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(54) Title: RHODIUM CATALYZED SILAFORMYLATION OF ALDEHYDES AND PRODUCTS OBTAINED THEREFROM

(57) Abstract

Aldehydes substituted with carbon radicals such as alkyl, aromatic, and heterocyclic, can be silaformylated with a silane reagent and carbon monoxide in the presence of rhodium catalyst to produce alpha-silyloxyaldehydes. The alpha-silyloxyaldehydes are useful intermediates in the synthesis of biologically active molecules.

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RHODIUM CATALYZED SILAFORMYLATION OF ALDEHYDES AND PRODUCTS OBTAINED THEREFROM

Technical Field. The invention relates to a method for preparing chiral and achiral α-silyloxyaldehydes. More specifically the invention relates to a process for silaformylating aldehydes with a silicon hydride and carbon monoxide in the presence of a rhodium catalyst.

State of the Art. A method for the silaformylation of aldehydes is shown in Murai et al., Angew. Chem. Int. Ed. Engl., 18: 393 and 837 (1979). Three aldehydes, R-CHO; (where R was cyclohexyl, pentyl, and heptyl), were reacted with carbon monoxide (50 Kg/cm^2) and dimethylphenylsilane in the presence of a $Co_2(CO)_8/PPh_3$ catalyst. A benzene solution was used at a temperature of 100°C and a three-fold excess of aldehyde had to be employed. Although this method could produce α-silyloxyaldehydes, the limited substrate scope, high reaction temperatures and pressures, and excess aldehyde limit this method's scope and utility.

It is known that at elevated temperature in the presence of a cobalt catalyst, a silane reagent extensively reacts and thus consumes the desired α-silyloxyaldehyde product. This consumption drastically lowers the yield of the desired α-silyloxyaldehyde based on the starting aldehyde. Although highly desirable, a catalytic synthesis of diastereomerically pure α-silyloxyaldehydes has not been developed.

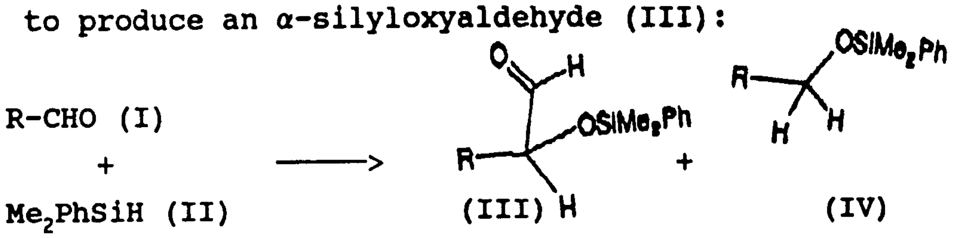
It would be an improvement in the art to have a catalytic synthesis of α-silyloxyaldehydes useful with a broad range of aldehydes which would operate under reaction conditions wherein the desired product is stable. Such a catalytic process would provide α-silyloxyaldehydes, enhancing these compounds' utility as intermediates in chemical synthesis.

DISCLOSURE OF THE INVENTION

The invention includes a process wherein aldehydes of the formula: R-CHO, (I) are reacted with a silane of the formula:

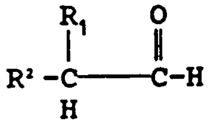
$$Me_2PhSiH, \qquad (II)$$

in the presence of carbon monoxide and a rhodium catalyst, to produce an α-silyloxyaldehyde (III):



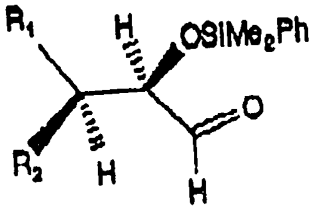
In these formulae, R is a substituted or unsubstituted alkyl, aryl, aralkyl, or heterocyclic hydrocarbon.

The invention also includes a process for synthesizing compounds of specific relative stereochemistry by reacting aldehydes of the formula:



$$R^2-\underset{H}{\overset{R_1}{C}}-\overset{O}{\overset{\|}{C}}-H \qquad (V)$$

wherein R_1 is aryl and R^2 can be alkyl, aryl, aralkyl, dialkylamino, or alkoxy radicals, with silane reagent of formula (II) and carbon monoxide in the presence of catalyst. Relatively pure syn-isomer:



was isolated.

The rhodium(I) catalyzed silaformylation of aldehydes has broad application, affords high yields of the α-silyloxyaldehydes, and does not require the use of excess aldehyde.

Once made, the α-silyloxyaldehydes are useful, for among other things, as intermediates, and can be converted to α-silyloxime derivatives which are useful synthetic intermediates in the diastereoselective synthesis of β-aminoalcohols.

DETAILED DESCRIPTION OF THE INVENTION

The aldehyde used in the process will generally be chosen for its constituent R group. Preferably the R group will be selected from the group of substituted or unsubstituted phenyl, lower (C1 to C4) alkyl, furanyl, pyrrolyl, and thiophenyl.

As used herein, alkyl is preferably a saturated or unsaturated, branched or unbranched hydrocarbon having one to twenty carbon atoms, e.g. methyl, ethyl, isopentyl, and allyl. Alkoxy groups will typically have one to four carbon atoms and include groups such as methoxy and ethoxy.

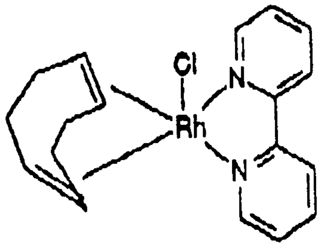
Aryl, as used herein, is an aromatic hydrocarbon group, preferably having six to ten carbon atoms, such as phenyl or naphthyl.

Aralkyl, as used herein, is an arene group (having both aliphatic and aromatic portions), preferably having seven to thirteen carbon atoms, such as benzyl, ethylbenzyl, n-propylbenzyl, or isobutylbenzyl.

A "substitution" with regard to the various R moieties generally relates to substituting a group such as alkoxy, halogen, hydroxy, nitro, or lower alkyl onto an aromatic ring for a hydrogen that would normally be present. Substitutions can also be made on an alkyl or alkoxy chain.

Halogen, as used herein, generally refers to fluorine, chlorine, bromine or iodine.

A variety of rhodium complexes can be used as a catalyst. Preferred rhodium catalysts for the silaformylation of aldehydes are rhodium cycloöctadiene chloride ($[(COD)RhCl]_2$) or a compound of the formula:



Utilization of monohydric dimethylphenylsilane is found to work superbly in the rhodium(I) catalyzed sila-formylation of aldehydes. Since no evidence exists for the production of "diol" products, the relative rate of reaction for the starting aldehyde substrate must be much greater than that of the newly formed α-silyloxyaldehyde. A simple bulb-to-bulb distillation affords analytically pure α-silyloxyaldehydes. (See Example I) Ketone substrates (e.g. acetophenone) yield silylenol ethers as the major product. This result suggests that β-hydrogen elimination is much faster than migratory insertion of carbon monoxide.

A general process for synthesizing the compounds of the invention is given in Scheme 1.

Scheme I

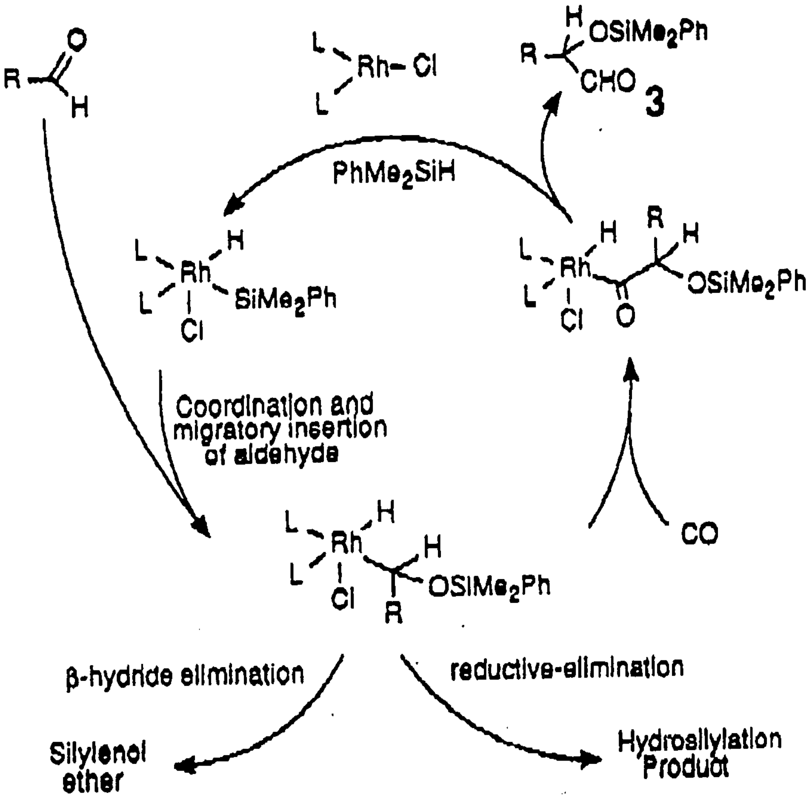
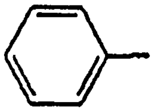
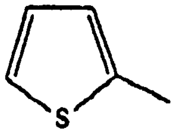
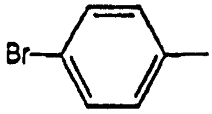
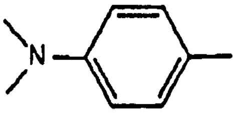
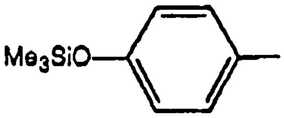
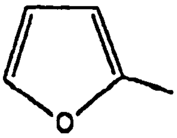
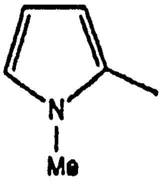
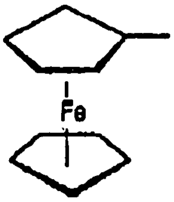


Table I. Summary of Results for the Rhodium Catalyzed Silaformylation of Aldehydes.

Product	*R*	*Yield*[b]	*Product*	*R*	*Yield*[b]
3a		74%	3f		72%
3b		84%	3g[c]	$CH_3CH_2CH_2$-	60%
3c		80%	3h[c]	$(CH_3)_2CH$-	75%
3d		50%	3i		90%
3e		60%	3j		88%

a A THF solution (8mL) of the appropriate aldehyde (1.5 mmol) and Me_2PhSiH (0.20 g, 1.5 mmol) was degassed (freeze-pump-thaw x 3) and then cannulated into a glass vessel containing the $[(COD)RhCl]_2$ (1.8 mg, 0.5 mol-%). The vessel was placed in the bomb and charged with carbon monoxide (1724 kilopascals above atmospheric) and allowed to react at ~23°C for 24 hours

b Yields reported were determined by NMR spectroscopy using an internal NMR standard (1,1,1-trichlorethane). Isolated yields were slightly lower, but comparable.

c 6895 kilopascals over atmospheric of carbon monoxide pressure used.

It can be seen from Table I that the reaction is quite general and works well for heterocyclic as well as aliphatic systems. The very mild reaction conditions permit discrimination of the starting aldehyde from the newly formed and more sterically demanding α-silyloxyaldehyde. In the case of isobutyraldehyde small amounts of enol ether formed and at lower carbon monoxide pressures (1724 kilopascals over atmospheric) hydrosilylation product was observed.

For aromatic aldehydes, carbon monoxide pressures of 862 kilopascals over atmospheric produce slightly lower yields of the α-silyloxyaldehydes with concomitant formation of the hydrosilylation byproduct (~10%).

Preferably, strong electron-withdrawing substituents will be avoided in the silaformylation reaction. For example, p-nitrobenzaldehyde shows only a 40% conversion with only some silaformylation product (20% yield). Pyridine carboxaldehydes (both the 2- and 4-) were to be completely unreactive under the reaction conditions.

Preferred temperature ranges for the reaction vary from 0°C to 25°C.

The rhodium catalyzed silaformylation is selective for the aldehyde functionality in the presence of an ester. Highly functionalized aromatic compounds have been isolated in 70% yield. Spectral data collected from the crude reaction mixture indicated complete chemoselectivity for the aldehyde group.

The invention is further described by reference to the following illustrative EXAMPLES.

EXAMPLES

Methods. All manipulations of compounds and solvents were carried out by using standard Schlenk techniques. Solvents were degassed and purified by distillation under nitrogen from standard drying agents. Spectroscopic measurements utilized the following instrumentation: ^{1}H NMR, Varian XL 300; ^{13}C NMR, JOEL-270, Varian XL 300 (at 75.4 MHz); Infrared, Perkin Elmer 1750 FT-IR; UV-vis, HP-8452A diode array spectrometer. NMR chemical shifts are reported in δ versus Me_4Si in ^{1}H NMR and assigning the $CDCL_3$ resonance at 77.00 ppm in ^{13}C spectra. The benzaldehyde, 4-bromobenzaldehyde, 4-dimethylaminobenzaldehyde, 1-methyl-2-pyrrolecarboxaldehyde, 2-thiophenecarboxaldehyde, butyraldehyde, isobutyraldehyde, 2-furaldehyde, and ferrocenecarboxaldehyde were purchased from Aldrich Chemical Co. and used as received. Dimethylphenylsilane, triethylsilane, triphenylsilane was purchased from Hüls America, Inc. and used as received. The $[(COS)RhCl]_2$, 4-acetoxybenzaldehyde, and 4-(trimethylsilyloy) benzaldehyde were prepared from literature procedures. Giordano, G.; Crabtree, R.H., Inorg. Synth. 1979, 19, 218; Highet, R.J.; Highet, P.F. J. Org. Chem. 1965, 30, 902; and Cooper, G. J. Org. Chem. 1961, 26, 925. Elemental analyses were performed at Atlantic Microlab, Inc., Norcross, Georgia.

Silaformylation Procedure. A round-bottom flask (50mL) was charged with the appropriate aldehyde (1.5 mmol), dimethylphenylsilane (0.20 g, 1.5 mmol), and THF

(8 mL). The mixture was degassed by three consecutive freeze-pump-thaw cycles and then cannulated into a nitrogen purged glass vessel containing $[(COD)RhCl]_2$ (0.0018 g, 0.0038 mmol, 0.5 mol %). The glass vessel was placed in a stainless steel bomb and purged three times with carbon monoxide (345 $\leftrightarrow$ 3448 kilopascals over atmospheric). The bomb was brought to the desired reaction pressure and stirred at room temperature for 24 h. The glass vessel was removed from the bomb and the solvent removed under reduced pressure. The reaction mixture was analyzed by ^1H NMR using 1,1,1-trichloroethane as an internal standard to obtain the NMR yields. Purification of the α-silyloxyaldehyde was achieved through distillation at 0.1 mm Hg.

EXAMPLE I

$\underline{C_6H_5CH(OSiMe_2Ph)CHO}$ $\underline{(3a).}$ α-[(phenyldimethylsilyl)-oxy]benzeneacetaldehyde (74 %, bp 130-140°C at 0.1 mm Hg); ^1H NMR ($CDCl_3$) δ 9.52 (s, 1 H, C$\underline{H}$O), 7.55-7.28 (m, 10 H, Ar H), 4.99 (s, 1 H, -C$\underline{H}$CHO), 0.43, 0.37, 0.33 (s's, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 198.4 (CHO), 139.4 (Ar C), 136.3 (Ar C), 135.9 (Ar C), 133.3 (Ar CH), 132.8 (Ar CH), 132.7 (Ar CH), 130.0 (Ar CH), 129.7 (Ar CH), 129.0 (Ar CH), 128.5 (Ar CH), 128.3 (Ar CH), 128.2 (Ar CH), 128.1 (Ar CH), 128.0 (Ar CH), 127.8 (Ar CH), 127.5 (Ar CH), 126.5 (Ar CH), 126.2 (Ar CH), 79.9 (-$\underline{C}$HCHO), 0.6, -1.4, -1.6, ($SiCH_3$); IR (CH_2Cl_2) $\nu_{c=o}$ 1736 cm^{-1}. Anal. Calcd for $C_{16}H_{18}O_2Si$: C, 71.06; H, 6.72%. Found: C, 71.12; H, 6.94%. It is noteworthy to mention that in each silaformylation reaction studied to date at least two NMR signals for the pro-diastersotopic silicon methyl groups have been observed. Apparently, rotomers about the silicon-oxygen bond exist and have been indirectly supported by molecular mechanics analysis.

EXAMPLE II

$\underline{(4\cdot BrC_6H_4)CH(OSiMe_2Ph)CHO}$ $\underline{(3b).}$ α-[(phenyldimethylsilyl)oxy]-4-bromobenzeneacetaldehyde (84%, bp 130-140°C at 0.1 mm Hg); ^{1}H NMR (CDCl$_3$) δ 9.49 (s, 1 H, C$\underline{H}$O), 7.54-7.20 (m, 9 H, Ar CH), 4.92 (s, 1 H, -C$\underline{H}$CHO), 0.44, 0.38 (s's, 6H, SiCH$_3$); ^{13}C NMR (CDCl$_3$) δ 198.7 (CHO), 136.1 (Ar C), 135.2 (Ar C), 133.4 (Ar CH), 132.9 (Ar CH), 131.8 (Ar CH), 131.7 (Ar CH), 130.1 (Ar CH), 129.2 (Ar CH), 128.2 (Ar CH), 128.0 (Ar CH), 127.8 (Ar CH), 127.6 (Ar CH), 122.5 (Ar C), 79.4 (-$\underline{C}$HCHO), -1.3, -1.4 (SiCH$_3$); IR (CH$_2$Cl$_2$) $v_{c=o}$ 1731 cm^{-1}. Anal. Calcd for C$_{16}$H$_{17}$O$_2$BrSi: C, 55.01; H, 4.91%. Found: C, 54.91; H 4.95%.

EXAMPLE III

{4·(Me$_2$N)C$_8$H$_4$}CH(OSiMe$_3$Ph)CHO (3c). α-[(phenyldimethylsilyl)oxy]-4-(dimethylamino)benzeneacetaldehyde (80%, bp 130-140°C at 0.1 mm Hg); ^{1}H NMR (CDCl$_3$) δ 9.48 (s, 1 H, C$\underline{H}$O), 7.56-7.53 (m, 2 H, Ar CH), 7.40-7.33 (m, 3 H, Ar CH), 7.18-7.16 (m, 2 H, Ar CH), 6.71-6.68 (m, 2 H, Ar CH), 4.91 (s, 1 H, -C$\underline{H}$CHO), 2.92 (s, 6 H, N (CH$_3$)$_2$), 0.40, 0.34, 0.33 (s's, 6 H, SiCH$_3$); ^{13}C NMR (CDCl$_3$) δ 198.3 (CHO), 150.4 (Ar C), 136.7 (Ar C), 133.3 (Ar CH), 132.8 (Ar CH), 132.7 (Ar CH), 129.6 (Ar CH), 129.0 (Ar CH), 128.0 (Ar CH), 127.8 (Ar CH), 127.7 (Ar CH), 127.5 (Ar CH), 123.0 (Ar C), 112.3 (Ar CH), 79.8 (-$\underline{C}$HCHO), 40.1 (N(CH$_3$)$_2$), 0.7, -1.2, -1.5 (SiCH$_3$); IR (CH$_2$Cl$_2$) $v_{c=o}$ 1733 cm^{-1}. Anal. Calcd for C$_{18}$H$_{23}$NO$_2$Si: C, 68.96; H, 7.41%. Found: C, 68.96; H, 7.49%.

EXAMPLE IV

{4·(Me$_3$SiO)C$_8$H$_4$}CH(OSiMe$_2$Ph)CHO (3d). α-[(phenyldimethylsilyl)oxy]-4-[(trimethylsilyl)oxy]benzeneacetaldehyde (50%, bp 130-140°C at 0.1 mm Hg); ^{1} NMR (CDCl$_3$) δ 9.50 (s, 1 H, CHO), 7.54-7.49 (m, 2 H, Ar CH), 7.43-7.29 (m, 3 H, Ar CH), 7.20-7.17 (m, 2 H, Ar CH), 6.86-6.81 (m, 2 H, Ar CH), 4.93 (s, 1 H, -C$\underline{H}$CHO), 0.41, 0.35, 0.26 (3 s, 15 H, SiCH$_3$); ^{13}C NMR (CDCl$_3$) δ 199.0 (CHO), 155.5 (Ar C), 136.6 (Ar C), 133.5 (Ar CH), 129.9 (Ar CH), 128.9 (Ar C), 128.1 (Ar CH), 127.9 (Ar CH), 127.6 (Ar CH), 120.3 (Ar CH), 79.8 (-$\underline{C}$HCHO), 0.2, -1.2, -1.4 (SiCH$_3$); IR

(CH_2Cl_2) $\nu_{c=o}$ 1733 cm^{-1}. Anal. Calcd for $C_{19}H_{28}O_3Si_2$: C, 63.63; H, 7.32%. Found: C, 63.84; H, 7.09%.

EXAMPLE V

{2·(N-Methylpyrroyl)}CH(OSiMe$_2$Ph)CHO (3e). (60%, bp 110-120°C at 0.1 mm Hg); ^{1}H NMR ($CDCl_3$) δ 9.60 (s, 1 H, C$\underline{H}$O), 7.61-7.32 (m, 5 H, Ar H), 6.57-6.56 (m, 1 H pyrrole CH), 607 (m, 2 H, pyrrole CH's), 5.09 (s, 1 H, C$\underline{H}$CHO), 3.41 (s, 3 H, NCH_3), 0.38, 0.33, 0.30 (s's, 6 H, $SiCH_3$); ^{13}C NMR δ 197.1 (CHO), 139.5 (Ar C), 136.4 (Ar C), 133.4 (Ar CH), 133.3 (Ar CH), 132.8 (Ar CH), 129.6 (Ar CH), 129.4 (Ar CH), 129.0 (Ar CH), 127.7 (pyrrole CH), 127.6 (pyrrole CH), 127.5 (pyrrole CH), 125.8 (pyrrole CH), 124.4 (pyrrole CH), 122.8 (pyrrole CH), 110.9 (pyrrole CH), 108.7 (pyrrole CH), 107.3 (pyrrole CH), 106.3 (pyrrole CH), 74.5 (-$\underline{C}$HCHOO, 35.6 (NCH_3), 0.7, -1.5, -1.8 ($SiCH_3$); IR (CH_2Cl_2) $\nu_{c=o}$ 1738 cm^{-1}. Anal. Calcd for $C_{15}H_{19}NO_2Si$: C, 65.66; H, 7.14%. Found: C, 65.88; H, 7.02%.

EXAMPLE VI

{2·Thiophenyl}CH(OSiMe$_2$Ph)CHO (3f). α-[(phenyldimethylsilyl)oxy]-2-thiopheneacetaldehyde (72%, bp 90-100°C at 0.1 mm Hg); ^{1}H NMR ($CDCl_3$) δ 9.52 (S, 1 H, C$\underline{H}$O), 7.57-7.27 (m, 7H, Ar CH/thiophene CH), 7.01-6.95 (m, 1 H, thiophene CH), 5.19 (s, 1 H, -C$\underline{H}$CHO), 0.44, 0.40, 0.33 (3 s, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 196.9 (CHO), 139.4 (Ar C), 136.1 (Ar C), 133.5, 132.9, 130.0, 129.2, 127.5, 127.6, 127.2, 126.3, 125.3 (Ar and thiophene CH's), 76.2 (-CHCHO), 0.8, -1.3, -1.6 ($SiCH_3$); IR (CH_2Cl_2) $\nu_{c=o}$ 1737 cm^{-1}. Anal. Calcd for $C_{14}H_{16}O_2SSi$: C, 60.84; H, 5.83%. Found: C, 60.4; H, 6.10%.

EXAMPLE VII

$CH_3(CH_2)_2$CH(OSiMe$_2$Ph)CHO (3g). (60%, bp 90-100°C at 0.1 mm Hg); ^{1}H NMR ($CDCl_3$) δ 9.55 (s, 1 H, C$\underline{H}$O), 7.59-7.31 (m, 5H, ArCH), 3.97 (dt, $\underline{J}$=6.5, 1.2 Hz, 1 H, -C$\underline{H}$CHO), 1.81-1.30 (m, 4 H, CH_2's), 0.86 (t, J=7.3 Hz, 3 H, CH_3), 0.43, 0.42, 0.33 (s's, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 203.5 (CHO), 136.8 (Ar C), 133.4 (Ar CH), 133.3 (Ar CH), 132.9 (Ar CH), 129.9 (Ar CH), 129.8 (Ar CH), 129.2 (Ar CH), 127.9 (Ar CH), 127.8 (Ar CH), 127.6 (Ar CH), 78.9 (-CHCHO), 34.3 (-CH_2CHCHO), 17.9 (CH_3CH_2-), 13.8 (CH_3CH_2-) 0.8, -1.4, -1.50 ($SiCH_3$); IR (CH_2Cl_2) $v_{c=o}$ 1734 cm^{-1}. Anal. Calcd for $C_{13}H_{20}O_2Si$: C, 66.04; H, 8.54%. Found: C, 65.82; H, 8.56%.

EXAMPLE VIII

$(CH_3)_2$CHCH($OSiMe_2$Ph)CHO (3h). (75%, bp 90 - 100°C at 0.1 mm Hg); ^1H NMR ($CDCl_3$) δ 9.55 (s, 1 H, CHO), 7.64-7.31 (m, 5 H, Ar CH), 3.75 (dd, J=4.9, 1.9 Hz, 1 H, -CHCHO), 2.06-1.99 (m, 1 H, $(CH_3)_2CH$-), 0.93 (d, J=6 Hz, 3 H, $CHCH_3$), 0.91 (d, J=6 Hz, 3 H, $CHCH_3$), 0.41 (s, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 203.9 (CHO), 136.9 (Ar C), 133.4 (Ar CH), 133.3 (Ar CH), 132.9 (Ar CH), 129.8 (Ar CH), 129.6 (Ar CH), 129.2 (Ar CH), 127.8 (Ar CH), 127.6 (Ar CH), 82.0 (-CHCHO), 31.1 ($(CH_3)_2CH$-), 19.2 ($(CH_3)_2CH$-), 18.8 ($(CH_3)_2CH$-), 18.5 ($(CH_3)_2CH$-), 16.8 ($(CH_3)_2CH$-), 14.8 ($(CH_3)_2CH$-), 0.8, -1.46, -1.51, ($SiCH_3$); IR (CH_2Cl_2) $v_{c=o}$ 1734 cm^{-1}. Anal. Calcd for $C_{13}H_{20}O_2Si$: C, 66.04; H, 8.54%. Found: C, 66.15; H, 8.52%.

EXAMPLE IX

(2-Furyl)CH($OSiMe_2$Ph)CHO (3i). (90%, bp 90 - 100°C at 0.1 mm Hg); ^1H NMR ($CDCl_3$) δ 9.63 (s, 1 H, CHO), 7.60-7.52 (m, 2 H, Ar CH), 7.43-7.32 (m, 4 H, Ar CH and furyl CH), 6.34-6.32 (m, 1 H, furan CH), 6.28-6.26 (m, 1 H, furyl CH), 5.02 (s, 1 H, CHCHO), 0.40, 0.35, 0.33 (s's, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 196.8 (CHO), 149.3 (furyl C), 143.3 (furyl CH), 136.2 (Ar C), 133.4 (Ar CH), 132.8 (Ar CH), 129.8 (Ar CH), 129.1 (Ar CH), 127.8 (Ar CH), 127.5 (Ar CH), 110.4 (furyl CH), 109.7 (furyl CH), 73.8 (CHCHO), 0.7, -1.5, -1.9 ($SiCH_3$); IR (CH_2Cl_2) $v_{c=o}$ 1736 cm^-

^{1}. Anal. Calcd for $C_{14}H_{16}O_3Si$: C, 64.57; H, 6.21%. Found: C, 64.41; H, 6.24%.

EXAMPLE XI

$\{\eta^5\text{-}C_5H_5\}Fe\{\eta^5\text{-}C_5H_4CH(OSiMe_2Ph)CHO\}$ (3j). α-[(phenyldimethylsilyl)oxy]ferroceneacetaldehyde (88%, purified by flash chromatography through deactivated flourosil); ^{1}H NMR ($CDCl_3$) δ 9.61, 9.62 (s's, 1 H, CHO), 7.59-7.34 (m, 5 H, phenyl CH's), 4.74 (S, 1 H, CHCHO), 4.21-4.17 (m, 3 H, Cp CH's), 4.11 (s, 5 H, Cp), 4.04-4.03 (m, 1 H, Cp CH), 0.40, 0.38, 0.33 (3s, 6H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 196.9 (CHO), 136.9 (Ar C), 133.5 (Ar CH), 132.9 (Ar CH), 129.8 (Ar CH), 129.2 (Ar CH), 127.9 (Ar CH), 127.6 (Ar CH), 82.1 (Cp C), 75.6 (Cp CH), 68.8 (CHCHO), 68.6 (Cp CH), 68.4 (Cp CH), 68.3 (Cp CH), 67.5 (Cp CH), 66.6 (Cp CH), 0.8, -1.0, -1.1 ($SiCH_3$); IR (CH_2Cl_2) $v_{c=o}$ 1734 cm-^{1}. Anal. Calculated for $C_{20}H_{22}O_2SiFe$: C, 63.49; H, 5.86%. Found: C, 63.26; H, 6.10%.

EXAMPLE XII

Preparation of N-benzyl-α-[(phenyldimethylsilyl)-oxy]benzeneacetaldehyde **imine (4)**. A THF (8 mL) solution of **the compound of EXAMPLE I** (0.05 g, 1.85 mmol) was treated with benzylamine (0.20 g, 1.85 mmol) in the presence of molecular sieves (4 Å) at 0°C for 15 min. The mixture was filtered and the solvent removed under reduced pressure to afford pure 4.H NMR ($CDCl_3$) δ 7.66 (d, J=5.9 Hz, 1 H, CH=N), 7.54 (d, J=7.7 Hz, 2 H, phenyl CH's), 7.43-7.15 (m, 13 H, phenyl CH's), 5.33 (d, J=5.9 HZ, 1 H, PhCH($OSiMe_2Ph$)C=N-), 4.49 (s, 2 H, $PhCH_2N$=), 0.38, 0.37 (s's, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 166.1 (CHN), 140.3, 138.6, 133.5, 129.7, 128.4, 128.0, 127.8, 127.7, 127.0, 126.2 (Ar C's), 76.8 (CH($OSiMe_2Ph$)), 64.3 (CH_2N=), -1.0, -1.3 ($SiCH_3$); IR (CH_2Cl_2) $v_{c=n}$ 1655 cm^{-1}.

EXAMPLE XIII

{4-(Acetoxy)C_6H_4}CH(OSiMe_2Ph)CHO (5). α-[(phenyldimethylsilyl)oxy]-4-(acetoxy)benzeneacetaldehyde (70%, purified by flash chromatography through deactivated flourosil); ^{1}H NMR ($CDCl_3$) δ 9.49 (s, 1 H, $C\underline{H}O$), 7.53 (dd, *J*=7.5, 1.8 Hz, 2 H, Ar), 7.40-7.34 (m, 5 H, Ar), 7.09 (D, *J*=8.4 Hz, 2 H, Ar), 4.98 (d, *J*=1.8 HZ, 1 H, $C\underline{H}CHO$), 2.27 (s, 3H, CH_3), 0.44, 0.39 (s's, 6 H, $SiCH_3$); ^{13}C NMR ($CDCl_3$) δ 198.5 (CHO), 169.0 ($O_2\underline{C}CH_3$), 150.6 (Ar C), 133.5 (Ar C), 133.3 (Ar CH), 132.8 (Ar CH), 129.9 (Ar CH), 127.9 (Ar CH), 127.5 (Ar CH), 122.2 (Ar CH), 121.8 (Ar CH), 79.4 ($\underline{C}HCHO$), 20.8 (CH_3), -1.4, -1.5 ($SiCH_3$); IR (CH_2Cl_2) $v_{c=o}$ 1736 cm^{-1}.

EXAMPLES XIV to XVII

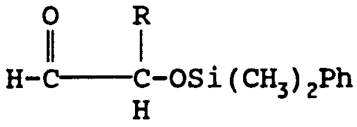
Other monohydridic silane reducing reagents such as Et_3SiH, EtO_3SiH, $MePh_2SiH$ and Ph_3SiH were tested and were found not to be effective reagents for the rhodium(I) catalyzed silaformylation of aldehydes at the mild temperatures employed. Triethylsilane and $MePh_2SiH$ were recovered intact and the triphenylsilane and triethoxysilane decomposed to unidentified products.

References herein to specific Examples or embodiments should not be interpreted as limitations to the invention's scope which is determined by the claims.

CLAIMS

What is claimed is:

1. A process for the preparation of an α-silyloxyaldehyde of the formula:



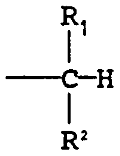
$$H-\overset{\overset{O}{\|}}{C}-\underset{H}{\overset{\overset{R}{|}}{C}}-OSi(CH_3)_2Ph$$

wherein

Ph is phenyl, and

R is a substituted or unsubstituted alkyl, aryl, aralkyl, or heterocycle, or

R is



$$-\underset{\underset{R^2}{|}}{\overset{\overset{R_1}{|}}{C}}-H$$

wherein R_1 and R^2 are independently selected from the group alkyl, aryl, aralkyl, alkoxy, dialkylamino, or heterocycle radical,

said process comprising:

reacting a compound of the formula:

R-CHO

with dimethylphenylsilane in the presence of carbon monoxide and a rhodium catalyst to form said α-silyloxyaldehyde.

2. The process of claim 1 wherein R is selected from the group of substituted or unsubstituted phenyl, lower (C_1 to C_4) alkyl, furanyl, pyrrolyl, and thiophenyl.

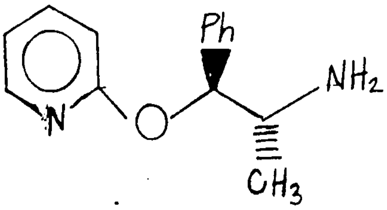
3. The process of claim 1 wherein the reaction takes place at a temperature of between about 0° and about 25° centigrade.

4. The process of claim 1 wherein the rhodium catalyst is bis(rhodium cyclooöctadiene chloride).

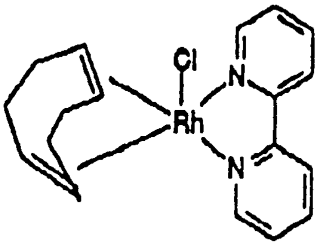
5. The process of claim 1 wherein the rhodium catalyst is a compound of the formula:

$$[\mathrm{L^*RhCl}]_2$$

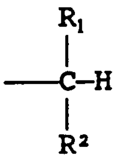
wherein L* is 2,2′-bipyridine, phenanthroline and chiral bidendate nitrogen ligand of the formula:



6. The process of claim 1 wherein said rhodium catalyst is a compound of the formula:



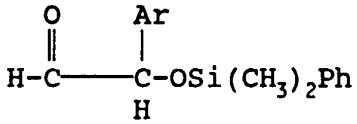
7. The process of claim 1 wherein R is:



$$-\overset{\displaystyle R_1}{\underset{\displaystyle R^2}{\overset{|}{\underset{|}{C}}}}-H$$

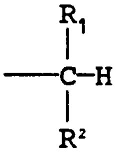
and the thus synthesized compound has a specific relative stereochemistry.

8. An α-silyloxyaldehyde of the formula:



$$\mathrm{H{-}C({=}O){-}C(Ar)(H){-}OSi(CH_3)_2Ph}$$

wherein Ph is phenyl, and
Ar is a substituted or unsubstituted aryl, aralkyl, or heterocycle, or
Ar is

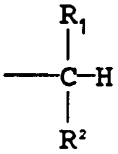


$$\mathrm{{-}C(R_1)(R^2){-}H}$$

wherein R_1 and R^2 are independently selected from the group alkyl, aryl, aralkyl, alkoxy, dialkylamino or heterocycle.

9. The compound of claim 8 wherein Ar is selected from the group of substituted or unsubstituted phenyl, furanyl, pyrrolyl, and thiophenyl.

10. The compound of claim 8 wherein Ar is:



$$\mathrm{{-}C(R_1)(R^2){-}H}$$

and said compound is optically pure.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/00781

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :C07F 7/08; C07F 7/10; C07D 307/12
US CL :556/427, 436; 548/406; 549/214

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 556/427, 436; 548/406; 549/214

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,124,468(KRAFFT et al.) 23 JUN 1992, see the entire document.	1-7
A	US, A, 4,383,120(YATES) 10 MAY 1983, see the entire document.	1-7
A	US, A, 4,448,980(SOGAH) 15 MAY 1984, see the entire document.	1-7
A	US, A, 4,783,543(SCHULZ et al.) 08 NOV 1988, see the entire document.	1-7
A	US, A, 4,785,126(BRUNO) 15 NOV 1988, see the entire document.	1-7
A	US, A, 2,803,637(SPEIER) 20 AUG 1957, see the entire document.	8-10
A	US, A, 4,424,392(PETTY) 03 JAN 1984, see the entire document.	8-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be part of particular relevance
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"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search 28 May 1993	Date of mailing of the international search report 28 JUN 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer PAUL F. SHAVER
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