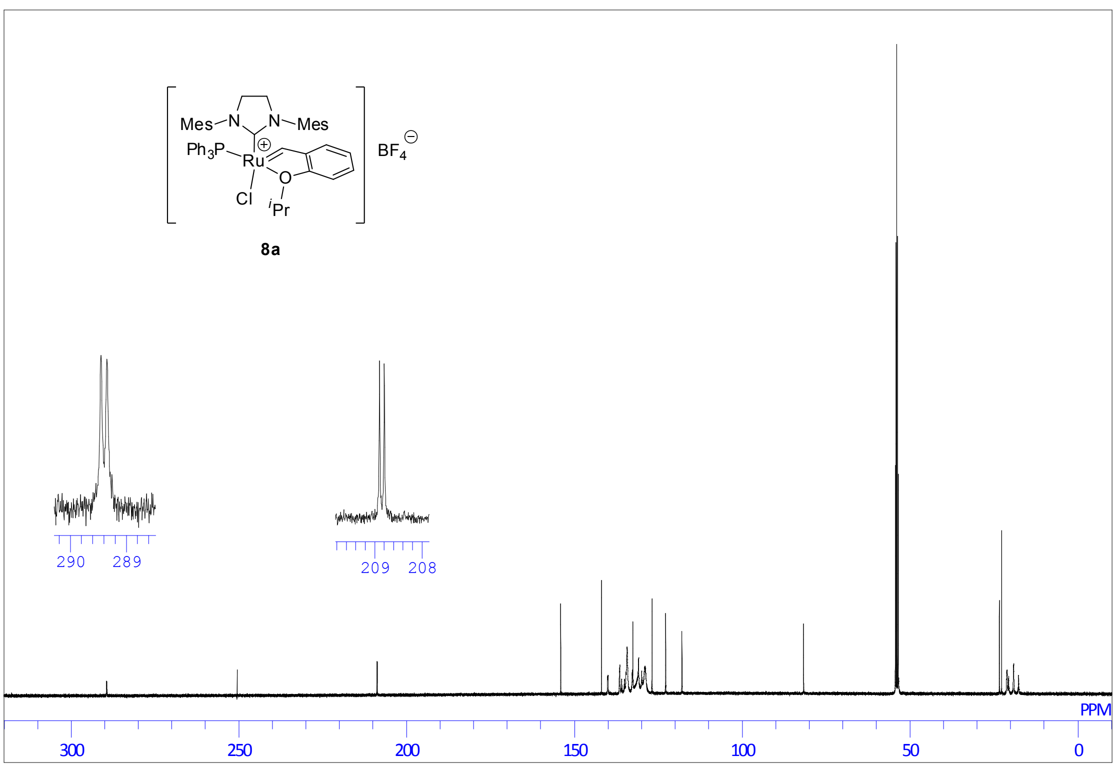

Figure S2. ^{13}C NMR spectrum of **8a** (CD_2Cl_2, 125.7 MHz).

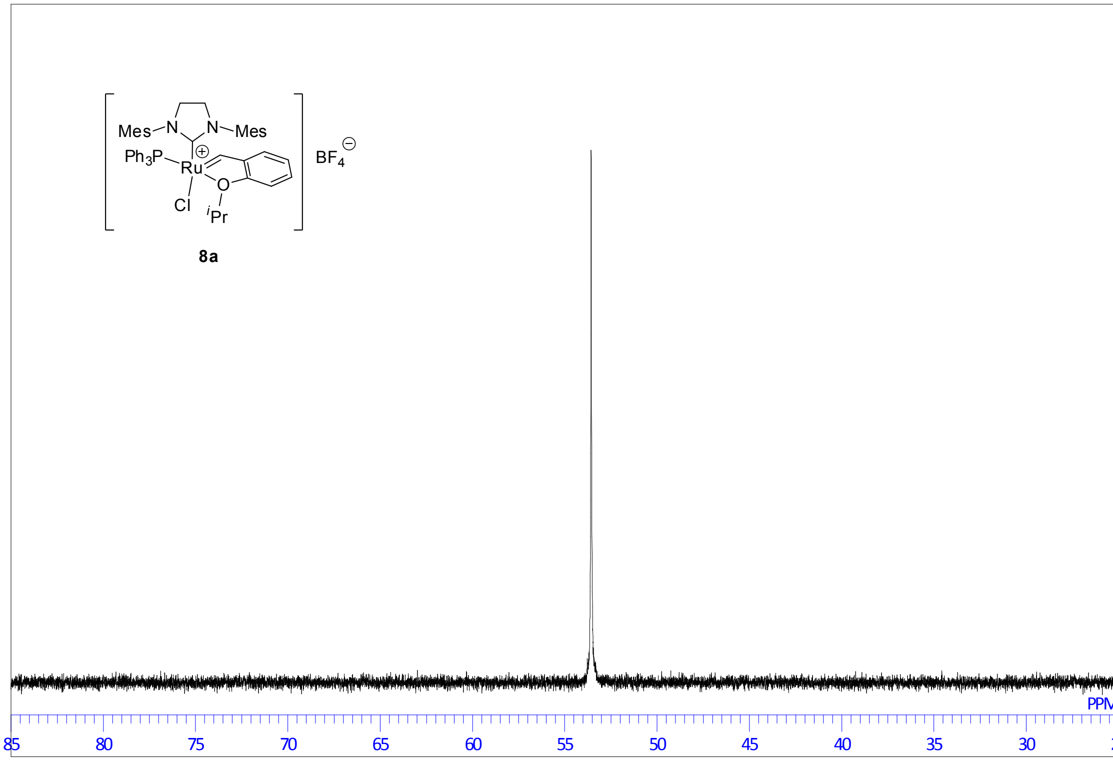

Figure S3. ^{31}P NMR spectrum of **8a** (CD_2Cl_2, 121.4 MHz).

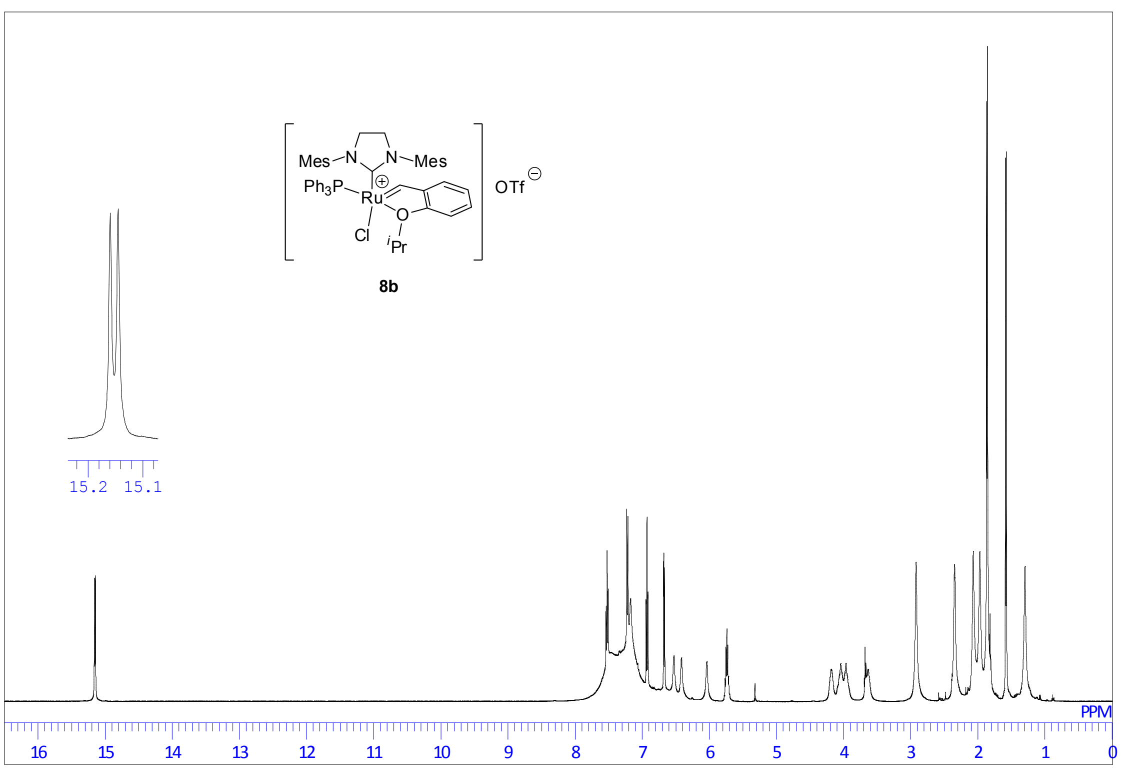

Figure S4. ^{1}H NMR spectrum of **8b** (CD_2Cl_2, 500 MHz).

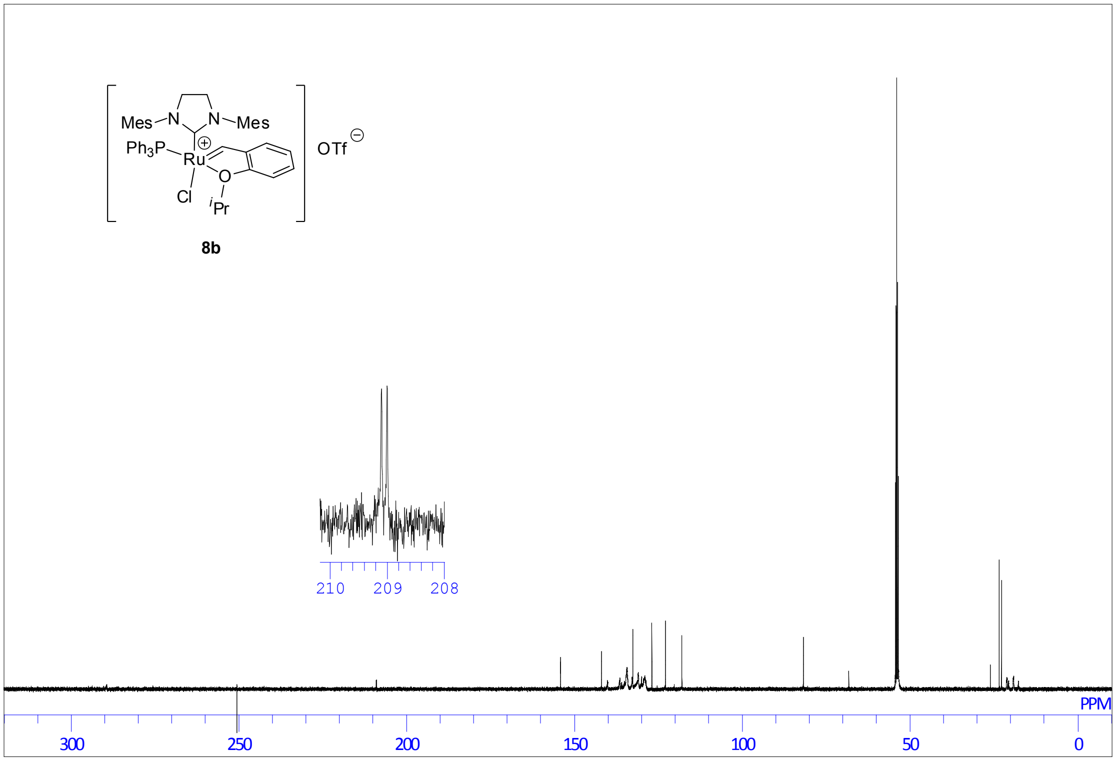

Figure S5. ^{13}C NMR spectrum of **8b** (CD_2Cl_2, 125.7 MHz).

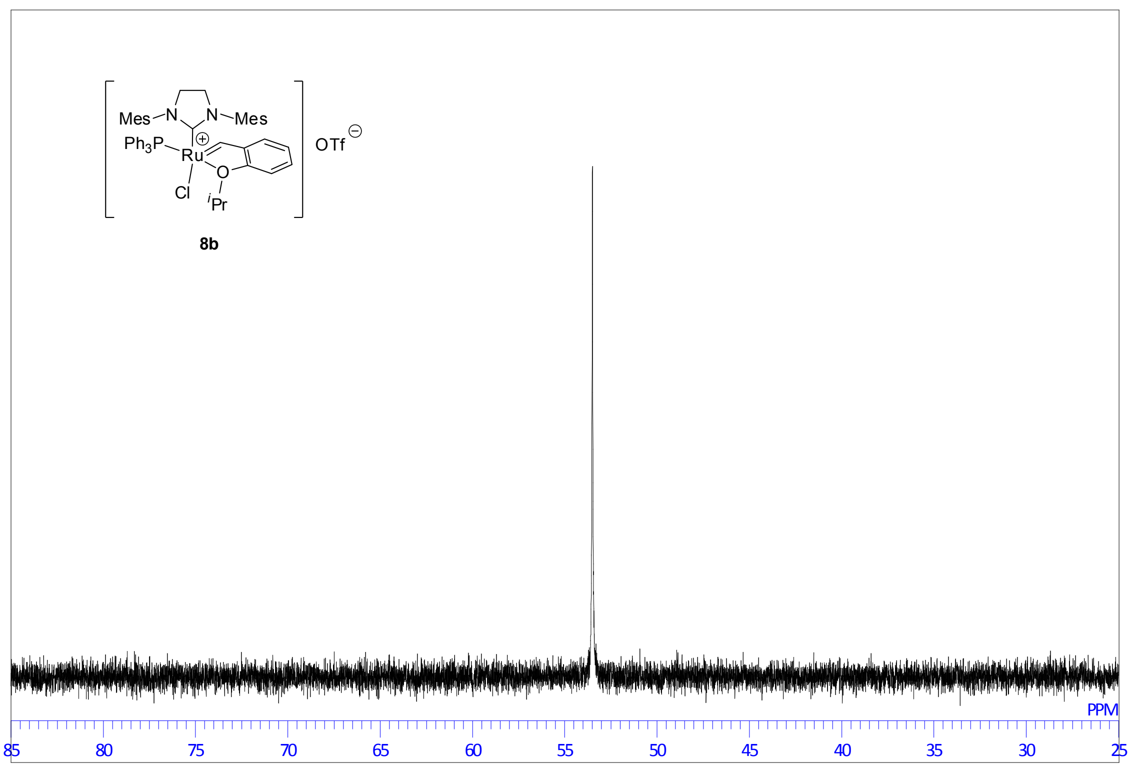

Figure S6. ^{31}P NMR spectrum of **8b** (CD_2Cl_2, 121.4 MHz).

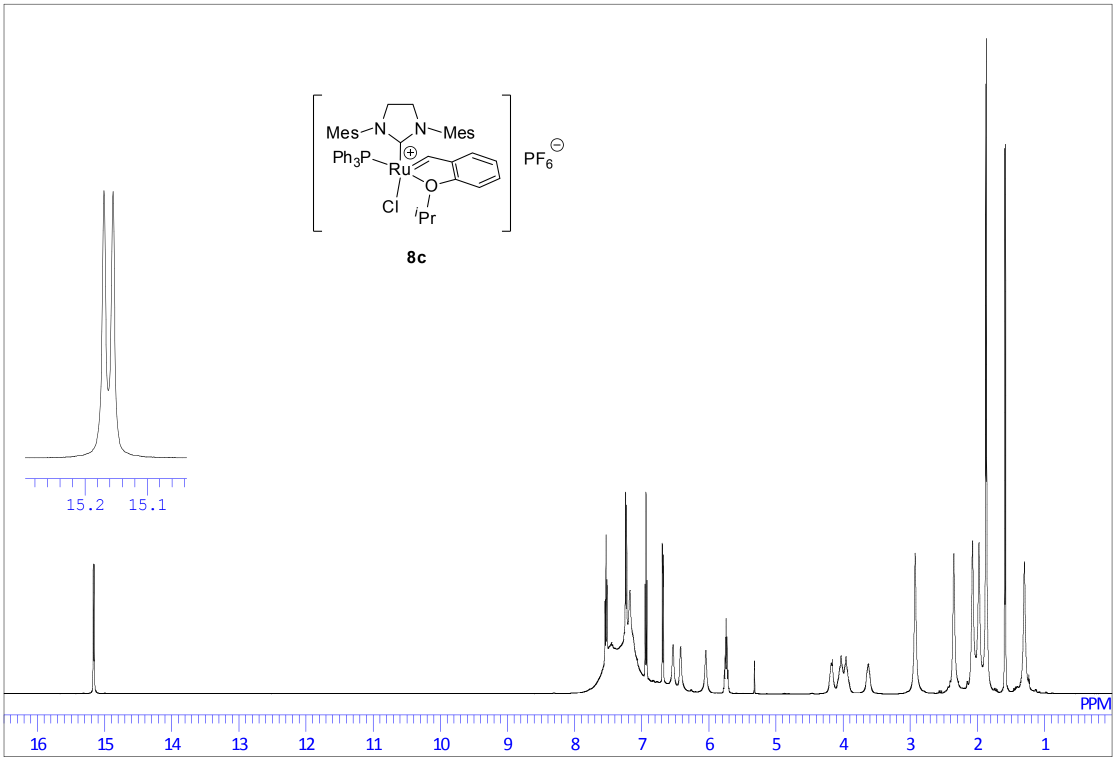

Figure S7. ^{1}H NMR spectrum of **8c** (CD_2Cl_2, 500 MHz).

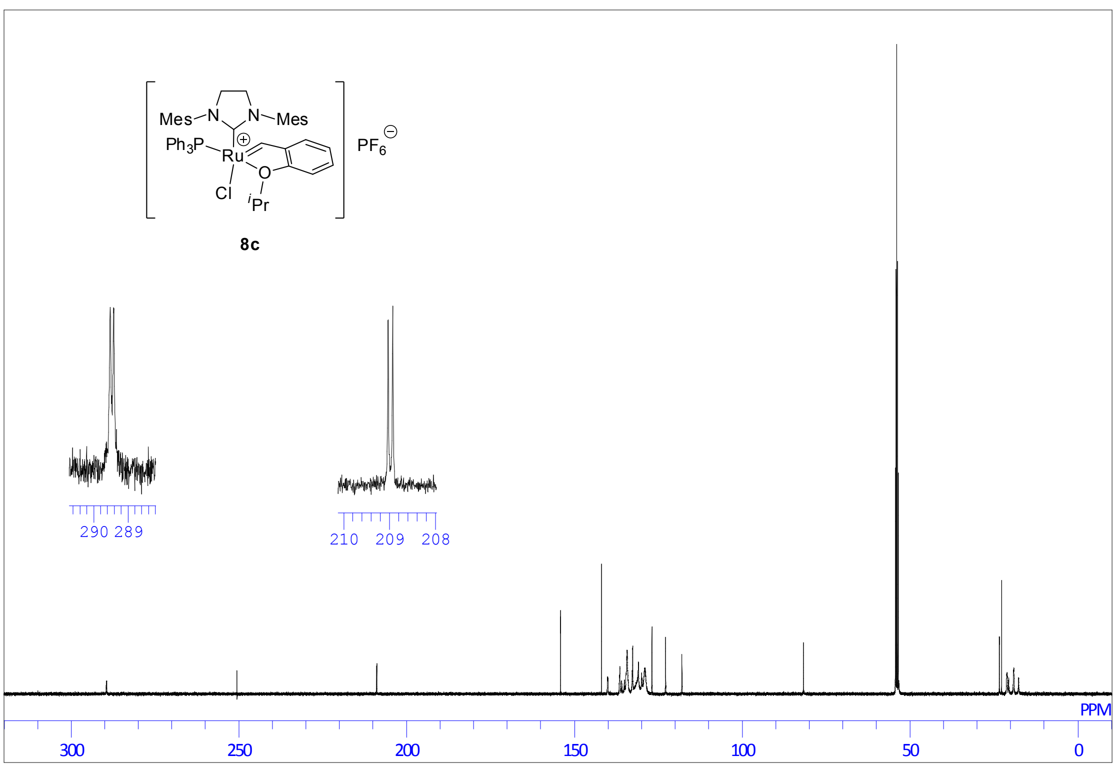

Figure S8. ^{13}C NMR spectrum of **8c** (CD_2Cl_2, 125.7 MHz).

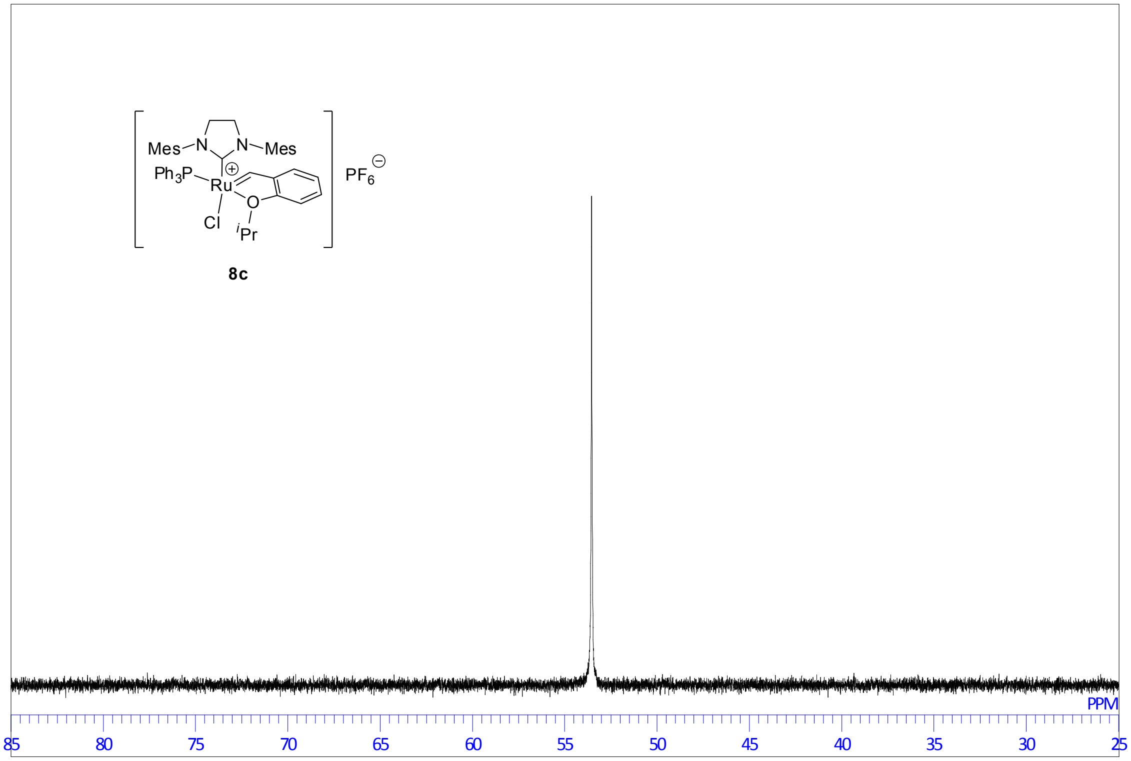

Figure S9. ^{31}P NMR spectrum of **8c** (CD_2Cl_2, 121.4 MHz).

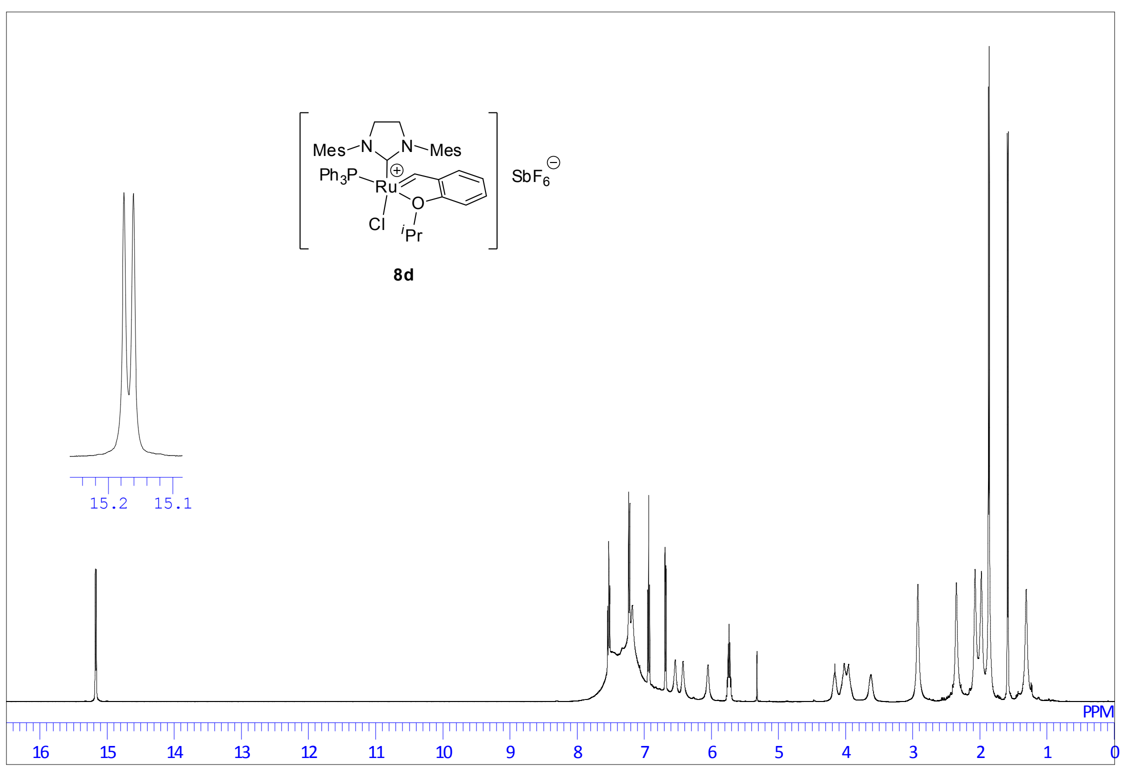

Figure S10. ^{1}H NMR spectrum of **8d** (CD_2Cl_2, 500 MHz).

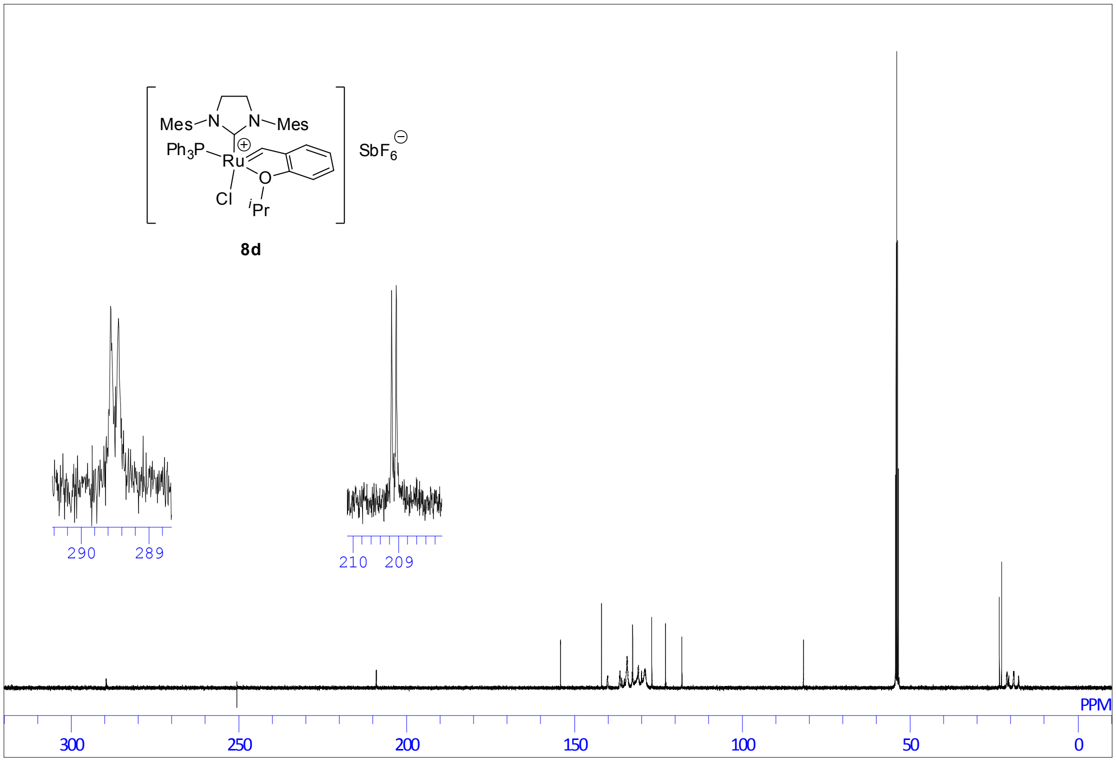

Figure S11. ^{13}C NMR spectrum of **8d** (CD_2Cl_2, 125.7 MHz).

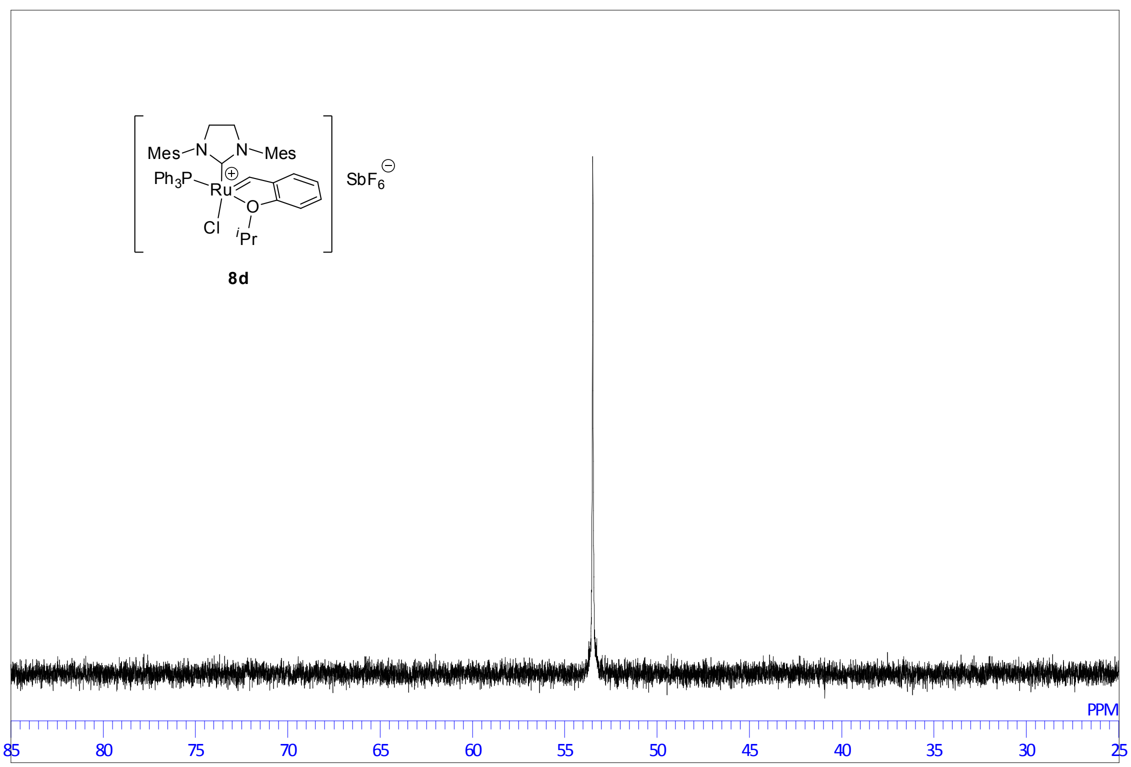

Figure S12. ^{31}P NMR spectrum of **8d** (CD_2Cl_2, 121.4 MHz).

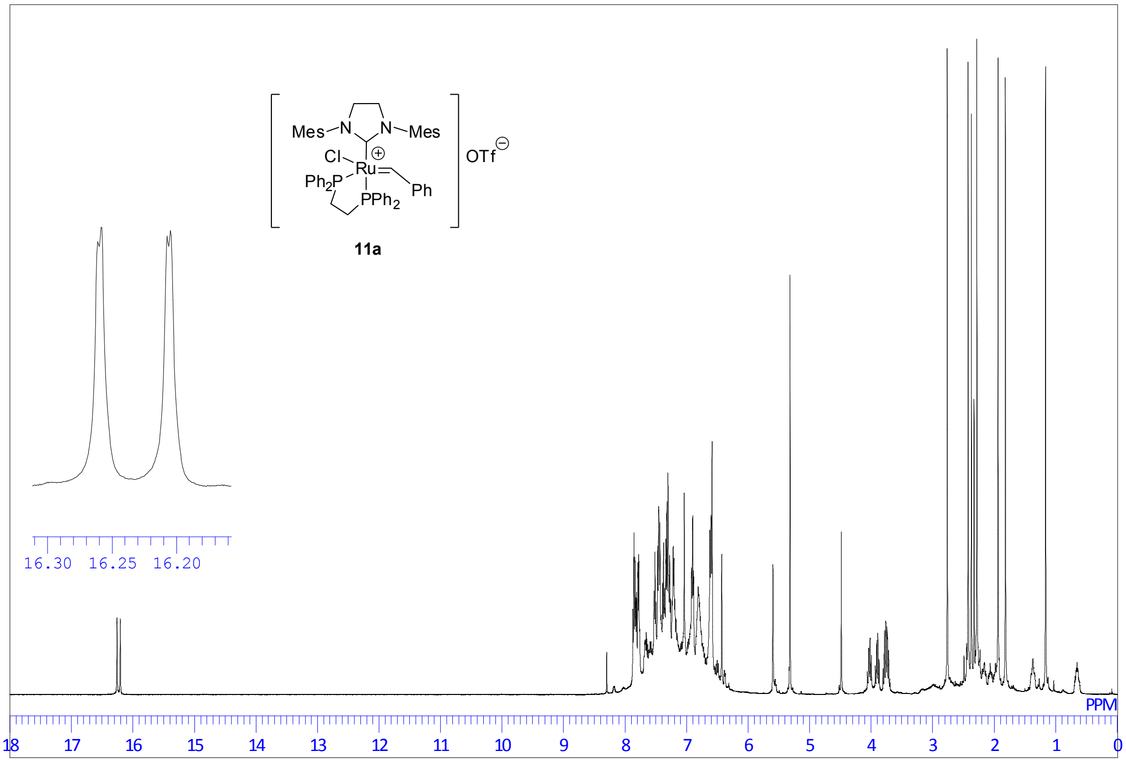

Figure S13. ^{1}H NMR spectrum of **11a** (CD_2Cl_2, 500 MHz).

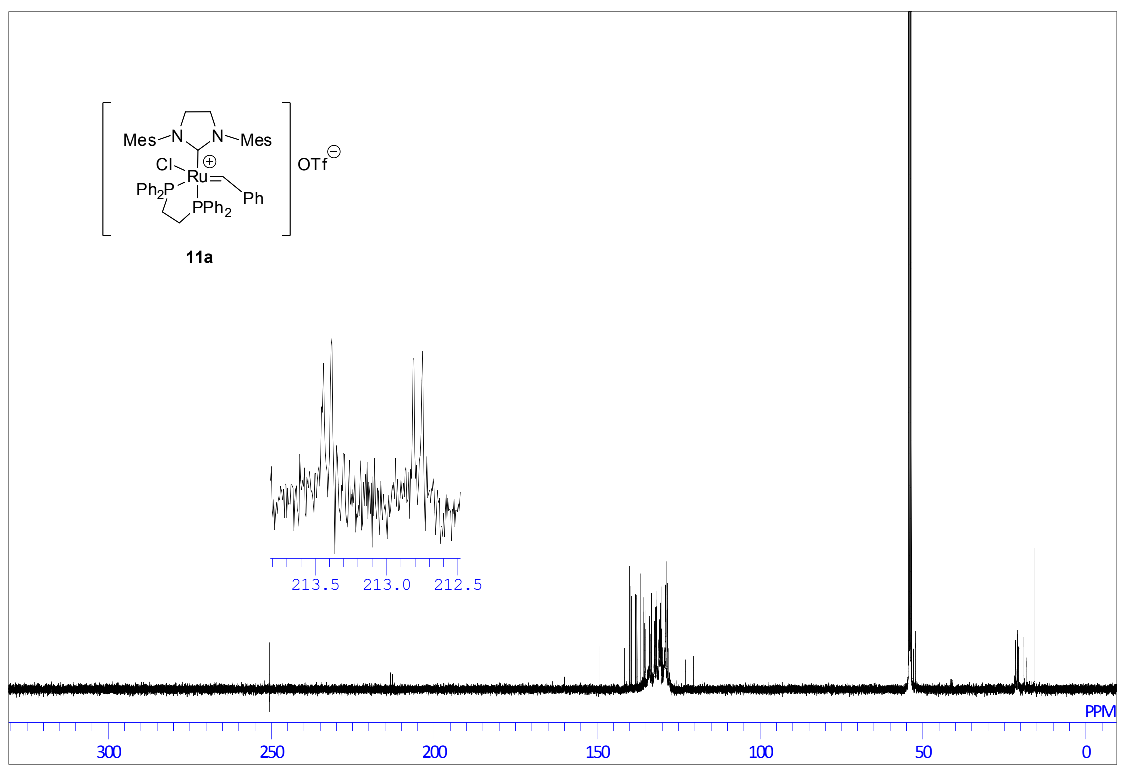

Figure S14. ^{13}C NMR spectrum of **11a** (CD_2Cl_2, 125.7 MHz).

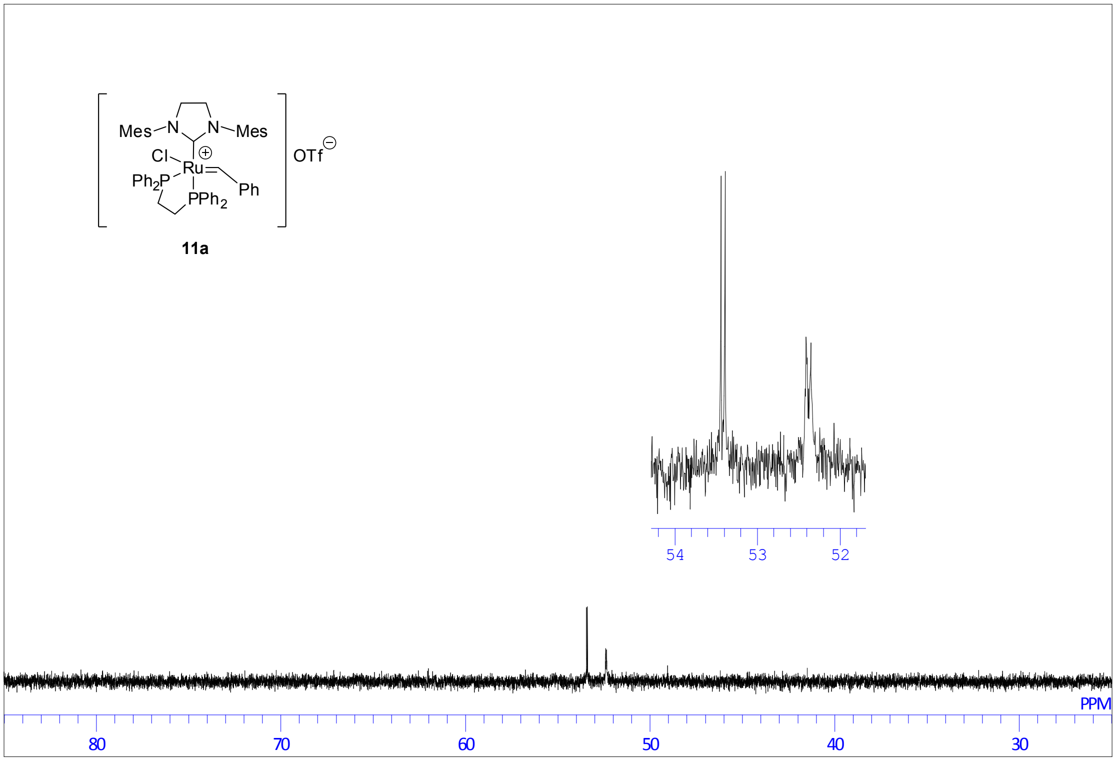

Figure S15. ^{31}P NMR spectrum of **11a** (CD_2Cl_2, 121.4 MHz).

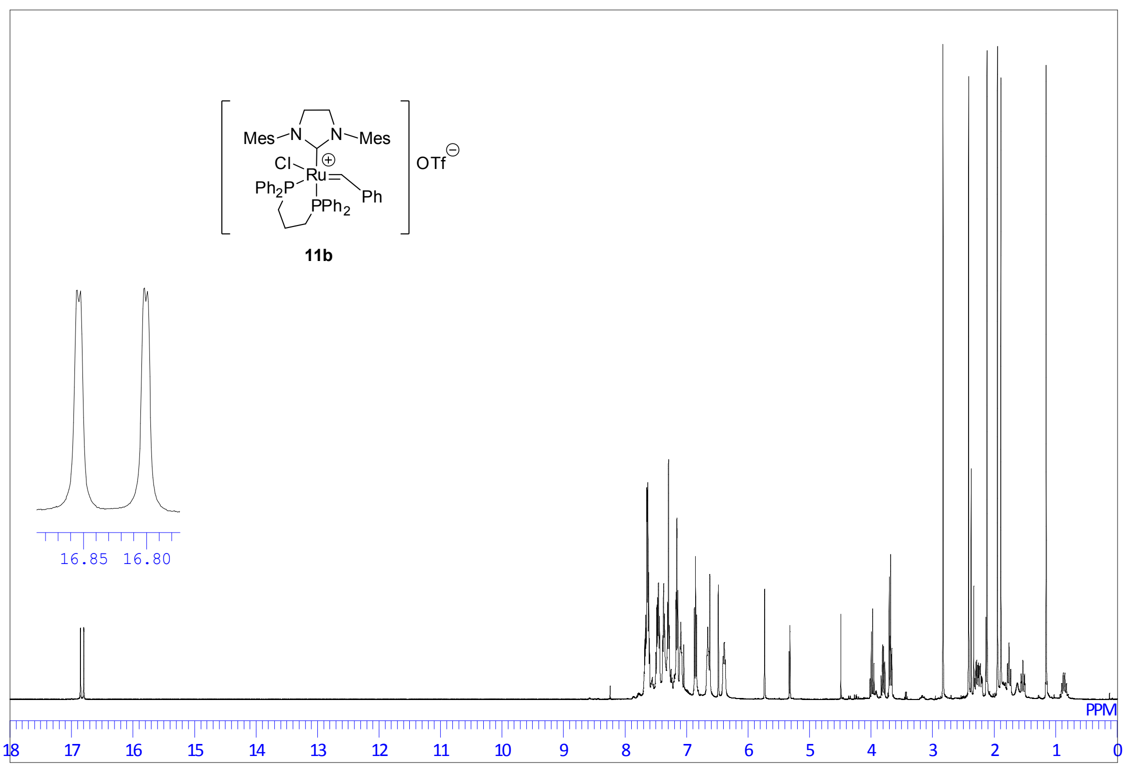

Figure S16. ^{1}H NMR spectrum of **11b** (CD_2Cl_2, 500 MHz).

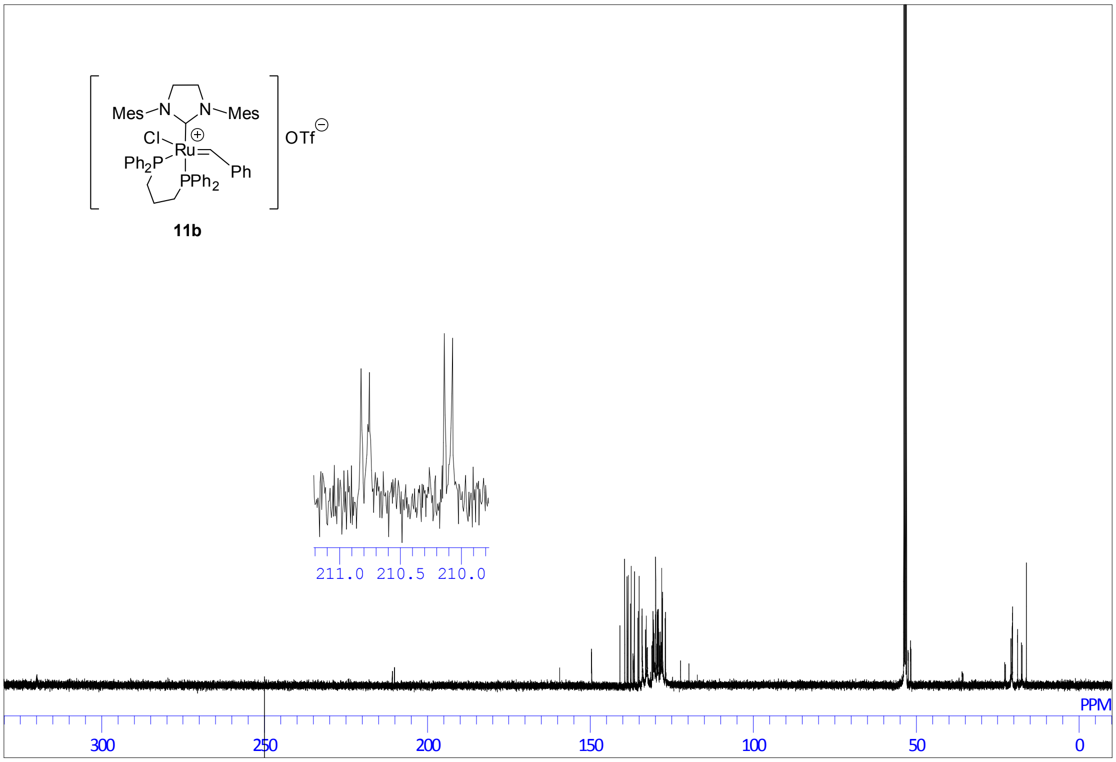

Figure S17. ^{13}C NMR spectrum of **11b** (CD_2Cl_2, 125.7 MHz).

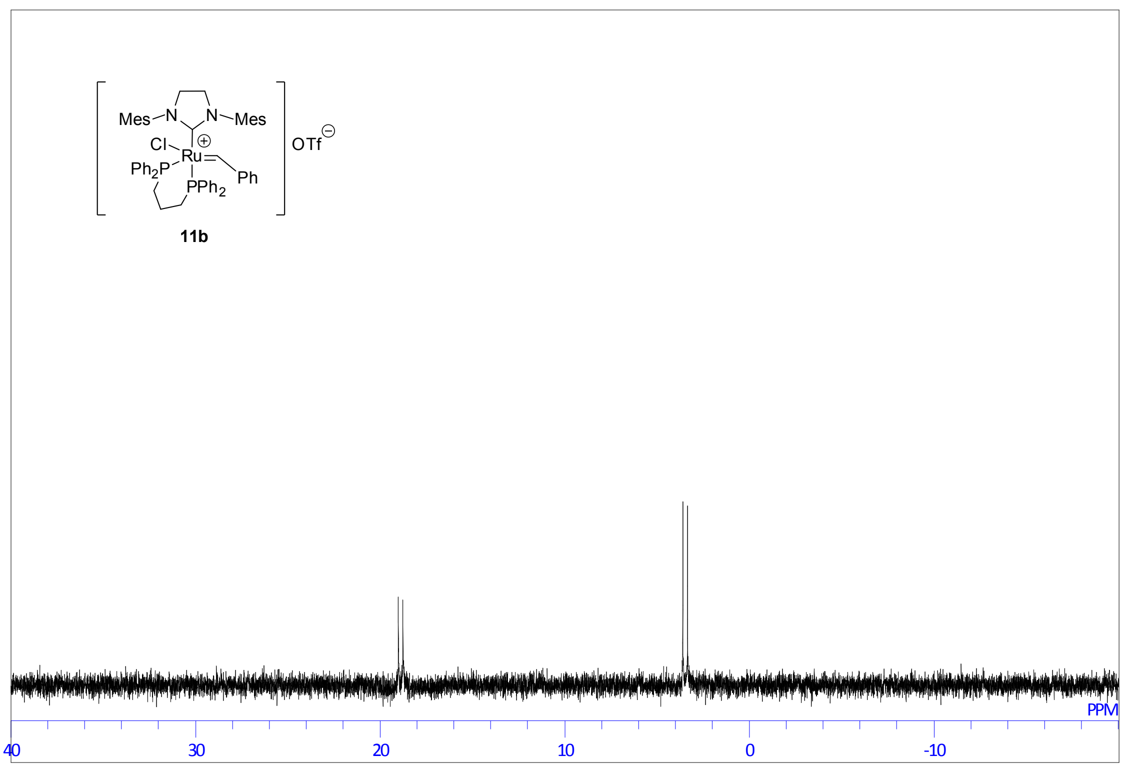

Figure S18. ^{31}P NMR spectrum of **11b** (CD_2Cl_2, 121.4 MHz).

Table S1. Data for RCM of 12 by 7[a]

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
1.4	7.6	7.4	64.5	16.3	93.8	28.0	98.9	42.5	99.7
1.7	11.4	8.0	68.2	17.1	94.4	29.0	99.2	43.8	99.8
2.1	15.9	8.6	71.5	17.9	95.3	30.1	99.5	45.0	99.6
2.5	20.0	9.2	74.6	18.8	96.1	31.1	99.4	46.3	99.7
2.9	24.9	9.9	77.5	19.6	96.6	32.2	99.3	47.6	99.8
3.4	29.4	10.5	80.1	20.5	97.1	33.3	99.3	48.9	99.7
3.8	34.3	11.2	82.5	21.4	97.4	34.4	99.4	50.2	99.7
4.3	38.8	11.9	84.8	22.3	97.9	35.5	99.6	51.5	99.6
4.8	43.7	12.6	86.7	23.2	98.1	36.6	99.7	52.9	99.6
5.3	48.1	13.3	88.3	24.1	98.3	37.8	99.5		
5.8	52.6	14.0	89.9	25.1	98.5	38.9	99.6		
6.3	56.6	14.8	91.5	26.0	98.8	40.1	99.6		
6.9	60.6	15.5	92.4	27.0	98.9	41.3	99.5		

[a] The reaction was carried out using **7** (0.80 μmol) and **12** (19.3 μl, 19.2 mg, 80 μmol) in CD_2Cl_2 (800 μl) at 30 ^{o}C. [b] Conversion of **12** to **13** calculated from the ratio of integrals of the methylene protons of **12** and **13** in ^{1}H NMR spectrum.

Table S2. Data for RCM of 12 by 8a[a]

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
0.7	0.2	11.1	1.0	38.5	6.4	83.1	19.3	144.7	44.3
0.7	-0.6	11.7	1.3	39.7	6.4	84.7	19.4	146.9	45.5
0.8	-0.3	12.3	1.9	40.8	7.1	86.4	20.5	149.1	46.4
0.9	-0.2	12.9	1.9	42.0	6.6	88.1	21.1	151.3	47.4
1.0	-0.1	13.6	2.1	43.2	7.3	89.8	21.3	153.6	47.9
1.2	-0.3	14.2	1.8	44.4	7.4	91.6	22.1	155.8	49.0
1.3	-0.4	14.9	2.3	45.6	7.3	93.3	23.2	158.1	50.0
1.5	-0.3	15.6	2.4	46.8	8.4	95.1	23.6	160.4	50.7
1.7	-0.4	16.3	1.9	48.1	8.2	96.9	24.0	162.7	51.6
1.9	-0.2	17.1	2.8	49.3	8.9	98.7	25.0	165.1	52.3
2.1	-0.1	17.8	2.4	50.6	8.8	100.5	26.0	167.4	52.5
2.3	0.1	18.6	2.2	51.9	9.4	102.3	26.3	169.8	53.2
2.6	0.5	19.4	3.0	53.2	9.3	104.2	27.2	172.2	53.4
2.8	0.5	20.2	2.8	54.6	10.4	106.0	28.3	174.6	54.2
3.1	0.2	21.0	3.4	55.9	10.0	107.9	29.0	177.0	54.7
3.4	0.0	21.8	3.2	57.3	11.0	109.8	29.5	179.4	55.6
3.7	0.4	22.7	3.6	58.7	11.6	111.7	30.2	181.9	55.9
4.1	0.5	23.5	3.1	60.1	11.8	113.7	31.1	184.3	56.8
4.4	0.0	24.4	4.0	61.5	11.6	115.6	31.8	186.8	57.6
4.8	0.4	25.3	3.6	62.9	12.5	117.6	33.1	189.4	59.8
5.2	0.4	26.2	3.9	64.4	13.0	119.6	34.0	191.9	60.3
5.6	0.9	27.2	3.8	65.8	13.1	121.6	34.8	194.4	61.0
6.0	0.9	28.1	4.1	67.3	14.1	123.6	35.3	197.0	61.8
6.4	0.6	29.1	4.1	68.8	14.4	125.6	36.2	199.6	62.3
6.9	0.2	30.1	4.9	70.3	14.6	127.7	37.2	202.1	63.1
7.3	0.6	31.1	4.9	71.9	15.4	129.7	38.3	204.7	63.6
7.8	1.2	32.1	4.8	73.4	16.0	131.8	39.1	207.4	64.4
8.3	0.7	33.1	4.8	75.0	15.9	133.9	39.8	210.0	65.0
8.8	1.2	34.2	5.1	76.6	16.6	136.0	41.0	212.6	65.5
9.4	1.3	35.2	6.0	78.2	17.3	138.2	41.8	215.3	66.1
9.9	0.9	36.3	5.9	79.8	18.0	140.3	42.8	218.0	66.8
10.5	1.0	37.4	6.0	81.4	18.0	142.5	43.6	220.7	67.3

Table S2. (Continued)

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
223.4	68.0	319.1	83.5	431.9	92.1	561.8	96.4	708.7	98.3
226.1	68.5	322.4	84.0	435.7	92.4	566.1	96.3	713.6	98.4
228.9	69.2	325.7	84.3	439.6	92.7	570.5	96.4	718.5	98.3
231.7	69.6	329.0	84.6	443.4	93.0	574.9	96.5	723.4	98.3
234.4	70.3	332.3	84.9	447.2	92.9	579.2	96.6	728.3	98.6
237.2	70.8	335.6	85.2	451.1	93.0	583.6	96.6	733.2	98.6
240.1	71.4	339.0	85.6	455.0	93.3	588.1	96.7	738.2	98.6
242.9	72.0	342.4	85.9	458.9	93.4	592.5	96.9	743.2	98.7
245.7	72.5	345.7	86.3	462.8	93.7	596.9	97.0	748.1	98.8
248.6	73.0	349.1	86.6	466.7	93.7	601.4	96.9	753.1	98.7
251.5	73.6	352.6	87.0	470.7	93.9	605.9	97.0	758.2	98.6
254.4	74.2	356.0	87.4	474.7	94.1	610.4	97.1	763.2	98.7
257.3	74.7	359.4	87.5	478.6	94.0	614.9	97.2	768.2	98.9
260.2	75.2	362.9	87.8	482.6	94.3	619.4	97.4	773.3	98.8
263.2	75.6	366.4	88.0	486.7	94.3	624.0	97.2	778.4	98.8
266.2	76.2	369.9	88.2	490.7	94.4	628.6	97.3	783.5	98.9
269.1	76.6	373.4	88.7	494.7	94.5	633.1	97.4	788.6	98.9
272.1	77.2	376.9	88.8	498.8	94.7	637.7	105.7	793.7	98.9
275.2	77.5	380.5	89.1	502.9	94.8	642.4	97.3	798.9	99.0
278.2	78.1	384.1	89.3	507.0	94.9	647.0	97.6	804.1	98.9
281.2	78.6	387.6	89.6	511.1	95.1	651.6	97.7	809.2	99.1
284.3	79.0	391.2	90.0	515.2	95.1	656.3	97.7	814.4	99.1
287.4	79.5	394.9	90.2	519.4	95.3	661.0	98.0	819.7	99.1
290.5	79.9	398.5	90.3	523.6	95.4	665.7	97.9	824.9	99.0
293.6	80.3	402.1	90.6	527.7	95.3	670.4	98.1	830.1	99.1
296.7	80.8	405.8	90.9	531.9	95.6	675.1	98.1	835.4	99.0
299.9	81.2	409.5	91.0	536.2	95.7	679.9	98.0	840.7	99.2
303.1	81.6	413.2	91.2	540.4	95.8	684.7	98.1	846.0	99.2
306.2	82.0	416.9	91.5	544.6	96.0	689.4	98.2	851.3	99.2
309.4	82.4	420.6	91.5	548.9	96.1	694.2	98.2	856.6	99.2
312.7	82.8	424.4	91.8	553.2	96.1	699.1	98.3	862.0	99.2
315.9	83.1	428.2	92.0	557.5	96.3	703.9	98.2		

[a] The reaction was carried out using **8a** (0.80 µmol) and **12** (19.3 µl, 19.2 mg, 80 µmol) in CD_2Cl_2 (800 µl) at 30 ^oC. [b] Conversion of **12** to **13** calculated from the ratio of integrals of the methylene protons of **12** and **13** in ^1H NMR spectrum.

Table S3. Data for RCM of 12 by 8b[a]

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
0.9	0.0	3.1	-0.1	8.0	0.3	15.8	0.8	26.5	2.6
1.0	-0.4	3.3	-0.2	8.5	0.4	16.6	0.9	27.4	2.7
1.0	-0.2	3.6	0.1	9.1	0.7	17.3	0.9	28.3	2.4
1.1	-0.5	4.0	0.0	9.6	0.8	18.0	1.0	29.3	3.2
1.3	-0.1	4.3	-0.2	10.1	1.1	18.8	1.2	30.3	2.9
1.4	-0.1	4.6	0.2	10.7	0.4	19.6	1.4	31.3	2.9
1.5	-0.3	5.0	0.5	11.3	0.6	20.4	2.0	32.3	2.9
1.7	-0.3	5.4	0.4	11.9	0.6	21.2	2.2	33.3	3.0
1.9	-0.3	5.8	0.0	12.5	0.6	22.0	1.9	34.4	3.2
2.1	0.3	6.2	0.8	13.1	1.3	22.9	2.1	35.5	3.7
2.3	0.0	6.6	0.6	13.8	0.6	23.8	1.9	36.5	3.9
2.5	-0.5	7.1	0.2	14.5	0.6	24.6	1.9	37.6	4.3
2.8	0.1	7.6	0.3	15.1	0.8	25.5	2.0	38.8	4.3

Table S3. (Continued)

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
39.9	4.2	61.7	9.3	88.3	18.4	119.8	33.4	156.1	52.3
41.0	4.3	63.1	9.9	90.1	19.3	121.8	34.5	158.3	53.4
42.2	4.5	64.6	10.1	91.8	19.9	123.8	35.4	160.6	54.4
43.4	4.6	66.1	10.2	93.5	20.8	125.8	36.5	163.0	55.3
44.6	5.2	67.5	10.8	95.3	21.4	127.9	37.5	165.3	56.4
45.8	5.3	69.0	11.3	97.1	22.3	130.0	38.6	167.6	57.7
47.0	5.4	70.6	12.1	98.9	23.3	132.0	39.9	170.0	58.5
48.3	5.8	72.1	12.2	100.7	23.9	134.1	41.0	172.4	59.8
49.6	6.4	73.6	12.8	102.5	24.6	136.3	42.3	174.8	60.5
50.8	6.7	75.2	13.4	104.4	25.6	138.4	43.2	177.2	61.9
52.1	6.7	76.8	13.9	106.3	26.5	140.5	44.4	179.6	62.7
53.5	7.4	78.4	14.6	108.1	27.2	142.7	45.4	182.1	63.9
54.8	7.4	80.0	15.1	110.0	28.4	144.9	46.8	184.6	64.7
56.1	7.6	81.6	15.7	112.0	29.6	147.1	47.7	187.0	65.9
57.5	7.9	83.3	16.1	113.9	30.5	149.3	48.9	189.5	66.6
58.9	8.2	85.0	16.9	115.8	31.4	151.5	49.8		
60.3	9.2	86.6	17.6	117.8	32.5	153.8	51.2		

[a] The reaction was carried out using **8b** (0.80 µmol) and **12** (19.3 µl, 19.2 mg, 80 µmol) in CD_2Cl_2 (800 µl) at 30 ^{o}C. [b] Conversion of **12** to **13** calculated from the ratio of integrals of the methylene protons of **12** and **13** in ^{1}H NMR spectrum.

Table S4. Data for RCM of 12 by 8c[a]

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
0.7	1.0	8.8	2.1	30.1	7.5	64.4	20.1	111.7	39.2
0.7	0.8	9.4	2.3	31.1	7.7	65.8	20.8	113.7	40.0
0.8	1.0	9.9	2.3	32.1	8.1	67.3	21.2	115.6	40.8
0.9	1.3	10.5	2.2	33.1	8.4	68.8	22.0	117.6	41.6
1.0	0.8	11.1	2.7	34.2	8.6	70.3	22.6	119.6	42.3
1.2	1.0	11.7	2.4	35.2	9.0	71.9	23.2	121.6	43.0
1.3	0.8	12.3	2.7	36.3	9.7	73.4	23.9	123.6	43.8
1.5	0.8	12.9	2.7	37.4	10.0	75.0	24.6	125.6	44.6
1.7	0.8	13.6	3.3	38.5	10.4	76.6	25.1	127.7	45.3
1.9	1.1	14.2	3.1	39.7	10.8	78.2	25.6	129.7	46.1
2.1	1.2	14.9	3.6	40.8	11.3	79.8	26.4	131.8	47.0
2.3	1.0	15.6	3.3	42.0	11.3	81.4	27.2	133.9	47.6
2.6	1.2	16.3	3.5	43.2	11.9	83.1	27.9	136.0	48.3
2.8	1.2	17.1	3.7	44.4	12.3	84.7	28.4	138.2	49.1
3.1	1.2	17.8	3.8	45.6	12.8	86.4	29.2	140.3	49.9
3.4	1.5	18.6	3.9	46.8	13.5	88.1	30.0	142.5	50.7
3.7	1.5	19.4	4.6	48.1	14.0	89.8	30.6	144.7	51.5
4.1	1.5	20.2	4.7	49.3	14.4	91.6	31.3	146.9	52.1
4.4	1.3	21.0	4.6	50.6	14.7	93.3	31.8	149.1	52.9
4.8	1.3	21.8	5.0	51.9	15.2	95.1	32.6	151.3	53.8
5.2	1.7	22.7	5.0	53.2	15.7	96.9	33.3	153.6	54.5
5.6	1.7	23.5	5.5	54.6	16.3	98.7	34.1	155.8	55.3
6.0	1.5	24.4	5.5	55.9	16.7	100.5	34.8	158.1	55.9
6.4	1.6	25.3	5.8	57.3	17.2	102.3	35.6	160.4	56.7
6.9	1.4	26.2	6.4	58.7	17.8	104.2	36.4	162.7	57.4
7.3	1.6	27.2	6.5	60.1	18.4	106.0	37.0	165.1	58.0
7.8	1.9	28.1	7.0	61.5	19.0	107.9	37.9	167.4	58.7
8.3	1.9	29.1	7.3	62.9	19.5	109.8	38.6	169.8	59.6

Table S4. (Continued)

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
172.2	60.3	266.1	81.0	380.4	91.5	515.2	96.0	670.3	97.4
174.6	61.0	269.1	81.4	384.0	92.0	519.3	96.1	675.1	97.4
177.0	61.6	272.1	81.8	387.6	92.0	523.5	96.3	679.8	97.7
179.4	62.5	275.1	82.3	391.2	92.2	527.7	96.1	684.6	97.7
181.9	63.0	278.1	82.7	394.8	92.4	531.9	96.4	689.4	97.6
184.3	63.9	281.2	83.0	398.4	92.6	536.1	96.2	694.2	97.7
186.8	64.4	284.2	83.3	402.1	92.7	540.3	96.4	699.0	97.7
189.3	65.2	287.3	84.0	405.7	92.9	544.6	96.5	703.8	97.6
191.8	65.8	290.4	84.1	409.4	92.9	548.8	96.5	708.7	97.9
194.4	66.4	293.5	84.6	413.1	93.2	553.1	96.7	713.5	98.0
196.9	67.0	296.7	85.0	416.8	93.3	557.4	96.6	718.4	97.8
199.5	67.8	299.8	85.3	420.6	93.4	561.7	97.0	723.3	97.9
202.1	68.4	303.0	85.5	424.3	93.8	566.1	96.6	728.2	97.9
204.7	69.0	306.2	86.1	428.1	93.8	570.4	96.9	733.2	97.7
207.3	69.8	309.4	86.2	431.9	94.0	574.8	96.7	738.1	97.8
209.9	70.3	312.6	86.5	435.7	94.1	579.2	96.7	743.1	97.9
212.6	71.0	315.8	86.9	439.5	94.2	583.6	97.0	748.1	97.7
215.2	71.6	319.1	87.2	443.3	94.2	588.0	96.9	753.1	98.1
217.9	72.1	322.3	87.6	447.2	94.5	592.4	97.2	758.1	98.1
220.6	72.6	325.6	87.8	451.0	94.7	596.9	97.0	763.1	98.0
223.3	73.2	328.9	88.2	454.9	94.7	601.3	97.0	768.2	97.9
226.1	73.7	332.2	88.3	458.8	95.0	605.8	97.0	773.2	97.9
228.8	74.4	335.6	88.6	462.7	95.0	610.3	97.1	778.3	98.1
231.6	74.9	338.9	88.9	466.7	94.7	614.8	97.4	783.4	98.1
234.4	75.4	342.3	89.3	470.6	95.2	619.4	97.1	788.5	98.1
237.2	76.0	345.7	89.3	474.6	95.3	623.9	97.3	793.7	98.1
240.0	76.6	349.1	89.6	478.6	95.4	628.5	97.4	798.8	98.0
242.8	77.1	352.5	90.0	482.6	95.2	633.1	97.3	804.0	98.4
245.7	77.5	355.9	90.1	486.6	95.5	637.7	96.9	809.2	98.1
248.5	78.0	359.4	90.4	490.6	95.9	642.3	97.4	814.4	98.2
251.4	78.6	362.8	90.7	494.7	95.6	646.9	97.4	819.6	97.9
254.3	79.2	366.3	90.8	498.7	95.7	651.6	97.4	824.8	98.2
257.2	79.5	369.8	91.1	502.8	95.9	656.2	97.5	830.1	98.0
260.2	80.0	373.3	91.4	506.9	96.1	660.9	97.5	835.3	98.1
263.1	80.5	376.9	91.3	511.0	95.7	665.6	97.3		

[a] The reaction was carried out using **8c** (0.80 μmol) and **12** (19.3 μl, 19.2 mg, 80 μmol) in CD_2Cl_2 (800 μl) at 30 °C. [b] Conversion of **12** to **13** calculated from the ratio of integrals of the methylene protons of **12** and **13** in ^{1}H NMR spectrum.

Table S5. Data for RCM of 12 by 11a[a]

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
0.8	-0.1	2.2	-0.2	5.3	0.4	10.0	0.7	16.4	1.2
0.8	-0.1	2.4	0.2	5.7	0.5	10.6	0.7	17.2	1.6
0.9	-0.4	2.7	-0.2	6.1	0.5	11.2	0.7	17.9	1.5
1.0	-0.3	2.9	0.2	6.5	0.3	11.8	1.0	18.7	1.8
1.1	-0.2	3.2	0.0	7.0	0.4	12.4	0.9	19.5	1.8
1.3	-0.1	3.5	0.0	7.4	0.6	13.0	0.8	20.3	1.7
1.4	0.0	3.8	0.0	7.9	0.7	13.7	0.9	21.1	1.9
1.6	-0.2	4.2	0.0	8.4	0.4	14.3	0.9	21.9	2.0
1.8	-0.2	4.5	0.0	8.9	0.5	15.0	1.2	22.8	2.0
2.0	-0.2	4.9	0.1	9.5	0.6	15.7	1.3	23.6	1.9

Table S5. (Continued)

time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]	time, min	conv, %[b]
24.5	2.3	42.1	3.9	64.5	5.9	91.7	7.9	123.7	9.8
25.4	2.1	43.3	4.0	65.9	6.0	93.4	8.1	125.7	9.8
26.3	2.5	44.5	4.1	67.4	6.3	95.2	8.0	127.8	9.9
27.3	2.6	45.7	4.3	68.9	6.2	97.0	8.3	129.8	10.2
28.2	2.4	46.9	4.5	70.4	6.5	98.8	8.3	131.9	10.0
29.2	2.8	48.2	4.3	72.0	6.5	100.6	8.6	134.0	10.2
30.2	2.9	49.4	4.5	73.5	6.6	102.4	8.6	136.1	10.3
31.2	2.7	50.7	4.8	75.1	6.6	104.3	8.7	138.3	10.4
32.2	3.0	52.0	4.9	76.7	7.0	106.1	9.0	140.4	10.3
33.2	3.2	53.3	5.0	78.3	7.0	108.0	9.0	142.6	10.5
34.3	3.1	54.7	5.2	79.9	7.2	109.9	9.1	144.8	10.6
35.3	3.3	56.0	5.3	81.5	7.2	111.8	9.1	147.0	10.6
36.4	3.3	57.4	5.2	83.2	7.3	113.8	9.3	149.2	10.7
37.5	3.4	58.8	5.6	84.8	7.4	115.7	9.4		
38.6	3.7	60.2	5.7	86.5	7.5	117.7	9.4		
39.8	3.9	61.6	5.6	88.2	7.7	119.7	9.8		
40.9	3.7	63.0	5.9	89.9	7.9	121.7	9.7		

[a] The reaction was carried out using **11a** (0.80 μmol) and **12** (19.3 μl, 19.2 mg, 80 μmol) in CD_2Cl_2 (800 μl) at 30 ^{o}C. [b] Conversion of **12** to **13** calculated from the ratio of integrals of the methylene protons of **12** and **13** in ^{1}H NMR spectrum.

Table S6. GC response factors and retention times[a]

compound	response factor[b]	retension time, min
tridecane	--	11.7
14	1.20	10.9
Z-**15**	2.48	18.3
E-**15**	2.48	18.6
Z-**16**	1.30	21.4
E-**16**	1.30	21.7
Z-**17**	1.03	24.5
E-**17**	1.03	24.3

[a] Instrument conditions were as follows; Inlet temperature: 250 ^{o}C, detector temperature: 250 ^{o}C, hydrogen flow: 32 ml/min, air flow: 400 ml/min, constant col + makeup flow: 30 ml/min. GC Method was as follows; 50 ^{o}C for 5 min, followed by a temperature increase of 10 ^{o}C/min to 240 ^{o}C and a subsequent isothermal period at 240 ^{o}C for 5 min (total run time = 29 min). Response factors and retention times are instrument dependent; values may vary on alternate machines. [b] Determined by reported method.[S3]

Table S7. Data for CM of 14 and 15 by 7[a]

	16		17	
time	conversion[b]	*E*/*Z*[c]	conversion[b]	*E*/*Z*[c]
min	%		%	
1	70	6.2	2	3.6
2	75	8.4	4	4.4
5	75	10.0	6	4.9
8	74	10.1	4	5.3
10	73	10.1	4	5.6
15	72	10.1	5	5.9
20	72	10.0	5	5.8
30	72	10.1	5	5.9

[a] The reaction was carried out using **7** (3.1 mg, 5.0 μmol), **14** (0.20 mmol), **15** (0.40 mmol) and tridecane (0.10 mmol) in 1.0 ml of CH_2Cl_2 at 23 ^oC. [b] Conversion of **14** to the product determined by GC analysis. [c] Molar ratio of *E* isomer and *Z* isomer of the product determined by GC analysis.

Table S8. Data for CM of 14 and 15 by 8a[a]

	16		17	
time	conversion[b]	*E*/*Z*[c]	conversion[b]	*E*/*Z*[c]
min	%		%	
5	6.6	2.67	0.0	(NA)[d]
10	11.0	2.99	0.0	(NA)[d]
15	17.2	2.98	0.0	(NA)[d]
30	33.8	3.27	0.0	(NA)[d]
45	46.9	3.76	0.0	(NA)[d]
60	56.6	4.34	0.0	(NA)[d]
90	66.7	5.27	2.9	(NA)[d]
120	73.9	6.14	2.5	(NA)[d]
240	80.9	8.79	4.9	(NA)[d]
480	78.8	10.6	8.9	6.97

[a] The reaction was carried out using **8a** (4.7 mg, 5.0 μmol), **14** (0.20 mmol), **15** (0.40 mmol) and tridecane (0.10 mmol) in 1.0 ml of CH_2Cl_2 at 23 ^oC. [b] Conversion of **14** to the product determined by GC analysis. [c] Molar ratio of *E* isomer and *Z* isomer of the product determined by GC analysis. [d] GC signal of the product was too small to quantify.

Table S9. Data for CM of 14 and 15 by 8b[a]

time	16		17	
	conversion[b]	*E*/*Z*[c]	conversion[b]	*E*/*Z*[c]
min	%		%	
5	2.2	NA	0.0	(NA)[d]
10	7.4	2.62	0.0	(NA)[d]
15	11.9	2.82	0.0	(NA)[d]
30	28.4	3.16	0.0	(NA)[d]
45	41.9	3.46	0.0	(NA)[d]
60	51.5	3.84	1.5	(NA)[d]
90	64.6	4.77	2.2	(NA)[d]
120	73.1	5.70	2.8	(NA)[d]
240	81.1	8.41	4.9	(NA)[d]
480	79.1	9.95	9.4	5.18

[a] The reaction was carried out using **8b** (5.0 mg, 5.0 μmol), **14** (0.20 mmol), **15** (0.40 mmol) and tridecane (0.10 mmol) in 1.0 ml of CH_2Cl_2 at 23 °C. [b] Conversion of **14** to the product determined by GC analysis. [c] Molar ratio of *E* isomer and *Z* isomer of the product determined by GC analysis. [d] GC signal of the product was too small to quantify.

Table S10. Data for CM of 14 and 15 by 11a[a]

time	16		17	
	conversion[b]	*E*/*Z*[c]	conversion[b]	*E*/*Z*[c]
min	%		%	
5	0.0	NA	0.0	(NA)[d]
10	1.1	NA	0.0	(NA)[d]
15	1.9	NA	0.0	(NA)[d]
30	6.2	2.22	0.0	(NA)[d]
45	9.7	2.70	0.0	(NA)[d]
60	13.8	2.95	0.0	(NA)[d]
90	24.4	2.88	0.0	(NA)[d]
120	33.7	3.20	0.0	(NA)[d]
240	46.2	3.57	0.0	(NA)[d]
480	46.9	3.59	0.0	(NA)[d]

[a] The reaction was carried out using **11a** (10.8 mg, 10.0 μmol), **14** (0.20 mmol), **15** (0.40 mmol) and tridecane (0.10 mmol) in 1.0 ml of CH_2Cl_2 at 23 °C. [b] Conversion of **14** to the product determined by GC analysis. [c] Molar ratio of *E* isomer and *Z* isomer of the product determined by GC analysis. [d] GC signal of the product was too small to quantify.

Table S11. Data for CM of 14 and 15 by 11b[a]

	16		**17**	
time	conversion[b]	*E*/*Z*[c]	conversion[b]	*E*/*Z*[c]
min	%		%	
5	0.0	(NA)[d]	0.0	(NA)[d]
10	0.0	(NA)[d]	0.0	(NA)[d]
15	0.0	(NA)[d]	0.0	(NA)[d]
30	0.0	(NA)[d]	0.0	(NA)[d]
45	0.0	(NA)[d]	0.0	(NA)[d]
60	0.0	(NA)[d]	0.0	(NA)[d]
90	0.0	(NA)[d]	0.0	(NA)[d]
120	0.0	(NA)[d]	0.0	(NA)[d]
240	0.0	(NA)[d]	0.0	(NA)[d]
480	0.0	(NA)[d]	0.0	(NA)[d]

[a] The reaction was carried out using **11b** (10.9 mg, 10.0 μmol), **14** (0.20 mmol), **15** (0.40 mmol) and tridecane (0.10 mmol) in 1.0 ml of CH_2Cl_2 at 23 ^oC. [b] Conversion of **14** to the product determined by GC analysis. [c] Molar ratio of *E* isomer and *Z* isomer of the product determined by GC analysis. [d] GC signal of the product was too small to quantify.