CHAPTER IV

EXPERIMENTAL

General NMR spectra were obtained in $CDCl_3$ at 200 MHz (^1H) or 50 MHz (^{13}C) on a Varian Gemini Instrument. Chemical shifts (δ) are in ppm and coupling constants (*J*) are in Hz. All reactions were followed by thin layer chromatography (TLC): glass or plastic sheets coated with silica gel F_{254} (Merck) and visualized using uv light (254 nm), iodine, molybdate or $KMnO_4$. Flash chromatography was carried out on silica gel: 230-400 mesh. Tetrahydrofuran and dioxane were distilled from Na/benzophenone, dichloromethane and acetonitrile were distilled from CaH_2 and dimethylformamide was distilled from CaH_2 under reduced pressure. Other chemicals were obtained from Fluka, Merck or Strem and used as received. Carbon monoxide was obtained from Praxair. Evaporation refers to the rotary evaporation of solvent under aspirator pressure. Infrared spectra were acquired using a Perkin Elmer 1760X. Mass spectrometry and high resolution mass spectrometry were determined using a GCQ Mass Spectrometer from Finigand a Mat 90 from Finigan. Elemental analysis result was obtained at the Instrument Center of Chulalongkorn University.

1-Allyloxy-*p*-methoxybenzene (54) : Anhydrous potassium carbonate (11.15 g, 80.7 mmole) and allyl bromide (4.65 ml, 53.8 mmole) were added to a solution of *p*-methoxphenol (8.01 g, 64.5 mmole) in DMF (64 ml) protected with a drying tube. The reaction mixture was stirred overnight, then diluted with EtOAc, washed (H_2O and brine) and evaporated. The residue was partitioned between dilute sodium hydroxide solution and hexane. The organic layer was washed (brine), dried (Na_2SO_4) and evaporated to give the allyl ether **(54)** as an oil (8.78 g, 100%). ^1H NMR δ 3.80 (3H, s, OMe), 4.50 (2H, d, J = 5.1 Hz, H1), 5.27 (1H, d, J = 11.7 Hz, =CH_2), 5.40 (1H, d, J = 16.9 Hz, =CH_2), 6.40 (1H, m, CH=), 6.80 (4H, s, C_6H_4OMe); ^{13}C NMR δ 55.4, 69.2, 114.4, 115.4, 117.2, 133.5, 152.5, 153.7 ; IR (υ,cm^{-1}) 2956 (CH), 1650 (C≡C) ; MS (m/z) 164 (100) (M^+), 123 (71) (M^+- C_3H_5), 95 (55) (C_6H_7O)

1-(*p*-Methoxyphenoxy)-propane-2,3-diol (55) : $K_3Fe(CN)_6$ (12.5 g, 38.0 mmole), K_2CO_3 (5.25 g, 38.0 mmole) and $K_2OsO_4 \cdot H_2O$ (58.4 mg, 0.16 mmole) was added to a solution of allyl ether **(54)** (2.08 g, 12.7 mmole) in *tert*-butyl alcohol (40 ml) and water (40 ml). The reaction mixture was stirred for 24 hours at room temperature. Saturated aq. Na_2SO_3 solution was added and the mixture was, stirred and filtered through celite. The filtrate was extracted with EtOAc. The organic layers were washed (brine), dried (Na_2SO_4) and evaporated to give the diol **(55)** as a white solid (2.23 g, 89%). m.p. = 77- 79 °C; ^{1}H NMR δ 2.80 (2H, d, J = 5.3 Hz, H3), 3.80 (3H, s, OMe), 4.00 (1H, d, J = 2.6 Hz, H1), 4.03 (1H, s, H1′), 4.10 (1H, m, CHOH), 6.83 (4H, s, C_6H_4OMe); ^{13}C NMR δ 55.6, 63.6, 69.8, 70.5, 114.6, 115.5, 152.5, 154.1 ; IR (υ,cm^{-1}) 3346 (OH), 2937 (CH) ; MS (m/z) 198 (45) (M^+), 124 (100) ($C_7H_7O_2$+H), 109 (95) ($C_6H_5O_2$)

1-(*p*-Methoxyphenyl)glycerol 2,3-cyclic sulfate (56) : pyridine (162 μl, 2.02 mmole) and thionyl chloride (96 μl, 1.31 mmole) were added to a solution of the diol **(55)** (200 mg, 1.01 mmole) in CH_2Cl_2 (1 ml) protected with a drying tube at 0 °C. The reaction mixture was stirred for 1 hr. at 0 °C and then EtOAc was added. The mixture was filtered through silica gel, washing with EtOAc. After concentration of the filtrate, the residue was dissolved in CH_3CN (2 ml). $NaIO_4$ (324 mg, 1.5 mmole), $RuCl_3.3H_2O$ (catalytic amount) and H_2O (2 ml) were added at room temperature. After 3 hrs, the mixture was diluted with EtOAc, the two phases were separated and the organic layers were washed with H_2O, sat. $NaHCO_3$ solution and brine. The organic layer was dried (Na_2SO_4), concentrated and purified by flash chromatography on silica gel (6 g) eluting with 10% EtOAc : hexane to give the cyclic sulfate **(56)** as a white solid (196 mg, 75%). m.p. = 83-85 °C; ^{1}H NMR δ 3.77 (3H, s, OMe), 4.26 (2H, dd, J = 5.1, 2.9 Hz, H3), 4.80 (1H, dd, J = 28.6, 8.8 Hz, H1), 4.80 (1H, dd, J = 13.2, 6.6 Hz, H1′), 5.20 (1H, m, H2), 6.80 (4H, s, C_6H_4OMe); ^{13}C NMR δ 55.7, 66.6, 69.7, 78.9, 114.8, 115.0, 115.6, 115.8, 151.6, 154.9 ; IR (υ,cm^{-1}) 3446 (OH), 2956-2783 (CH), 2176 (C≡C), 1250 (Si-CH_3) ; MS (m/z) 260 (95) (M^+), 123 (100) (M^+- $C_8H_9O_2$), 109 (21) ($C_6H_5O_2$), 95 (51) (C_6H_7O)

1-(*p*-Methoxyphenoxy)-5-trimethylsilyl-pent-4-yn-2-ol (57) : A solution of ethynyltrimethysilane (136 µl, 0.98 mmole) in THF (1 ml) was cooled to –78 °C. *n*-BuLi (1.57 M in hexane, 673 µl, 1.06 mmole) was added, followed by after 30 min, a solution of the cyclic sulfate **(56)** (183 mg, 0.70 mmole) in THF (2 ml) were added dropwise to the mixture at –78 °C. The mixture was stirred for 1 hour at room temperature. H_2SO_4 (11 µl) and H_2O (13 µl) were added and the now apaque, cloudy mixture was stirred for 30 min at room temperature.The acid was neutralized with sat. sodium bicarbonate solution. The mixture was extracted with three portions of EtOAc. The combined organic layers were washed (H_2O and brine), dried (Na_2SO_4) and evaporated to give the alcohol **(57)** as an oil (184 mg, 94 %). ^{1}H NMR δ 0.20 (9H, s, $SiMe_3$), 2.40 (2H, d, J = 5.9 Hz, H3), 3.80 (3H, s, OMe), 3.94 (1H, dd, J = 9.5, 6.6 Hz, H1), 4.06 (1H, dd, J = 9.5, 3.7 Hz, H1′), 4.11 (1H, m, CHOH), 6.90 (4H, s, C_6H_4OMe) ; ^{13}C NMR δ -0.2, 24.8, 55.4, 68.4, 71.2, 87.3, 102.2, 114.5, 115.4, 152.5, 153.9 ; IR (υ,cm^{-1}) 3431 (OH), 2958 (CH), 2176 (C≡C), 1232 (Si-CH_3) ; MS (m/z) 278 (100) (M^+), 189 (40) (M^+-$SiMe_3$-Me-H), 124 (46) (M^+- $C_7H_7O_2$- H), 109 (26) ($C_6H_5O_2$)

1-(*p*-Methoxyphenoxy)-pent-4-yn-2-ol (58) : A catalytic amount of sodium methoxide was added to a solution of the alcohol **(57)** (135 mg, 0.49 mmole) in dry methanol (2 ml). The mixture was stirred for 4 hours. The organic solvent was evaporated and the residue was acidified with sat. ammonium chloride solution and extracted with EtOAc. The organic layers were washed (brine), dried (Na_2SO_4) and evaporated to give the terminal alkyne **(58)** as an oil (103 mg, 98 %). ^{1}H NMR δ 2.08 (1H, t, J = 2.9 Hz, CH), 2.58 (2H, dd, J = 6.6, 2.9 Hz, H3), 3.80 (3H, s, OMe), 3.95 (1H, dd, J = 9.5, 6.6 Hz, H1), 4.06 (1H, dd, J = 9.5, 3.7 Hz, H1′), 4.17 (1H, m, CHOH), 6.85 (4H, s, C_6H_4OMe) ; ^{13}C NMR δ 23.3, 55.4, 68.2, 70.7, 71.0, 79.9, 114.4, 115.3, 152.3, 153.8 ; IR (υ,cm^{-1}) 3447 (OH), 3287 (CH), 2936 (CH), 2120 (C≡C) ; MS (m/z) 206 (100) (M^+), 124 (34) ($C_7H_7O_2$+H), 109 (28) ($C_6H_5O_2$)

2-(*t*-Butyldimethlsiloxy)-1-(*p*-methoxyphenoxy)-pent-4-yne (64) : *t*-butyldimethylchlorosilane (880 mg, 5.84 mmole), *N*,*N*-dimethylaminopyridine (130 mg, 1.06 mmole) and imidazole (795 mg, 11.7 mmole) were added to a solution of the terminal alkyne **(58)** (1.10 g, 5.3 mmole) in THF (5.3 ml) at room temperature under N_2 with a water bath. The mixture was stirred overnight, acidified with sat. ammonium chloride solution and extracted with EtOAc. The organic layers were washed (brine), dried (Na_2SO_4) and evaporated to give the silyl ether **(64)** as an oil (1.66 g, 98 %). ^{1}H NMR δ 0.10 (3H, s, CH_3), 0.13 (3H, s, CH_3), 0.90 (9H, s, *t*-Bu), 2.00 (1H, t, J = 2.9 Hz, C<u>H</u>), 2.42 (1H, ddd, J = 16.8, 5.9, 2.9 Hz, H3), 2.54 (1H, ddd, J = 16.8, 5.9, 2.9 Hz, H3′), 3.80 (3H, s, O<u>Me</u>), 3.85 (1H, dd, J = 9.5, 6.6 Hz, H1), 3.99 (1H, dd, J = 9.5, 5.1 Hz, H1′), 4.13 (1H, m, C<u>H</u>OTBS), 6.84 (4H, s, C_6<u>H_4</u>OMe) ; ^{13}C NMR δ -4.8, -4.6, 18.1, 24.6, 25.7, 55.6, 69.7, 70.3, 71.6, 80.8, 114.5, 115.3, 152.8, 153.7 ; IR (υ,cm^{-1}) 3287 (≡CH), 2955(CH), 2179 (C≡C) 1233 (Si-CH_3), 1124 (Si-O), 1049 (C-O-C), 940 (C-O-C), 840 (Si-O) ; MS (m/z) 320 (47) (M^+), 263 (100) (M^+-C_4H_9), 245 (46) (M^+-C_4H_9-H_2O), 209 (58) (M^+-$C_4H_{10}O$)

2-(*t*-Butyldimethylsiloxy)-1-(*p*-methoxyphenoxy)-hexa-4,5-diene (75) : Paraformaldehyde (58 mg, 1.94 mmole), anhydrous copper (I) iodide (74 mg, 0.39 mmole) and diisopropylamine (218 µl, 1.56 mmole) were added to a solution of the alkyne **(64)** (249 mg, 0.78 mmole) in anhydrous 1,4-dioxane (3 ml). The mixture was heated at reflux overnight under N_2 and then cooled. Air was bubbled through the reaction mixture for 3 hours and then the reaction mixture was filtered through celite, washing with EtOAc. The solution was evaporated forming a gum-like residue which was acidified with 2 M hydrochloric acid and extracted with EtOAc several times. The organic layers were washed with water and brine, dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (7.5 g) eluting with 2 % EtOAc : hexane to give the allenol **(75)** as an oil (177 mg, 68 %). ^{1}H NMR δ 0.10 (3H, s, CH_3), 0.12 (3H, s, CH_3), 0.90 (9H, s, *t*-Bu), 2.30 (2H, m, H3), 3.75 (3H, s, O<u>Me</u>), 3.82 (1H, d, J = 2.9 Hz, H1), 3.86 (1H, s, H1′), 4.10(1H, m, C<u>H</u>OTBS), 4.65 (2H, dt, J = 6.9, 2.9 Hz, <u>H_2</u>C=C=), 5.20 (1H, q, J = 6.9 Hz, C<u>H</u>=), 6.89 (2H, d, J = 8.8 Hz, C_6<u>H_4</u>OMe),

7.27 (2H, d, J = 8.8 Hz, $C_6\underline{H}_4OMe$) ; ^{13}C NMR δ -4.8, -4.4, 18.1, 25.9, 34.1, 55.6, 70.8, 72.1, 74.3, 85.8, 114.6, 115.2, 153.0, 153.7, 209.5 ; IR (υ,cm^{-1}) 2929 (CH), 1957 (=C=), 1234 (Si-CH_3), 1182 (Si-O), 1049 (C-O-C), 837 (Si-O), 985 (C-O-C) ; MS (m/z) 335 (84) (M^+- H), 277 (71) (M^+-C_4H_9), 259 (62) (M^+-C_4H_9-H_2O), 209 (100) ($C_{10}H_{12}O_3Si$)

2-(*t*-Butyldimethylsiloxy)-hexa-4,5-dien-1-ol (76) : Ceric ammonium nitrate (CAN) (571 mg, 1.00 mmole) was added to an ice-cold solution of allene **(75)** (145 mg, 0.40 mmole) in CH_3CN-H_2O (4.4-1.1 ml). After 30 min, sat. sodium bicarbonate solution was added to the mixture. The mixture was filtered through celite, extracted with EtOAc and washed with H_2O and brine. The combined organic layer was dried (Na_2SO_4), filtered and evaporated. The residue was purified by flash chromatography on silica gel (4.5 g) eluting with 10 % EtOAc : hexane to give the allenol **(76)** as an oil (61 mg, 62 %). ^1H NMR δ 0.10 (3H, s, CH_3), 0.12 (3H, s, CH_3), 0.90 (9H, s, *t*-Bu), 2.20 (2H, m, H3), 3.49 (1H, dd, J = 11.0, 6.6 Hz, H1), 3.60 (1H, dd, J = 11.0, 6.6 Hz, H1′), 3.80 (1H, m, C$\underline{H}$OTBS), 4.65 (2H, dt, J = 6.6, 3.7 Hz, $\underline{H}_2C$=C=) , 5.06 (1H, q, J = 6.6 Hz, =C$\underline{H}$) ; ^{13}C NMR δ -4.7, -4.6, 18.0, 25.8, 33.1, 65.8, 72.5, 74.5, 85.8, 209.4 ; IR (υ,cm^{-1}) 3423 (OH), 2955 (CH), 1957 (=C=), 1257 (Si-O) ; MS (m/z) 229 (80) (M^++ H), 171 (68) (M^+- C_4H_9), 79 (100) (C_6H_7)

1-(Trifluoromethanesulfonyloxy)-2-(*t*-butyldimethylsiloxy)-hexa-4,5-diene (77) : pyridine (80 μl, 1.00 mmole) and trifluoromethanesulfonic anhydride (95 μl, 0.60 mmole) were added to an ice-cold solution of 2-(*tert*-butyldimethylsiloxy)-hexa-4,5-dien-1-ol **(76)** (107 mg, 0.50 mmole) in CH_2Cl_2 (2 ml). The solution was stirred for 1 hour. The reaction mixture was diluted with CH_2Cl_2, washed with H_2O, 5% HCl, dried (Na_2SO_4), filtered and evaporated to give the triflate **(77)** as an oil (154 mg, 74 %). ^1H NMR δ 0.10 (6H, s, CH_3), 0.98 (9H, s, *t*-Bu), 2.20 (1H, ddd, J = 16.8, 5.9, 2.9 Hz, H3), 2.30 (1H, ddd, J = 16.8, 5.9, 2.9 Hz, H3′), 4.05 (1H, m, C$\underline{H}$OTBS), 4.38 (1H, dd, J = 9.5, 6.6 Hz,

H1), 4.41 (1H, dd, J = 9.5, 5.1 Hz, H1′), 4.70 (2H, dt, J = 5.9, 2.9 Hz, $\underline{H}_2C=C=$) , 5.10 (1H, q, J = 5.9 Hz, $=C\underline{H}$)

1-Azido-2-(*t*-butyldimethylsiloxy)-hexa-4,5-diene (78) : Sodium azide (112 mg, 1.70 mmole) was added to a solution of triflate **(77)** (106 mg, 0.30 mmole) in DMF (1.4 ml) at room temperature. The mixture was stirred overnight, then poured into water and extracted with EtOAc. The organic solvent was evaporated. Water was added and the solution was extracted with hexane. The organic layers were washed (brine), dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (3 g) eluting with 2% EtOAc : hexane to give the azide **(78)** as an oil (54 mg, 62%). ^{1}H NMR δ 0.10 (6H, s, CH_3), 0.98 (9H, s, *t*-Bu), 2.20 (2H, m, H3), 3.18 (1H, dd, J = 12.8, 4.2 Hz, H1),3.23 (1H, dd, J = 12.8, 4.2 Hz, H1′), 4.10 (1H, m, C$\underline{H}$OTBS), 4.70 (2H, dt, J = 5.9, 2.9 Hz, $\underline{H}_2C=C=$), 5.08 (1H, q, J = 5.9, $\underline{H}C=$); IR (υ,cm^{-1}) 2957 (CH), 2103 (N=N=N), 1958 (=C=)

***N*-[2-(*t*-Butyldimethylsiloxy)-hexa-4,5-dienyl]-*p*-toluenesulfonamide (79)** : Glacial acetic acid (49 µl, 0.90 mmole) was added to a solution of azide **(78)** (54 mg, 0.20 mmole) in THF (1 ml) at room temperature with a water bath. Activated zinc (21 mg, 0.30 mmole) was added portionwise. The solution was stirred for an hour, then filtered through celite, washing with water (1ml) and CH_2Cl_2 (1 ml). Anhydrous sodium carbonate (91 mg, 0.90 mmole) and *p*-toluenesulfonyl chloride (49 mg, 0.30 mmole) were added with a water bath and the solution was stirred for 2 hours then filtered through celite, washed with water and extracted with CH_2Cl_2. The organic layers were washed (brine), dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (1.5 g) eluting with 4% EtOAc : hexane to give the sulfonamide **(79)** as an oil (74 mg, 63 %). ^{1}H NMR δ -0.01 (3H, s, CH_3), 0.01 (3H, s, CH_3), 0.81 (9H, s, *t*-Bu), 2.14 (2H, m, H3), 2.41 (3H, s Me), 2.94 (2H, m, H1), 3.78 (3H, m, C$\underline{H}$OTBS), 4.60 (2H, dt, J = 6.6, 2.9 Hz, $\underline{H}_2C=C=$), 4.95 (1H, q, J = 6.6 Hz, $C\underline{H}=$), 7.28 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$), 7.40 (1H, dd, J = 102.1, 8.1 Hz, N$\underline{H}$),

7.70 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$) ; ^{13}C NMR δ -4.9, -4.7, 17.9, 21.4, 25.7, 33.9, 47.6, 70.6, 74.7, 85.2, 127.0, 129.6, 136.9, 143.3, 209.4 ; IR (υ,cm^{-1}) 3294 (NH), 2929 (CH), 2857 (NH), 1957 (=C=), 1332 (SO_2N), 1163 (SO_2N) ; MS (m/z) 324 (100) (M^+-C_4H_9), 184 (24) (M^+- $C_{11}H_{21}OSi$), 155 (24) (Ts), 91 (16) ($PhCH_2^+$) ; HRMS calcd for $C_{19}H_{32}NO_3SSi$ (M^++H) [382.1872], found [382.1873]

3-[4-*t*-Butyldimethylsiloxy)-1-(toluene-4-sulfonyl)pyrrolidin-2-yl]-but-3-en-2-one (90) : Methyl iodide (9 µl, 0.14 mmole) was added to a solution of sodium tetracarbonyl cobaltate (129 µl of 1.10 M solution, 0.14 mmole) in THF at 0 °C under an atmosphere of carbon monoxide. The mixture was stirred for 30 min. A solution of allene **(79)** (49 mg, 0.13 mmole) in THF (0.5 ml) was added *via* cannula at room temperature under N_2. Stirring was continued for 10 min. Triethylamine (19 µl, 0.15 mmole) was added and the mixture was stirred overnight. Cobalt carbonyl complexes were decomposed by addition of iodine until the I_2 colour became permanent and gas evolution ceased. Sodium thiosulfate solution was added and the mixture was filtered through celite, washing with EtOAc. The mixture was washed with ammonium chloride and with brine, dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (1.5 g) eluting with 4% EtOAc : hexane to give the the *trans*-pyrrolidine **(90)** (13.9 mg, 25%). ^1H NMR δ Hz, -0.10 (3H, s, CH_3), -0.05 (3H, s, CH_3), 0.75 (9H, s, *t*-Bu), 1.73 (1H, dt, J = 12.9, 5.5 Hz, H3), 1.93 (1H, ddd, J = 12.9, 8.1, 5.5 Hz, H3′), 2.20 (3H, s, COMe), 2.24 (3H, s, ArMe), 3.34 (1H, dd, J = 10.3, 4.0 Hz, H5), 3.70 (1H, dd, J = 10.3, 4.7 Hz, H5′), 4.22 (1H, q, J = 4.7, C<u>H</u>OTBS), 4.63 (1H, t, J = 7.7 Hz, H2), 6.23 (1H, s, $\underline{H}_2C$=), 6.27 (1H, s, $C\underline{H}_2$=), 7.30 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$), 7.60 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$) : *cis*-pyrrolidine **(90)** (14 mg, 25%) ^1H NMR δ -0.10 (3H, s, CH_3), -0.05 (3H, s, CH_3), 0.80 (9H, s, *t*-Bu), 1.55 (1H, dt, J = 13.9, 4.0 Hz, H3), 1.98 (1H, ddd, J = 13.9, 9.2, 5.5 Hz, H3′), 2.40 (3H, s, COMe), 2.48 (3H, s, ArMe), 3.36 (1H, d, J = 2.2 Hz, H5), 3.41 (1H, d, J = 1.5 Hz, H5′), 3.92 (1H, q, J = 4.0, C<u>H</u>OTBS), 4.61 (1H, dd, J = 9.2, 4.0 Hz, H2), 6.23 (1H, s, $\underline{H}_2C$=), 6.44 (1H, d, J = 1.5 Hz, $C\underline{H}_2$=), 7.26 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$), 7.65 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4Me$); ^{13}C NMR δ -5.1, -5.0, 18.0, 21.5, 25.7, 26.4, 42.9, 56.9, 57.9, 69.9,

126.1, 127.9, 129.6, 143.4, 149.5, 198.9 ; IR (υ,cm^{-1}) 2931 (CH), 1673 (C=O), 1599 (C=C), 1097 (Si-O), 837 (Si-O) ; MS (m/z) 424 (6) (M^+-H), 366 (51) (M^+-C_4H_9), 268 (100) (M^+-Ts), 136 (79) ($C_8H_{11}ON$-H), 91 (35) ($PhCH_2^+$) ; HRMS calcd for $C_{21}H_{34}NO_4SSi$ (M^++H) [424.1978], found [424.1984]

1-(*p*-Methoxybenzyloxy)-5-trimethylsilyl-pent-4-yn-2-ol (61) : A solution of ethynyltrimethysilane (227 µl, 1.64 mmole) in THF (1 ml) was cooled to –78 °C. *n*-BuLi (1.52 M in hexane, 1.8 ml, 1.64 mmole) was added , followed by after 30 min, $BF_3.OEt_2$ (208 µl, 1.64 mmol). The stirring was continued for a further 10 min. A solution of the epoxide **(60)** (106 mg, 0.55 mmole) in THF (1 ml) and added dropwise to the mixture at –78 °C. The reaction was stirred at this temperature for 1 hour and then quenched with sat. sodium bicarbonate solution. The mixture was extracted with three portions of EtOAc. The combined organic layers were washed with H_2O and brine, dried (Na_2SO_4) and evaporated to give the alcohol **(61)** as an oil (160 mg, 100 %). ^{1}H NMR δ 0.18 (9H, s, $SiMe_3$), 2.43 (1H, dd, J = 4.4, 1.5 Hz, H3), 2.48 (1H, dd, J = 6.6, 1.5 Hz, H3′), 3.80 (3H, s, OMe), 4.00 (1H, m, CHOH), 4.50 (2H, s, $CH_2C_6H_4OMe$), 6.88 (2H, d, J = 8.8 Hz, C_6H_4OMe), 7.25 (2H, d, J = 8.8 Hz, C_6H_4OMe) ; ^{13}C NMR δ 0.0, 25.0, 55.3, 68.9, 72.5, 73.1, 87.3, 102.6, 130.0, 113.9, 129.4, 159.4 ; IR (υ,cm^{-1}) 3446 (OH), 2956-2783 (CH), 2176 (C≡C), 1250 (Si-CH_3) ; MS (m/z) 292 (1) (M^+), 277 (20) (M^+-CH_3), 121 (100) ($CH_2C_6H_4OMe$)

1-(*p*-Methoxybenzyloxy)-pent-4-yn-2-ol (62) : The same procedure as **(58)** was employed except that the alcohol **(61)** (1.7 g, 5.83 mmole) was used instead of the alcohol **(57)** to give the the terminal alkyne **(62)** as an oil (1.2 g, 96 %). ^{1}H NMR δ 2.02 (1H, t, J = 2.2 Hz, CH), 2.43 (2H, dd, J = 6.6, 2.2 Hz, H3), 3.46 (1H, dd, J = 9.5, 6.6 Hz, H1), 3.58 (1H, dd, J = 9.5, 4.4 Hz, H1′), 3.80 (3H, s, OMe), 4.00 (1H, m, CHOH), 4.50 (2H, s, $CH_2C_6H_4OMe$), 6.88 (2H, J = 8.8 Hz, C_6H_4OMe), 7.25 (2H, d, J = 8.8 Hz, C_6H_4OMe) ; ^{13}C NMR δ 23.5, 55.2, 68.7, 70.5, 72.5, 73.1, 80.3, 113.9, 129.4, 129.9, 159.4 ; IR (υ,cm^{-1}) 3438 (OH),

3288 (CH), 2955-2864 (CH), 2119 (C≡C) ; MS (m/z) 219 (56) (M^++ H), 121 (100) ($CH_2C_6H_4OMe$)

1-(*p*-Methoxybenzyloxy)-hexa-4,5-dien-2-ol (74) : The same procedure as **(75)** was employed except that the alcohol alkyne **(62)** (1.39 g, 6.32 mmole) was used instesd of the terminal alkyne **(64)** to give the allene **(74)** as an oil (1.33 g, 90 %). ^{1}H NMR δ 2.20 (2H, m, H3), 3.37 (1H, dd, J= 9.5, 7.3 Hz, H1), 3.52 (1H, dd, J = 9.5, 3.7 Hz, H1′), 3.80 (3H, s, OMe), 3.90 (1H, m, C<u>H</u>OH), 4.50 (2H, s, C<u>H</u>$_2$C$_6$H$_4$OMe), 4.70 (2H, dt, J = 7.3, 3.7 Hz, <u>H</u>$_2$C=C=), 5.13 (1H, q, J = 7.3 Hz, C<u>H</u>=), 6.89 (2H, d, J = 8.8 Hz, C$_6$<u>H</u>$_4$OMe), 7.27 (2H, d, 8.8 Hz, C$_6$<u>H</u>$_4$OMe) ; ^{13}C NMR δ 32.3, 54.9, 69.7, 72.7, 73.2, 74.6, 85.7, 113.5, 129.3, 129.7, 158.9, 208.9 ; IR (υ,cm^{-1}) 3444 (OH), 2863 (CH), 1956 (=C=) ; MS (m/z) 233 (29) (M^+- H), 121 (100) ($CH_2C_6H_4OMe$)

2-Hydroxy-hexa-4,5-dienyl *p*-methoxybenzoate (80) : 2,3-dichloro-5,6-dicyano-1,4-benzoquine (DDQ) (208 mg, 0.51 mmole) was added three equal portions to a solution of allenol **(74)** (107 mg, 0.46 mmole) in CH_2Cl_2 (3.3 ml) : MeOH (1 ml) and stirred overnight. Saturated aq. Na_2SO_3 solution was added and the mixture was extracted with EtOAc and washed with brine. The organic layers were dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (3g) eluting with 5% EtOAc : hexane to give the ester **(80)** as the major product (60 mg, 53%). ^{1}H NMR δ 2.45 (2H, m, H3), 3.79 (1H, dd, J = 11.7, 5.5 Hz,H1), 3.88 (1H, dd, J = 11.7, 4.0 Hz, H1′), 3.85 (3H, s, O<u>Me</u>), 4.67 (2H, dt, J = 6.6, 2.9 Hz, <u>H</u>$_2$C=C=), 5.13 (1H, q, J = 6.6 Hz, C<u>H</u>=), 5.15(1H, m, C<u>H</u>OH), 6.91 (2H, d, J = 8.8 Hz, C$_6$<u>H</u>$_4$OMe), 7.99 (2H, d, J = 8.8 Hz, C$_6$<u>H</u>$_4$OMe) ; ^{13}C NMR δ 30.0, 55.3, 64.2, 75.0, 76.3, 85.4, 113.6, 122.4, 131.7, 163.5, 166.3, 209.3 ; IR (υ,cm^{-1}) 2929 (CH), 1957 (=C=) and gave the allene diol **(81)** as minor product (5 mg, 10%).

Hexa-4,5-diene-1,2-diol (81) : Lithium hydroxide monohydrate (10 mg, 0.24 mmole) was added to a solution of the ester **(80)** (60 mg, 0.24 mmole) in THF (1 ml) : H_2O (1 ml) and the mixture was stirred overnight. The mixture was extracted with EtOAc and washed with H_2O and brine. The combine organic layer was dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (1.8 g) eluting with 30% EtOAc : hexane to give the allene diol **(81)** as an oil (25mg, 90%). ^{1}H NMR δ 2.19 (2H, ddd, J = 10.3, 7.3, 2.9 Hz, H3), 3.50 (1H, dd, J = 11.0, 7.3 Hz, H1), 3.81 (1H, dd, J = 11.0, 3.3 Hz, H1′), 3.81(1H, m, C<u>H</u>OH), 4.73 (2H, dt, J = 6.6, 2.9 Hz, <u>H</u>$_2$C=C=), 5.13 (1H, q, J = 6.6 Hz, C<u>H</u>=); ^{13}C NMR δ 32.3, 65.8, 71.7, 74.8, 85.8, 209.2; IR (υ,cm^{-1}) 3377 (OH), 2922 (CH), 1957 (=C=) ; MS (m/z) 115 (41) (M^+-H), 97 (100) (M^+-OH), 79 (85) (M^+-OH-H_2O), 69 (70) (M^+-45)

5-Buta-2,3-dienyl-2,2-dioxo-2λ^6–[1,2,3]oxathiazolidine-3-carboxylic acid benzyl ester (82) : $Et_3NSO_2NCO_2Bn$ (442 mg, 1.40 mmole) was added to a solution of the allene diol **(81)** (64 mg, 0.56 mmole) in THF (2 ml) under N_2. The resultant solution was heated at reflux for 1 hr., cooled to ambient temperature, concentrated, and then purified by flash chromatography on silica gel (1.8 g) eluting with 7% EtOAc : hexane to give the cyclic sulfamidate **(82)** (139 mg, 80%). ^{1}H NMR δ 2.60 (2H, m, H1), 3.80 (1H, t, J = 9.9 Hz, H4), 4.15 (1H, dd, J = 9.9, 5.9 Hz, H4′), 4.82 (2H, dt, J = 6.6, 3.3 Hz, <u>H</u>$_2$C=C=), 5.13 (1H, q, J = 6.6 Hz, C<u>H</u>=), 5.32 (2H, s, C<u>H</u>$_2$C$_6$H$_5$), 7.30 (5H,s, C$_6$<u>H</u>$_5$); ^{13}C NMR δ 29.7, 61.6, 67.2, 71.2, 75.8, 85.4, 126.0, 128.4, 128.8, 136.5, 171.0, 209.7 ; IR (υ,cm^{-1}) 2922 (CH), 1957 (=C=)

(2-Hydroxy-hexa-4,5-dienyl)-carbamic acid benzyl ester (83) : The cyclic sulfamidate **(82)** (139 mg, 0.45 mmole) was dissolved in a mixture of HCl (2 M. aq.)/ dioxane (1.8 ml : 1.8 ml) and the solution was stirred overnight. The mixture was extracted with three portions of EtOAc and washed with H_2O and brine. The combined organic layer was dried (Na_2SO_4) and evaporated. The residue was purified by flash chromatography on silica gel (4.2 g) eluting with

5% EtOAc : hexane to give the carbamate **(83)** (20 mg, 18%). ^{1}H NMR δ 2.45 (2H, m, H3), 3.30 (1H, ddd, J = 14.7, 7.0, 5.9 Hz, H1), 3.40 (1H, ddd, J = 14.7, 7.0, 3.8 Hz, H1′), 4.03 (1H, m, C<u>H</u>OH), 4.78 (2H, dt, J = 6.6, 3.3 Hz, <u>H</u>$_2$C=C=), 5.17 (2H, s, $CH_2C_6H_5$), 5.18 (1H, q, J = 6.6 Hz, C<u>H</u>=); ^{13}C NMR δ 34.8, 46.7, 61.3, 67.0, 75.5, 85.3, 128.0, 128.2, 128.5, 136.2, 156.2, 209.4 ; IR (υ,cm^{-1}) 3345 (OH), 2946 (CH), 1956 (=C=), 1708 (C=O), 1521 (NH) ; MS (m/z) 115 (41) (M^+-H), 97 (100) (M^+-OH), 79 (85) (M^+-OH-H_2O), 69 (70) (M^+-45)

1-(*p*-Methoxybenzyloxy)-hexa-4,5-dien-2-N-tosyl amide (84) : *p*-Tosyl isocyanate (75 µl, 0.49 mmole) was added to a solution of a allene **(74)** (105 mg, 0.45 mmole) in THF (1.8 ml) cooled in an ice bath. The reaction mixture was stirred for 1 hour at room temperature and then evaporated. The residue was purified by flash chromatography on silica gel (3 g) eluting with 20 % EtOAc : hexane to give allene **(84)** as an oil (193 mg, 98 %). ^{1}H NMR δ 2.30 (2H, m, H3), 3.47 (1H, d, J = 1.5 Hz, H1), 3.50 (1H, s, H1′), 3.80 (3H, s, O<u>Me</u>), 4.20 (2H, dd, J = 18.3, 11.0 Hz, C<u>H</u>$_2$C$_6$H$_4$OMe), 4.80 (2H, dt, J = 6.6, 3.7 Hz, <u>H</u>$_2$C=C=), 4.90 (1H, q, J = 6.6 Hz, C<u>H</u>=), 4.90 (1H, m, C<u>H</u>OH), 6.86 (2H, d, J = 8.1 Hz, C$_6$<u>H</u>$_4$OMe), 7.20 (2H, d, J = 8.8 Hz, SO$_2$C$_6$<u>H</u>$_4$Me), 7.30 (2H, d, J = 8.1 Hz, C$_6$<u>H</u>$_4$OMe), 7.60 (1H, s, N<u>H</u>), 7.90 (2H, d, J = 8.8 Hz, SO$_2$C$_6$<u>H</u>$_4$Me) ; ^{13}C NMR δ 21.6, 29.7, 55.2, 69.6, 72.8, 75.2, 75.3, 84.5, 113.8, 126.4, 128.3, 129.5, 129.6, 135.6, 144.9, 149.8, 159.3, 209.4 ; IR (υ,cm^{-1}) 3262 (NH), 2933 (CH), 1957 (=C=), 1740 (C=O), 1304 (SO_2N) ; MS (m/z) 197 (5) (CONHTs + H), 155 (12) (Ts), 135 (27) (M^+- 296), 121 (100) ($CH_2C_6H_4OMe$), 91 (32) ($PhCH_2^+$)

Hexa-4,5-dien-1-ol-2-*N*-tosyl carbamate (85) : The same procedure as **(76)** was employed except that the allene carbamate **(84)** (1.36 g, 5.83 mmole) was used instead of the allene **(75)** to give the allenol **(85)** as an oil (1.61 g, 89 %). ^{1}H NMR δ 2.30 (2H, m, H3), 2.40 (3H, s, Me), 3.58 (1H, dd, J = 12.4, 5.7 Hz, H1), 3.70 (1H, dd, J = 12.4, 3.7 Hz, H1′), 4.62 (2H, dt, J = 6.6, 3.7 Hz, <u>H</u>$_2$C=C=) , 4.85 (1H, m, C<u>H</u>OH), 4.87 (1H, q, J = 6.6 Hz, =C<u>H</u>), 7.35 (2H, d, J = 8.1 Hz, C$_6$<u>H</u>$_4$Me), 7.92 (2H, d, J = 8.1 Hz, C$_6$<u>H</u>$_4$Me) ; ^{13}C NMR δ 21.4, 29.1,

62.8, 75.2, 76.8, 84.4, 128.0, 129.5, 135.4, 144.8, 150.7, 209.0 ; IR (υ,cm^{-1}) 3520 (OH), 3246 (NH), 2903 (CH), 1957 (=C=), 1747 (C=O), 1384 (SO_2N), 1162 (SO_2N) ; MS (m/z) 294 (2) (M^++ H - H_2O), 253 (12) (M^+- C_4H_5), 155 (35) (Ts), 91 (100) ($PhCH_2^+$)

5-Buta-2,3-dienyl-3-(toluene-4-sulfonyl)-oxazolidin-2-one (86) : Diethylazodicarboxylate (20 µl, 0.15 mmole) was added to a solution of carbamate **(85)** (30 mg, 0.10 mmole) and triphenylphosphine (35 mg, 0.10 mmole) in THF (1 ml) at room temperature under N_2. After stirring for 1 hour, the organic solvent was evaporated. The residue was preabsorbed on silica gel and purified by flash chromatography on silica gel (1 g) eluting with 20 % EtOAc : hexane to give the oxazolidinone **(86)** as an oil (23 mg, 81 %). ^{1}H NMR δ 2.40 (2H, m, C$\underline{H}_2$CH=C=), 2.40 (3H, s, Me), 3.75 (1H, dd, J = 9.2, 6.6 Hz, C$\underline{H}_2$NTs), 4.13 (1H, dd, J = 4.4, 6.6 Hz, C$\underline{H}_2$NTs), 4.64 (1H, m, C$\underline{H}$OH), 4.76 (2H, dt, J = 6.6, 2.9 Hz, $\underline{H}_2$C=C=), 5.02 (1H, q, J = 6.6 Hz, =C$\underline{H}$), 7.40 (2H, d, J = 8.06 Hz, $C_6\underline{H}_4$Me), 7.95 (2H, d, J = 8.1 Hz, $C_6\underline{H}_4$Me) ; ^{13}C NMR δ 21.6, 32.6, 48.6, 63.9, 73.2, 76.1, 82.6, 128.1, 129.8, 133.8, 145.6, 209.4 ; IR (υ,cm^{-1}) 2933 (CH), 1957 (=C=), 1790 (C=O), 1370 (SO_2N), 1174 (SO_2N) ; MS (m/z) 294 (6) (M^+- H), 229 (7) (M^+- C_5H_4), 201 (18) (M^+- 92), 184 (100) (M^+- $C_6H_6O_2$), 155 (16) (Ts), 139 (14) (M^+- 154), 91 (100) ($PhCH_2^+$), 81 (13) (C_5H_5O)

***N*-(2-Hydroxyhexa-4,5-dienyl)-p-toluenesulfonamide (87)** : Lithium hydroxide (6 mg, 0.16 mmole) was added to a solution of the oxazolidinone **(86)** (25 mg, 0.08 mmole) in MeOH-H_2O (0.5-0.5 ml) and the mixture was stirred for 1 hour. The organic solvent was evaporated and the residue was extracted with EtOAc. The organic layer was washed (brine), dried (Na_2SO_4) and evaporated to give the sulfonamide **(87)** as an oil (20 mg, 98 %). ^{1}H NMR δ 2.15 (2H, m, H3), 2.40 (3H, s, Me), 2.85 (1H, ddd, J = 13.2, 7.3, 5.1 Hz, H1), 3.12 (1H, ddd, J = 13.2, 7.3, 3.7 Hz, H1′), 3.80 (1H, ddd, J = 13.2, 6.6, 2.9 Hz, C$\underline{H}$OH), 4.71 (2H, dt, J = 6.6, 3.7 Hz, $\underline{H}_2$C=C=), 5.06 (1H, q, J = 6.6 Hz, =C$\underline{H}$), 7.32 (2H, d, J = 8.1 Hz, $C_6\underline{H}_5$Me), 7.75 (2H, d, J = 8.1 Hz, $C_6\underline{H}_5$Me) ; ^{13}C NMR δ 21.4, 33.4, 47.9, 69.7,

75.0, 85.3, 126.9, 136.5, 143.3, 209.1 ; IR (υ,cm^{-1}) 3492 (OH), 3280 (NH), 2922 (CH), 1956 (=C=), 1321 (SO_2N), 1162 (SO_2N) ; MS (m/z) 268 (2) (M^+- H), 214 (7) (M^+- C_4H_5), 184 (12) (CH_2NHTs), 155 (38) (Ts), 139 (17) (M^+- 128), 91 (100) ($PhCH_2^+$) ; HRMS calcd for $C_{13}H_{18}NO_3$ (M^++H) [268.1007], found [268.1009]

Methyl-2-[4-Hydroxy-1-(toluene-4-sulfonyl)-pyrrolidin-2-yl]-acrylate (92) : A mixture of allene **(87)** (54 mg, 0.20 mmole), $PdCl_2$ (4 mg, 0.02 mmole) and $CuCl_2$ (104 mg, 0.61 mmole) in methanol (0.8 ml) was stirred under carbon monoxide until colour change from green to yellow. The mixture was filtered through celite and evaporated. The mixture was purified by flash chromatography on silica gel (1.62 g) eluting with 35% EtOAc: hexane to give the pyrrolidines **(92)** as an oil (37 mg, 56%) the major product. ^1H NMR δ 2.12 (2H, dddd, J = 13.4, 8.0, 3.7, 1.7 Hz, H3), 2.43 (3H, s, Me), 3.66 (1H, dd, J = 11.6, 4.1 Hz, H5), 3.43 (1H, ddd, J = 4.1, 2.8, 1.0 Hz, H5′), 3.74 (3H, s, OMe), 4.34 (1H, m, C<u>H</u>OH), 4.70 (1H, t, J = 7.5 Hz, C<u>H</u>NTs), 6.01 (1H, t, J = 1.0 Hz, <u>H</u>$_2$C=), 6.32 (1H, s, C<u>H</u>$_2$=), 7.32 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_5$Me), 7.74 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_5$Me) : the minor product. ^1H NMR δ 2.25 (2H, ddd, J = 15.7, 10.2, 5.8 Hz, H3), 2.43 (3H, s, Me), 3.61 (1H, dt, J = 10.8, 1.9 Hz, H5), 3.30 (1H, dd, J = 10.7, 4.8 Hz, H5′), 3.76 (3H, s, OMe), 4.18 (1H, m, C<u>H</u>OH), 4.70 (1H, t, J = 7.5 Hz, C<u>H</u>NTs), 6.08 (1H, t, J = 1.0 Hz, <u>H</u>$_2$C=), 6.32 (1H, s, <u>H</u>$_2$C=), 7.32 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_5$Me), 7.74 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_5$Me) ; ^{13}C NMR δ 21.0, 21.5, 41.2, 41.9, 51.8, 52.0, 56.5, 57.4, 59.2, 59.6, 60.4, 69.7, 70.1, 126.2, 127.0, 129.5, 129.7, 134.4, 140.5, 140.6, 143.6, 165.9 ; IR (υ,cm^{-1}) 3528 (OH), 2949 (CH), 1716 (C=O), 1598 (C=C), 1338 (SO_2N), 1158 (SO_2N) ; MS (m/z) 326 (24) (M^+- H), 308 (18) (M^++ H- H_2O), 240 (13) (M^+- $C_4H_5O_2$), 170 (46) (M^+- Ts), 154 (24) (M^+- Ts-H_2O), 92 (100) ($PhCH_2^+$+ H) ; HRMS calcd for $C_{15}H_{20}NO_5$ (M^++H) [326.1062], found [326.1060]

Methyl-2-[4-(-*t*-Butyldimethylsiloxy)-1-(p-toluenesulfonyl)-pyrrolidin-2-yl]-acrylate (93) : The same procedure as **(64)** was employed except that the

hydroxy pyrrolidine **(92)** (113 mg, 0.33 mmole) was used instead of the terminal alkyne **(58)** to give the silyl ether **(93)** as an oil (142 mg, 98 %). ^{1}H NMR δ -0.10 (6H, s, CH_3), 0.70 (9H, s, *t*-Bu), 1.91 (1H, t, J = 5.1 Hz, H3), 2.40 (3H, s, Me), 3.18 (1H, dd, J = 10.2, 4.4 Hz, H3′), 3.69 (1H, dd, J = 4.4, 2.9 Hz, H5), 3.70 (1H, t, J = 2.9 Hz, H5′), 4.60 (1H, t, J = 7.3 Hz, C<u>H</u>NTs), 3.80 (1H, s, OMe), 4.23 (1H, m, C<u>H</u>OTBS), 4.60 (1H, t, J = 7.32 Hz, C<u>H</u>NTs), 6.01 (1H, s, <u>H</u>$_2$C=), 6.38 (1H, s, <u>H</u>$_2$C=), 7.30 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_4$Me), 7.70 (2H, d, J = 8.1 Hz, C_6<u>H</u>$_4$Me); ^{13}C NMR δ -5.2, -5.1, -3.7, -3.1, 17.8, 20.9, 21.3, 25.5, 25.6, 41.3, 42.4, 51.7, 56.5, 56.7, 58.8, 60.2, 69.6, 70.4, 126.0, 126.8, 127.3, 127.6, 129.5, 129.6, 137.0, 140.8, 143.3, 166.0 ; IR (υ,cm^{-1}) 2953 (CH), 1718 (C=O), 1599 (C=C), 1348 (SO_2N), 1254 (Si-CH_3), 1162 (SO_2N), 1090 (C-O-C), 927 (C-O-C) ; MS (m/z) 328 (100) (M^+- C_4H_9), 270 (59) ($C_7H_7SO_2N$)

Methyl-[4-(*t*-butyldimethylsilyloxy)-1-(toluene-4-sulfonyl)-pyrrolidin-2-yl]-2-oxo-acetate (94) : Sodium (meta)periodate (150 mg, 0.70 mmole) and potassium osmate(VI) dihydrate (6 mg, 0.02 mmole) were added to a solution of pyrrolidine **(93)** (140 mg, 0.32 mmole) in dioxane : water (0.6:0.6 ml) and the mixture was stirred overnight. Sat. Na_2SO_3 was added the mixture. The mixture was filtered through celite and extracted with EtOAc. The organic extracts were washed with H_2O and brine. The combined organic layers were dried (Na_2SO_4), evaporated and purified by flash chromatography on silica gel (4.2 g) eluting with 10% EtOAc : hexane to give the α-ketoester **(94)**, as an oil (107mg, 76%). ^{1}H NMR δ -0.10 (6H, s, CH_3), 0.70 (9H, s, *t*-Bu), 2.15 (1H, m ,H3), 2.40 (3H, s, Me), 3.27 (1H, dt, J = 9.5, 1.7 Hz, H3′), 3.77 (2H, dd, J = 7.2, 3.7 Hz, H5), 3.90 (3H, s, OMe), 4.40 (1H, m, C<u>H</u>OTBS), 4.65 (1H, dd, J = 9.6, 7.3 Hz, C<u>H</u>NTs), 7.30 (2H, d, J = 8.3 Hz, C_6<u>H</u>$_4$Me), 7.74 (2H, d, J = 8.3 Hz, C_6<u>H</u>$_4$Me); ^{13}C NMR δ -5.2, -5.1, 21.4, 25.4, 39.7, 52.9, 62.8, 70.6, 70.7, 127.6, 127.7, 129.6, 129.7, 133.9, 1143.8, 161.2, 191.7; IR (υ,cm^{-1}) 2954 (CH), 1733 (C=O), 1349 (SO_2N), 1255 (SiMe), 1162 (SO_2N), 1089 (C-O-C), 920 (C-O-C); MS (m/z) 442 (1) (M^+-H), 384 (50) (M^+- C_4H_9), 354 (100) (M^+- $C_3H_3O_3$), 222 (76) ($C_{11}H_{13}O_2NSH$- H), 155 (14) (Ts) ; HRMS calcd for $C_{20}H_{32}NO_6SSi$ (M^++H) [442.1720], found [442.1718]

Methyl-2-[4-(*t*-Butyldimethylsilyloxy)-1-(toluene-4-sulfonyl)-pyrrolidin-2-yl]-2-hydroxy-but-3-enoate (95+96) : Vinyl magnesium chloride solution in THF (75 μl, 0.13 mmole) was added dropwise to a solution of α-ketoester **(94)** (56 mg, 0.13 mmole) in THF (1 ml) at –78 °C. The mixture was stirred for 10 min and then acidified with amberlite IRC 86, warmed to room temperature, filtered and evaporated. The residue was purified by flash chromatography on silica gel (1.68g) eluting with 5% EtOAc : hexane to give pyrrolidines **(95+96)** , as a yellow solid (56 mg, 95%). m.p. = 86-88 °C ; ^{1}H NMR δ -0.10 (6H, s, CH_3), 0.70 (9H, s, *t*-Bu), 2.04 (1H, ddd, J = 13.2, 6.6, 3.6 Hz ,H3), 2.40 (3H, s, Me), 3.24 (1H, dd, J = 11.0, 3.6 Hz, H3′), 3.64 (2H, dd, J = 11.0, 5.8 Hz, H5), 3.80 (3H, s, OMe), 4.20 (1H, dd, J = 8.6, 3.6 Hz, C<u>H</u>NTs), 4.40 (1H, m, C<u>H</u>OTBS), 5.2 (1H, dd, J = 16.8, 1.4 Hz, CH=C<u>H</u>$_2$), 5.86 (1H, dd, J = 16.8, 10.2 Hz, CH=C<u>H</u>$_2$), 7.30 (2H, d, J = 8.3 Hz, C_6<u>H</u>$_4$Me), 7.73 (2H, d, J = 8.3 Hz, C_6<u>H</u>$_4$Me); ^{13}C NMR δ -5.0, 17.9, 21.4, 25.6, 35.0, 36.8, 53.4, 55.8, 58.3, 62.9, 64.4, 69.7, 71.2, 80.3, 116.7, 127.7, 127.9, 129.6, 129.8, 135.3, 143.5, 173.5; IR (υ,cm^{-1}) 3501 (OH), 2954 (CH), 1729 (C=O), 1597 (C=C), 1337 (SO_2N), 1255 (Si-CH_3), 1212 (SO_2N); MS (m/z) 470 (2) (M^+- H), 412 (9) (M^+- C_4H_9), 354 (100) (M^+-TBS), 222 (44) ($C_{11}H_{13}O_2NSH$- H), 155 (11) (Ts), 91 (9) ($PhCH_2^+$) ; Found C 56.42 %, H 7.61 %, N 2.98 %, $C_{22}H_{35}NO_6SSi$ requires C 56.26 %, H 7.51 %, N 2.98 %