Tandem Catalysis: The Sequential Mediation of Olefin Metathesis, Hydrogenation, and Hydrogen Transfer Using Single Component Ru Complexes

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Supporting Information

General information. All manipulations were performed in a N_2 filled drybox or using standard Schlenk techniques. Allyl benzene, methyl vinyl ketone, *p*-chlorostyrene, methyl methacrylate, diethyl diallylmalonate (**3**), and 1,6-heptadien-4-ol (**6**) were purchased from Aldrich and used without further purification. *cis*-4-Cyclopentene-1,3-diol and (+)-citronellal were purchased from Fluka and used without further purification. *cis*-2-Butene-1,4-diol diacetate and 5-acetoxy-1-hexene were purchased from TCI America and used without further purification. Complexes $(PCy_3)_2Cl_2Ru{=}CHPh$ (**1**)[1] and $(H_2IMes)(PCy_3)Cl_2Ru{=}CHPh$ (**2**)[2] and substrates 1,6-heptadien-4-one (**6**),[3] 1,8-nonadien-5-one (**12**),[4] 2-allyl-2-(2-methyl-allyl)-malonic acid diethyl ester (**15**),[5] 1,4-bis-allyloxy-but-2-yne (**21**),[4] 2-methyl-acrylic acid but-3-enyl ester (**24**),[6] *N*-allyl-*N*-isopropyl-acrylamide (**27**),[7] and undec-10-enoic acid but-3-enyl ester (**30**)[8] were prepared as previously reported. Substrates 4,4-dicarbethoxycyclopentene (**4**),[2] cyclopent-3-enone (**7**), cyclopent-3-enol (**10**),[2] cyclohept-4-enone (**13**), 4,4-dicarbethoxy-1-methylcyclopentene (**16**),[5] 2,5,2',5'-tetrahydro-[3,3']bifuranyl (**22**),[9] 3-methyl-5,6-dihydro-pyran-2-one (**25**),[6] 1-isopropyl-1,5-dihydro-pyrrol-2-one (**28**),[10] oxacyclotetradec-11-en-2-one (**31**),[8] acetic acid 4-phenyl-but-2-enyl ester (**33**),[11] acetic acid 7-oxo-oct-5-enyl ester (**35**),[6] 4-phenyl-but-3-en-2-one (**37**),[12] and 3-(4-chloro-phenyl)-acrylic acid methyl ester

(**39**)[12] are known metathesis products. ^{1}H (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded on a GE-300 NMR, referenced to residual protiated solvent (resonances downfield to the standard are reported as positive), and are reported in parts per million (ppm). Multiplicities are abbreviated as follows: singlet (s), doublet (d), triplet (t), and multiplet (m). Low-resolution mass spectra were obtained on a Hewlett Packard 5890 series II gas chromatograph interfaced with a Hewlett Packard 5989A mass spectrometer. IR spectra were recorded on a Perkin-Elmer Paragon 1000 FT-IR spectrometer. Specific rotations $[\alpha]_D$ were determined on a Jasco Model P-1010 polarimeter in methanol and are given in 10^{-1} deg cm^2 g^{-1}. Elemental analyses were performed at Midwest Microlab LLC., Indianapolis, IN. High-resolution mass spectra (HR-MS) (EI and FAB) were provided by the UCR Mass Spectrometry Facility (University of California, Riverside).

General Tandem Metathesis – Hydrogenation Procedure. Olefin substrate(s) (~0.5 mmol), mesitylene or 1,3,5- trimethoxybenzene (~0.2 mmol, internal standard), and $(PCy_3)_2Cl_2Ru$=CHPh (**1**) or $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**) (15 - 45 μmol) were dissolved in dichloromethane or 1,2-dichloroethane in a screw top vial. The vial was sealed with a cap containing a PTFE septum, removed from the drybox, and placed under an atmosphere of Ar. The reaction mixture was heated to 40 ˚C for 1 h (or until complete consumption of starting material was observed by GC). Then, either a balloon of H_2 was attached *via* a syringe needle or the reaction mixture was transferred to a Fisher-Porter bottle (H_2 pressures ~100 psi) or a Parr bomb (H_2 pressures >100 psi) and the desired amount of hydrogen was introduced to the reaction. After heating the vessel at 70 ˚C for 8-24 h, the reaction mixture was cooled to ambient temperature, reduced in volume to ~0.5 mL (*via* a rotary evaporator) and purified directly on a silica gel column (hexanes/ethyl acetate as eluent).

Cyclopentane-1,1-dicarboxylic acid diethyl ester (5, Table 1, entry 1a).[13] Using the general procedure with diethyl diallyl malonate (**3**, 125 μL, 0.52 mmol), mesitylene (25 μL, 0.18 mmol), $(PCy_3)_2Cl_2Ru$=CHPh (**1**) (25 mg, 31 μmol), and 5 mL of 1,2-dichloroethane afforded 106 mg (95%) cyclopentane-1,1-dicarboxylic acid diethyl ester as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 4.17 (q, *J*=7.1 Hz, 4 H), 2.18 (t, *J*=6.0 Hz, 4H), 1.68 (quint, *J*=4.1 Hz, 4H), 1.24 (t, *J*=7.1 Hz,

6H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 172.9, 61.4, 60.5, 34.7, 25.7, 14.3; IR (neat): 2981 (s), 2875 (m), 1731 (vs, C=O), 1447 (s), 1390 (m), 1367 (s), 1324 (m), 1260 (vs), 1176 (vs), 1098 (s), 1078 (s), 1028 (s), 953 (w), 908 (w), 862 (m), 754 (w), 705 (w).

Cyclopentanone (8, Table 1, entry 1b). Using the general procedure with hepta-1,6-dien-4-one (**6**, 50 mg, 0.45 mmol), mesitylene (35 μL, 0.25 mmol), $(PCy_3)_2Cl_2Ru$=CHPh (**1**) (12 mg, 15 μmol), and 5 mL of 1,2-dichloroethane quantitatively afforded cyclopentanone (determined by GC/GC-MS analysis).

Cyclopentanol (11, Table 1, entry 1c). Using the general procedure with hepta-1,6-dien-4-ol (**9**, 53 mg, 0.47 mmol), mesitylene (35 μL, 0.25 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**1**) (15 mg, 18 μmol), and 5 mL of 1,2-dichloroethane quantitatively afforded cyclopentanol (determined by GC/GC-MS analysis).

Cycloheptanone (14, Table 1, entry 2). Using the general procedure with 1,8-nonadien-5-one (**12**, 60 mg, 0.43 mmol), mesitylene (15 μL, 0.11 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 10 mg, 12 μmol), and 25 mL of 1,2-dichloroethane afforded 39 mg (81%, 86% by conversion of **12**) of cycloheptanone as a colorless oil. All spectra were identical to an authentic sample purchased from Aldrich.

3-Methyl-cyclopentane-1,1-dicarboxylic acid diethyl ester (17, Table 1, entry 3).[14] Using the general procedure with 2-allyl-2-(2-methyl-allyl)-malonic acid diethyl ester (**15**, 100 mg, 0.39 mmol), mesitylene (25 μL, 0.18 mmol), $(PCy_3)_2Cl_2Ru$=CHPh (**1**) (10 mg, 12 μmol), and 5 mL of 1,2-dichloroethane afforded a 70% conversion to product **17** (determined by GC/GC-MS analysis).

3-Allyloxy-5-(2-methallyloxy)-cyclopentene (18). This compound was prepared using a modified procedure of 3,5-cyclopentenediol bis(allyl) ether (see ref. 9). A 20 mL round bottom flask was charged with 391 mg (3.91 mmol) of *cis*-4-cyclopentene-1,3-diol and dissolved in 15 mL of dry DMF. After cooling the resulting solution to 0 ºC, the slow addition of 94 mg (3.92 mmol) of NaH resulted

in the immediate bubbling of H_2. After stirring at 0 ºC for 30 min, 0.43 mL (4.26 mmol) of 3-bromo-2-methyl-propene (methallyl bromide) was added *via* syringe to the suspension and the reaction mixture was allowed to warm to room temperature. After 8 h at room temperature, the resulting yellow solution was diluted with water (30 mL) and extracted with Et_2O (5 x 20 mL). After concentrating the organic layer to a yellow oil, purification *via* column chromatography (silica gel, hexanes/ethyl acetate as eluent) afforded 452 mg (75% yield) of 4-(2-methyl-allyloxy)-cyclopent-2-enol as a clear, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.01 (s, 2H), 4.96 (t, *J*=0.8 Hz, 1H), 4.88 (d, *J*=0.8 Hz, 1H), 4.64-4.56 (bdd, *J*=6.3 Hz and 4.4 Hz, 1H), 4.38-4.32 (m, 1H), 3.91 (t, *J*=1.4Hz, 2H), 2.70-2.56 (m, 1H), 2.08 (bs, 1H), 1.74 (s, 3H), 1.64-1.54 (dt, *J*=14 Hz and 5 Hz, 1H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 142.2, 137.0, 134.0, 112.2, 81.2, 74.9, 72.9, 40.9, 19.7; IR (neat): 3425 (br, vs), 2974 (m), 2939 (s), 1655 (s), 1451 (m), 1358 (m), 1322 (w), 1257 (w), 1180 (w), 1077 (vs), 899 (m), 764 (m); HR-MS calcd for $C_9H_{14}O_2$ (M^+): 154.0994, found 154.0992; Anal. calcd for $C_9H_{14}O_2$: C, 70.10; H, 9.15, found: C, 70.15; H, 8.90.

Note: the major byproduct of the above reaction was determined to be 3,5-bis-(2-methallyloxy)-cyclopentene (163 mg). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.02 (s, 2H), 4.97 (t, *J*=1.1 Hz, 2H), 4.87 (dd, *J*=1.4 Hz and 0.8 Hz, 2H), 4.38 (dd, *J*=6.3 Hz and 4.4 Hz, 2H), 3.90 (s, 4H), 2.68-2.56 (m, 1H), 1.75 (s, 6H), 1.70-1.60 (dt, *J*=14 Hz and 5 Hz, 1H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 142.4, 134.4, 111.9, 81.0, 72.4, 37.7, 19.7; IR (neat): 2975 (s), 2857 (m), 1655 (s), 1451 (m), 1370 (m), 1321 (w), 1257 (w), 1086 (m), 897 (m), 765 (w); HR-MS calcd for $C_{13}H_{20}O_2$ (M^+): 208.1463, found 208.1465; Anal. calcd for $C_{13}H_{20}O_2$: C, 74.96; H, 9.68, found: C, 75.13; H, 9.94.

A 20 mL round bottom flask was charged with 167 mg (1.08 mmol) of 4-(2-methyl-allyloxy)-cyclopent-2-enol and dissolved in 5.2 mL of dry DMF. After cooling the resulting solution to 0 ºC, the slow addition of 125 mg (5.21 mmol) of NaH resulted in the immediate bubbling of H_2. After stirring at 0 ºC for 30 min, 0.60 mL (6.93 mmol) of allyl bromide was added *via* syringe to the suspension and the reaction mixture was allowed to warm to room temperature. After 8 h at room temperature, the resulting yellow solution was diluted with water (15 mL) and extracted with Et_2O (3 x 10 mL). After concentrating the organic layer to a yellow oil, purification *via* column chromatography (silica gel, hexanes/ethyl acetate as

eluent) afforded 3-allyloxy-5-(2-methallyloxy)-cyclopentene (**18**) in 83% yield (175 mg) as a clear, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.03 (s, 2H), 6.02-5.88 (m, 1H), 5.27 (m, 1H), 5.15 (m, 1H), 4.97 (m, 1H), 4.87 (m, 1H), 4.40-4.33 (m, 2H), 4.00 (dt, *J*=5.5 Hz and 1.1 Hz, 2H), 3.90 (s, 2H), 2.69-2.57 (m, 1H), 1.73 (s, 3H), 1.71-1.60 (m, 1H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 142.4, 135.0, 134.5, 134.2, 116.7, 111.9, 81.1, 81.0, 72.5, 69.5, 37.7, 19.7; IR (neat): 3076 (m), 2975 (m), 2936 (m), 2855 (s), 1650 (m), 1456 (m), 1366 (s), 1322 (m), 1258 (w), 1190 (w), 1083 (vs), 993 (w), 899 (s), 763 (m); HR-MS calcd for $C_{12}H_{18}O_2$ (M^+): 194.1307, found 194.1309; Anal. calcd for $C_{12}H_{18}O_2$: C, 74.19; H, 9.34, found: C, 74.40; H, 9.23.

2-(2,5-dihydro-furan-2-ylmethyl)-4-methyl-2,5-dihydrofuran (19) Using the general metathesis procedure (no hydrogenation) with compound **18** (55 mg, 0.29 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 8 mg, 9 μmol), mesitylene (25 μL, 0.18 mmol), and 6 mL of 1,2-dichloroethane afforded 43 mg (91%) of compound **19** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.91 (m, 2H), 5.45 (d, *J*=1.4 Hz, 1H), 4.96-4.91 (m, 2H), 4.71-4.43 (m, 4H), 1.93-1.77 (m, 2H), 1.75 (m, 3H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 136.3, 130.2, 126.4, 124.0, 84.2, 83.7, 77.9, 75.1, 42.4, 12.5; IR (neat): 2926 (m), 2857 (m), 1755 (s), 1644 (m), 1506 (w), 1445 (m), 1382 (w), 1341 (w), 1145 (w), 1071 (s), 993 (w), 818 (w), 757 (w), 696 (w), 601 (w); HR-MS calcd. for $C_{10}H_{14}O_2$ (M+): 166.0994, found 166.0996; Anal. calcd for $C_{10}H_{14}O_2$: C, 72.26; H, 8.49, found: C, 72.40; H, 8.29.

4-Methyl-2-(tetrahydro-furan-2-ylmethyl)-2,5-dihydro-furan (20, Table 1, entry 4). Using the general procedure with compound **18** (55 mg, 0.29 mmol), mesitylene (10 μL, 0.07 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 8 mg, 9 μmol), and 6 mL of 1,2-dichloroethane afforded 43 mg (90%) of compound **20** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.45 (t, *J*=1.5 Hz, 1H), 4.91 (pseudo octet, *J*=1.9 Hz, 1H), 4.56-4.42 (m, 3H), 3.95-3.84 (m, 2H), 3.74-3.67 (m, 2H), 2.07-1.46 (m, 7H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 136.3, 123.9, 84.8, 77.8, 77.0, 67.8, 42.1, 31.8, 25.8, 12.5; IR (neat): 2931 (vs), 2890 (s), 1756 (vs), 1446 (m), 1381 (m),

1062 (vs), 764 (w), 613 (w); HR-MS calcd. for $C_{10}H_{16}O_2$ (M+): 168.1150, found 168.1151. Anal. calcd for $C_{10}H_{16}O_2$: C, 71.39; H, 9.59, found: C, 71.50; H, 9.60.

Octahydro-[3,3']bifuranyl (23, Table 1, entry 5).[15] Using the general procedure with compound **21** (250 mg, 1.5 mmol), mesitylene (40 μL, 0.29 mmol), $(PCy_3)_2Cl_2Ru$=CHPh (**1**, 38 mg, 46 μmol), and 10 mL of dichloromethane afforded (an inseparable diastereomeric mixture) of compound **23** (198 mg, 93%) as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 3.95-3.80 (m, 4H), 3.79-3.69 (m, 2H), 3.47-3.40 (m, 1H), 3.39-3.33 (m, 1H), 2.20-1.93 (m, 4H), 1.70-1.47 (m, 2H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 72.2, 72.0, 68.0, 67.8, 42.8, 42.7, 31.4, 31.3; IR (neat): 2963 (s), 2931 (s) 2863 (s), 1474 (w), 1452 (m), 1367 (w), 1210 (w), 1079 (s), 1041 (m), 963 (w), 909 (s), 689 (m), 668 (w); HR-MS calcd. for $C_8H_{14}O_2$ (M+): 142.0994, found 142.0996; Anal. calcd for $C_8H_{14}O_2$: C, 67.57; H, 9.92, found: C, 67.71; H, 9.71.

3-Methyl-tetrahydro-pyran-2-one (26, Table 1, entry 6).[16] Using the general procedure with compound **24** (160 mg, 1.14 mmol), mesitylene (25 μL, 0.18 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 37 mg, 44 μmol), and 5 mL of 1,2-dichloroethane afforded 100 mg (77%, 85% by conversion of **24**) of compound **26** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 4.06 (t, J=6.6. Hz, 2H), 2.53 (dt, J_1=7.14 Hz, J_2=6.9 Hz, 1H), 1.69-1.59 (m, 2H), 1.41-1.36 (m, 2H), 1.16 (d J=6.9 Hz, 3H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 177.2, 64.4, 34.3, 28.9, 25.9, 19.4; IR (neat): 2973 (vs), 2876 (s), 1732 (vs, C=O), 1471 (s), 1391 (s), 1366 (w), 1344 (m), 1261 (s), 1193 (s), 1157 (s), 1078 (s), 1029 (w), 984 (m), 930 (w), 907 (w), 843 (w), 753 (m), 700 (w).

1-Isopropyl-pyrrolidin-2-one (29, Table 1, entry 7).[17] Using the general procedure with compound **27** (97 mg, 0.63 mmol), mesitylene (25 μL, 0.18 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 20 mg, 24 μmol), and 5 mL of 1,2-dichloroethane afforded 68 mg (84%, 94% by conversion of **27**) of compound **29** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 4.37 (sept, J=6.9 Hz, 1H), 3.33 (t, J=6.9 Hz, 2H), 2.38 (t, J=7.7 Hz, 2H), 1.99 (quint, J=7.7 Hz, 2H), 1.13 (d, J=6.6 Hz, 6H); ^{13}C

{^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 174.4, 42.5, 41.9, 31.8, 20.0, 18.2; IR (neat): 2970 (s), 2927 (s), 1938 (w), 1676 (vs, C=O), 1493 (w), 1462 (m), 1424 (m), 1367 (m), 1312 (w), 1288 (s), 1241 (s), 1169 (w), 1128 (m), 1066 (m), 1012 (w), 932 (w), 878 (w), 842 (w), 736 (w), 651 (m).

Oxa-cyclotetradecan-2-one (32, Table 1, entry 8).[18] Using the general procedure with undec-10-enoic acid but-3-enyl ester **30** (120 mg, 0.50 mmol), 1,3,5-trimethoxybenzene (68 mg, 0.40 mmol), $(PCy_3)_2Cl_2Ru$=CHPh (**1**, 17 mg, 21 μmol), and 150 mL of 1,2-dichloroethane afforded 98 mg (84%, 93% by conversion of **30**) of compound **32** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 4.15 (t, *J*=5.5 Hz, 2H), 2.38 (t, *J*=6.3 Hz, 2H), 1.68-1.62 (m, 4H), 1.37-1.27 (m, 16H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 174.2, 63.5, 34.6, 27.9, 26.4, 26.3, 26.1, 25.9, 24.9, 24.8, 24.2, 23.9, 22.9; IR (neat): 2928 (vs), 2859 (s), 1736 (vs, C=O), 1461 (s), 1384 (w), 1346 (w), 1243 (m), 1169 (m), 1143 (m), 1106 (w), 1055 (w), 998 (w), 950 (w), 905 (w), 808 (w), 718 (w).

Acetic acid 4-phenyl-butyl ester (34, Table 2, entry 1).[19] Using the general procedure allyl benzene (100 mg, 0.85 mmol), *cis*-2-butene-1,4-diol diacetate (300 mg, 1.7 mmol,), mesitylene (30 μL, 0.22 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 20 mg, 25 μmol), and 5 mL of 1,2-dichloroethane afforded 135 mg (83%, 91% by conversion of allyl benzene) of compound **34** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.34-7.19 (m, 5H), 4.10 (t, *J*=6.3 Hz, 2H), 2.67 (t, *J*=7.1 Hz, 2H), 2.08 (s, 3H), 1.73-1.68 (m, 4H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 171.4, 142.2, 128.6, 128.5, 126.0, 64.6, 35.7, 28.4, 27.9, 21.2; IR (neat): 3086 (w), 3063 (m), 3027 (s), 2940 (vs), 2861 (s), 1947 (w), 1873 (w), 1739 (vs, C=O), 1604 (m), 1584 (w), 1496 (m), 1454 (s), 1387 (m), 1366 (s), 1241 (vs), 1043 (vs), 970 (w), 951 (w), 909 (w), 848 (w), 789 (w), 749 (s), 700 (s), 635 (w), 607 (m), 572 (w).

Acetic acid 6-oxo-octyl ester (36, Table 2, entry 2).[20] Using the general procedure methyl vinyl ketone (200 μL, 2.4 mmol), 5-acetoxy-1-hexene (200 μL, 1.2 mmol,), mesitylene (45 μL, 0.32 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 33 mg, 35 μmol), and 5 mL of 1,2-dichloroethane afforded 172 mg (77%, 91% by conversion of 5-

acetoxy-1-hexene) of compound **36** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 4.04 (t, *J*=6.9 Hz, 2H), 2.43 (t, *J*=7.7 Hz, 2H), 2.13 (s, 3H), 2.04 (s, 3H), 1.64-1.55 (m, 4H), 1.36-1.30 (m, 4H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 209.3, 171.4, 64.6, 43.8, 30.1, 28.9, 25.9, 23.8, 21.2; IR (neat): 2938 (vs), 2860 (s), 1736 (vs, C=O), 1464 (m), 1434 (w), 1387 (w), 1366 (s), 1243 (vs), 1163 (m), 1039 (s), 954 (w), 721 (w), 634 (w), 607 (w).

4-Phenyl-butan-2-one (38, Table 2, entry 3). Using the general procedure with methyl vinyl ketone (75 μL, 0.9 mmol), styrene (200 μL, 1.75 mmol,), mesitylene (30 μL, 0.22 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 38 mg, 45 μmol), and 5 mL of 1,2-dichloroethane afforded 106 mg (80%, 94% by conversion of methyl vinyl ketone) of compound **38** as a colorless oil. All spectra were identical to an authentic sample purchased from Aldrich. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.33-7.19 (m, 5H), 2.92 (t, *J*=7.3 Hz, 2H), 2.78 (t, *J*=7.3 Hz, 2H), 2.16 (s, 3H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 208.2, 141.2, 128.7, 128.5, 126.3, 45.4, 30.3, 29.9; IR (neat): 3086 (m), 3062 (m), 3028 (m), 2926 (s), 1716 (vs, C=O), 1603 (m), 1497 (m), 1454 (m), 1409 (w), 1359 (s), 1242 (w), 1162 (s), 1080 (w), 1031 (w), 964 (w), 750 (s), 700 (s).

3-(4-Chloro-phenyl)-propionic acid methyl ester (40, Table 2, entry 4).[21] Using the general procedure, methyl acrylate (210 μL, 2.3 mmol), *p*-chlorostyrene (140 μL, 1.2 mmol,), mesitylene (45 μL, 0.32 mmol), $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 33 mg, 35 μmol), and 5 mL of 1,2-dichloroethane afforded 160 mg (69%, 75% by conversion of *p*-chlorostyrene) of compound **40** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.26 (d, *J*=8.5 Hz, 2H), 7.14 (d, *J*=8.5 Hz, 2H), 3.67 (s, 3H), 2.93 (t, *J*=7.4 Hz, 2H), 2.62 (t, *J*=7.4 Hz, 2H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 173.2, 139.1, 132.2, 129.9, 128.8, 51.9, 35.7, 30.4; IR (neat): 3028 (m), 2996 (m), 2952 (s), 2846 (m), 1898 (w), 1732 (vs, C=O), 1598 (w), 1577 (w), 1494 (s), 1436 (s), 1409 (m), 1365 (s), 1295 (m), 1197 (vs), 1093 (s), 1016 (s), 988 (m), 952 (w), 901 (w), 820 (s), 782 (w), 727 (w), 716 (w), 638 (m), 516 (m).

4-Phenyl-but-3-en-2-ol (41).[22] Methyl vinyl ketone (75 μL, 0.9 mmol), styrene (200 μL, 1.75 mmol,), mesitylene (30 μL, 0.22 mmol), and $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 38 mg, 45 μmol) were dissolved in 5 mL of 1,2-dichloroethane in a screw top vial. The vial was sealed with a cap containing a PTFE septum and removed from the drybox. The reaction mixture was heated to 40 °C for 12 h (85% consumption of methyl vinyl ketone was observed by GC). (The following corresponds to "Method B" in the text.) The reaction vessel was then charged with NaOH (10 mg, 0.25 mmol), ethylene diamine (3.1 μL, 0.047 mmol) and isopropanol (5 mL) and a balloon of H_2 was attached *via* a syringe needle. The reaction was stirred at room temperature for 12 h. The reaction mixture was then diluted with CH_2Cl_2 (5 mL), washed with H_2O (3 x 3 mL), and then dried over K_2CO_3. The reaction mixture was then reduced in volume to 0.5 mL and purified directly on a silica gel column. The product was eluted with 10:1 hexanes:ethyl acetate to afford 110 mg (83%, 97% by conversion of methyl vinyl ketone) of compound **41** as a clear, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.26-7.10 (m, 5H), 6.44 (dd, *J*=15.9 Hz, *J*=0.8 Hz, 1H), 6.13 (dd, *J*=15.9 Hz and 6.3 Hz, 1H), 4.36 (qd, *J*=6.3 Hz and 1.1 Hz, 1H), 1.46 (bs, 1H), 1.24 (d, *J*=6.3 Hz, 3H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 133.5, 129.4, 128.6, 128.4, 127.6, 126.4, 68.9, 23.4; IR (neat): 3356 (vs), 3084 (m), 3060 (m), 3028 (s), 2973 (s), 2926 (m), 2872 (m), 1958 (w), 1878 (w), 1814 (w), 1704 (w), 1658 (w), 1599 (w), 1578 (w), 1494 (m), 1480 (m), 1450 (m), 1368 (m), 1331 (w), 1298 (m), 1205 (w), 1180 (w), 1142 (s), 1059 (s), 968 (s), 943 (m), 876 (w), 855 (w), 825 (w), 749 (s), 694 (s), 680 (s).

4-Phenyl-butan-2-ol (42).[23] The following procedure corresponds to Method A + Method B as described in the text. Methyl vinyl ketone (75 μL, 0.9 mmol), styrene (200 μL, 1.75 mmol,), mesitylene (30 μL, 0.22 mmol), and $(H_2IMes)(PCy_3)Cl_2Ru$=CHPh (**2**, 38 mg, 45 μmol) were dissolved in 5 mL of 1,2-dichloroethane in a screw top vial. The vial was sealed with a cap containing a PTFE septum and removed from the drybox. The reaction mixture was heated to 40 °C under Ar for 12 h (85% consumption of methyl vinyl ketone was observed by GC). The reaction was then transferred to a Fisher-Porter bottle and pressured with 100 psi of H_2. Heating at 70 °C for 10 h quantitatively afforded **38** (by GC analysis). The reaction was then transferred to a vial containing NaOH (10 mg, 0.25 mmol)

ethylene diamine (3.1 μL, 0.047 mmol) and isopropanol (5 mL) and sealed with a cap containing a PTFE septum. A balloon of H_2 was attached *via* syringe and the reaction was stirred at room temperature for 12 h. The reaction mixture was then diluted with CH_2Cl_2 (5 mL), washed with H_2O (3 x 3 mL), and then dried over K_2CO_3. Purification by column chromatography (silica gel, hexanes/ethyl acetate as eluent) afforded 41 mg (30%) of compound **42**.

Alternatively, after cross metathesis between methyl vinyl ketone and styrene, the reaction was transferred to a Fisher-Porter bottle containing NaOH (10 mg, 0.25 mmol), ethylene diamine (3.1 μL, 0.047 mmol) and isopropanol (5 mL). The flask was pressured with 100 psi of H_2 and heated to 70 °C for 10 h to afford compound **42** in 30% yield. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.22-7.07 (m, 5H), 3.74 (d, *J*=6.3 Hz, 2H), 3.39 (s, 1H), 2.72-2.53 (m, 2H), 1.72-1.64 (m, 2H), 1.14 (d, *J*= 6.3 Hz, 3H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 142.2, 128.6, 128.5, 126.0, 67.7, 41.1, 32.4, 23.8; IR (neat): 3416 (vs), 3087 (m), 3083 (m), 2967 (s), 2928 (s), 1959 (w), 1812 (w), 1637 (s), 1604 (m), 1496 (m), 1479 (w), 1454 (m), 1375 (m), 1311 (w), 1080 (w), 1129 (s), 1082 (w), 1055 (m), 1032 (m), 955 (w), 935 (w), 907 (w), 856 (w), 746 (w), 699 (w), 679 (w).

Cyclohept-4-enol (43).[24] In a N_2-filled drybox, 1,8-nonadien-5-one (**6**, 60 mg, 0.43 mmol), mesitylene (15 μL, 0.11 mmol), and (H_2IMes)(PCy_3)Cl_2Ru=CHPh (**2**, 10 mg, 12 μmol) were dissolved in 25 mL of 1,2-dichloroethane in a screw top vial. The vial was sealed with a cap containing a PTFE septum and removed from the drybox. The reaction mixture was heated under Ar to 40 °C for 3 h (93% consumption of starting material was observed by GC). The reaction was transferred to a two-neck round bottom flask containing K_2CO_3 (20 mg, 0.14 mmol) and isopropanol (20 mL) and equipped with a reflux condenser. The reaction was refluxed for 3 days to afford a 60% yield of cyclohept-4-enol (**43**) (by GC/GC-MS analysis).

Acetic acid 7-oxo-oct-5-enyl ester (**35**).[6] A screw-top vial was charged with 3-buten-2-ol (200 μL, 2.31 mmol), 5-acetoxy-1-hexene (165 mg, 1.16 mmol), mesitylene (50 μL, 0.35 mmol), and (H_2IMes)(PCy_3)Cl_2Ru=CHPh (**2**, 50 mg, 59 μmol) and dissolved in 6 mL of 1,2-dichloroethane. The vial was sealed with a cap

containing a PTFE septum and removed from the drybox. Heating the reaction mixture to 40 °C under Ar for 8 h afforded alcohol **44**[25] (89% conversion as determined by GC). The reaction was then transferred to a two-neck round bottom flask containing NaOH (10 mg, 0.25 mmol) and 3-pentanone (20 mL) and equipped with a reflux condenser. After heating the reaction to reflux for 3 days, the solvent was removed and the reaction was purified using column chromatography (silica gel, hexanes/EtOAc as eluent) to afford 164 mg of acetic acid 7-oxo-oct-5-enyl ester (**35**)[6] in 86% yield. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.78 (dt, *J*=15.9 Hz and 6.9 Hz, 1H), 6.07 (dt, *J*=15.9 Hz and 1.4 Hz, 1H), 4.07 (t, *J*=6.3 Hz, 1H), 2.27-2.21 (m, 2H), 2.24 (s, 3H), 2.04 (s, 3H), 1.72-1.48 (m, 4H); ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$, ppm): δ 198.4, 171.0, 147.4, 131.5, 64.0, 32.0, 28.2, 27.0, 24.5, 21.1.

(*R*)-3-Methyl-1-cyclopentadecanone or (*R*)-(-)-Muscone.[26] (6*R*)-2,6-Dimethyl-2,17-octadecadien-8-ol[26] (**44**) (50 mg, 0.17 mmol), mesitylene (10 μL, 0.072 mmol), and (H_2IMes)(PCy_3)Cl_2Ru=CHPh (**2**, 10 mg, 12 μmol) were dissolved in 200 mL 1,2-dichloroethane in a 500 mL round bottom flask. The reaction was heated to 50 °C for 12 h (74% conversion to RCM product **45**,[26] monitored by GC). The flask was then charged with NaOH (10 mg, 0.25 mmol) and 3-pentanone (50 mL) and equipped with a reflux condenser. The reaction was heated to reflux for 1 d (76% conversion to the oxidized product (*R*)-3-methylcyclopentadec-6-en-1-one (**46**),[26] by GC) and then cooled to room temperature. The reaction mixture was transferred to a Parr bomb, pressured to 800 psi with H_2, and heated to 80 °C for 1 d (quantitative conversion to (*R*)-Muscone, by GC). After cooling to room temperature, the reaction mixture was washed with H_2O (3 x 30 mL) and then dried over $MgSO_4$. Purification by column chromatography (silica gel, hexanes/ethyl acetate as eluent) afforded 29 mg (56% overall isolated yield from **44**) of (*R*)-(-)-Muscone as a fragrant, colorless oil. Higher overall yields (75%) of (*R*)-(-)-Muscone were obtained from (6*R*)-2,6-dimethyloctadeca-2,17-octadien-8-one[26] (obtained *via* Jones oxidation of **44**) using the general tandem RCM – hydrogenation protocol described above. $[\alpha]_D$ = -12.3 (*c* 0.9 in CH_3OH) (lit.[27] –12.5 in CH_3OH); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 2.45–2.38 (m, 3H), 2.18 (dd, *J*=15.1 Hz and 5.2 Hz, 1H), 2.12-1.88 (bm, 1H), 1.50-1.75 (bm, 2H), 1.1-1.5 (bs, 20H), 0.93 (d, *J*=6.6 Hz, 3H); ^{13}C {^{1}H} NMR (75 MHz,

$CDCl_3$, ppm): δ 211.9, 50.4, 42.1, 35.6, 29.10, 27.6, 27.2, 26.8, 26.6, 26.6, 26.6, 26.3, 26.2, 25.1, 23.1, 21.2; IR (neat): 2928 (s), 2856 (s), 1712 (s, C=O), 1607 (w), 1517 (w), 1460 (m), 1408 (w), 1367 (m), 1274 (w), 1172 (w), 1128 (w), 1055 (w), 722 (w); HR-MS calcd for $C_{16}H_{30}O$ (M^+): 238.2297, found 238.2295.

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