Tetrahedron Letters, Vol.31, No.6, pp 869-872, 1990
Printed in Great Britain

0040-4039/90 $3.00 + .00
Pergamon Press plc

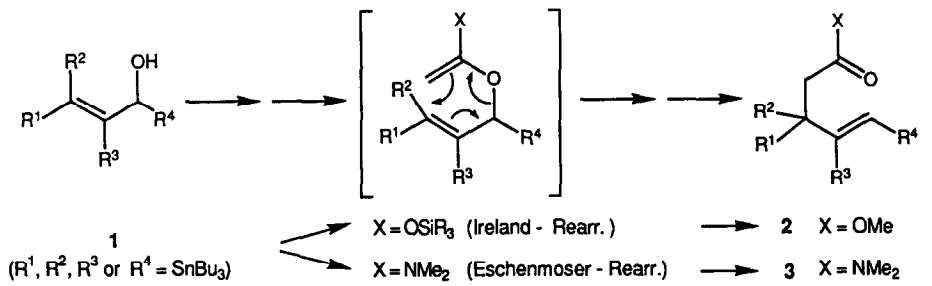
CLAISEN REARRANGEMENT OF ORGANOTIN COMPOUNDS

Kurt Ritter*
Organisch-chemisches Institut der Universität Heidelberg,
Im Neuenheimer Feld 270, D-6900 Heidelberg, F.R.G.

Summary: *The Ireland and Eschenmoser variations of the Claisen rearrangement of various organotin compounds afforded tributylstannyl-substituted, γ,δ-unsaturated esters or amides in fair to good yields. Ireland rearrangement of O-benzyl-protected glycolates gave (E)-2-benzyloxy-3-tributylstannyl-4-hexenoic esters with high diastereoselectivity.*

The Claisen rearrangement and its variations[1] have been extensively used for natural product synthesis[2,3] due to the ease of creating a new carbon-carbon bond and the predictability of stereochemical outcome.[4] However, the possibility of functionalizing the newly formed double bond has been neglected so far. Introduction of a suitable metal moiety into the allylic system of the starting material would provide a versatile approach to highly functionalized γ,δ-unsaturated esters. Organotin compounds have found increasing interest in synthetic organic chemistry over the last few years[5], for example vinylstannanes in Pd-catalyzed coupling reactions[5,6] or allyl- and crotylstannanes in Lewis acid catalyzed addition to aldehydes.[7]

Claisen rearrangement of organotin compounds would provide a facile access to both classes of stannanes. This paper reports the Ireland[2] ($X = OSiR_3$) and Eschenmoser[8] ($X = NMe_2$) variations of the Claisen rearrangement of different organotin compounds 1 leading to highly functionalized stannyl-substituted esters 2 or amides 3.



The alcohols 1a (method A)[9], 1c (method C)[10] and 1e (method E)[11] were prepared according to literature. Addition of tributylstannylmagnesium bromide to 3-methyl-2-butenal (4b) gave the labile alcohol 1b (method B), which was esterified immediately without prior purification. Hydroalumination of 3-butyn-2-ol (5) and subsequent treatment of the aluminate complex with tributyltin triflate[12] (method D) yielded (Z)-4-tributylstannyl-3-buten-2-ol (1d). Pd-catalyzed addition of phenyldimethylsilyl tributylstannanes to 3-butyn-2-ol (method E) provided the alcohol 1f with high regio- and stereo-

*New address: BASF AG, Hauptlaboratorium, D-6700 Ludwigshafen

selectivity, the tin moiety being attached to the internal olefin carbon. Subsequent desilylation[13] of 1f with tetra-n-butyl-ammonium fluoride (method F) gave the alcohol 1g.

Standard conditions were used for the Ireland variation of the Claisen rearrangement. Conversion of the allylic acetates 6a-6c into the corresponding O-silyl ketene acetals with KHMDS/tert.-$BuMe_2SiCl$, mild thermolysis, hydrolysis of the rearranged silyl esters and esterification with diazomethane afforded the γ,δ-unsaturated esters 2a-2c (see table I). The chairlike transition state 7A with R^4 in pseudoequatorial position is energetically favoured over 7B with R^4 in pseudoaxial position, resulting in exclusive formation of the (E)-isomers 2.

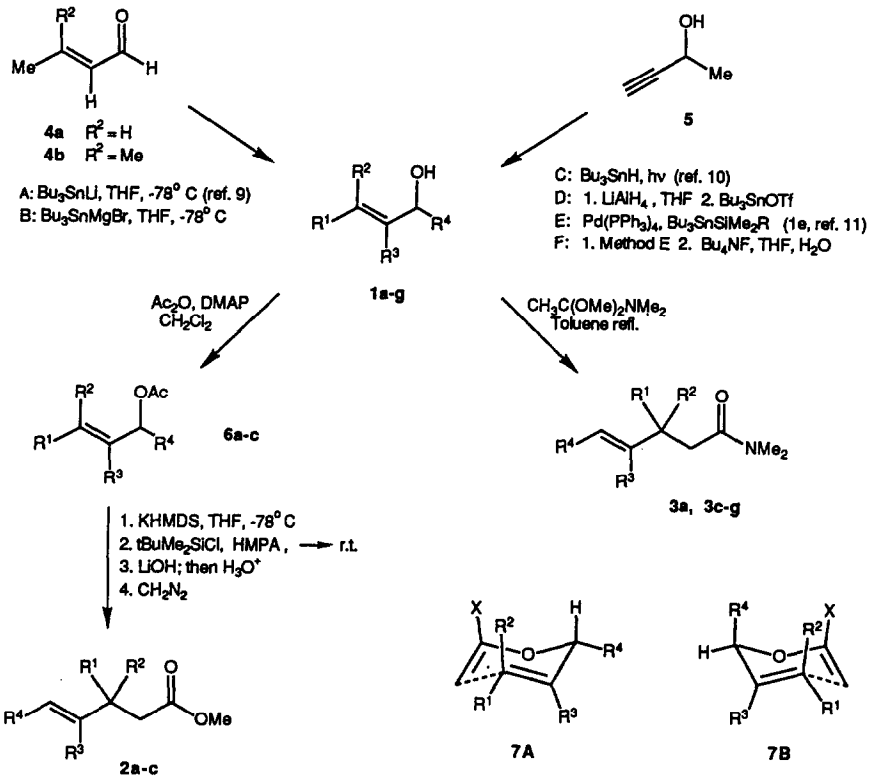


Table I. Preparation and Claisen Rearrangement of Alcohols 1 and Acetates 6a-c

Alcohol	Method (isol. yield)	R^1	R^2	R^3	R^4	Ireland-Var. (isolated yield)	Eschenmoser-Var. (isolated yield)
1a	A (68%)*	Me	H	H	$SnBu_3$	2a (60%)	3a (40%)
1b	B (60%)*	Me	Me	H	$SnBu_3$	2b (62%)	-
1c	C (67%)	$SnBu_3$	H	H	Me	2c (54%)	3c (88%)
1d	D (71%)	H	$SnBu_3$	H	Me	-	3c (91%)
1e	E (87%)	$SiMe_3$	H	$SnBu_3$	Me	-	3e (81%)
1f	E (79%)	$SiMe_2Ph$	H	$SnBu_3$	Me	-	3f (85%)
1g	F (33%)	H	H	$SnBu_3$	Me	-	3g (91%)

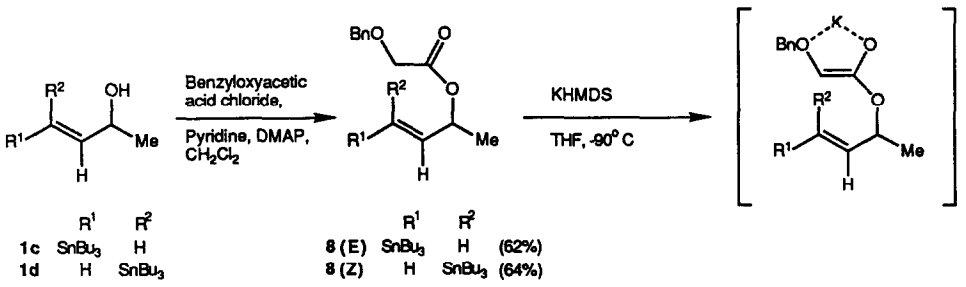
* isolated as acetate 6

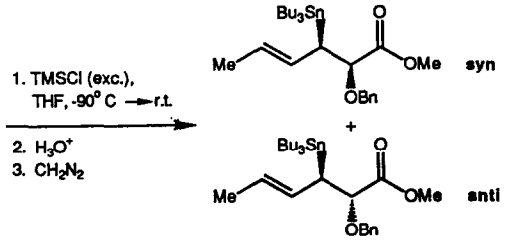
DMAP: dimethylaminopyridine; KHMDS: potassium hexamethyldisilazide; HMPA: hexamethyl phosphoric triamide

The Eschenmoser variation of the Claisen rearrangement is a simple procedure, refluxing an allylic alcohol and N,N-dimethylacetamide dimethyl acetal in a high boiling solvent. Rearrangement of the ketene O,N-acetal, formed by trans-acetalization and elimination of methanol, afforded the γ,δ-unsaturated amides. Eschenmoser rearrangement of the different stannyl alcohols 1a, 1c - 1g gave, as expected, only the (E)-configurated, stannyl-substituted amides 3 (see table I). The (E)-tributylstannyl-butenol 1c reacted 6 times faster than the (Z)-isomer 1d to provide the same product 3c, reflecting the energy difference of the transition states with the tributyltin moiety in a pseudoequatorial (7A, $R^1 = SnBu_3$, $R^2 = H$) or pseudoaxial position (7A, $R^1 = H$, $R^2 = SnBu_3$).

For highly diastereoselective Ireland rearrangement control of stereochemistry of the ester enolate is necessary, since enolate and olefin geometry are reflected in the stereochemical relationship of the newly formed vicinal chiral centers. As Ireland demonstrated in the case of butenyl propionates[14], the enolate geometry is dramatically dependent on the solvent. Several investigators[15] used the chelation effect of the counterion to form predominantly the (E)-enolate from O-protected butenyl glycolates and to achieve thereby high diastereoselectivity in the Claisen rearrangement.

Ireland rearrangement of (Z)- or (E)-4-tributylstannyl-3-buten-2-yl (benzyloxy)acetate (8) through intermediate O-silyl ketene acetal afforded (E)-2-benzyloxy-3-tributylstannyl-4-hexenoic acid methyl ester (9) in excellent chemical yield (92%). As a consequence of the defined enolate geometry the ester 9 syn is the main product (syn : anti ratio 39:1; determined by HPLC) from glycolate 8(E), the ester 9 anti (anti : syn ratio > 40:1) from glycolate 8(Z). Diastereomers[16] were assigned from the vicinal coupling constant[17] between H-2 and H-3 (9 syn: J = 8.7 Hz; 9 anti: J = 4.6 Hz).





9

Further work should be directed to the Claisen rearrangement of chiral tin compounds. Optically active 3-butyn-2-ol was prepared by reduction of 3-butyn-2-one with enzymes[18] or chiral hydrides.[19] Enantioselective reduction of acyl stannanes by chiral BINAL-H reagents was reported recently.[20] Kinetic resolution[21] of alcohols 1 by Sharpless epoxidation should provide optically active tin compounds. Lewis acid catalyzed addition of stannanes 3 to aldehydes is currently under investigation.

Acknowledgement: The author wishes to thank the "Verband der Chemischen Industrie" for a scholarship and Prof. G. Helmchen for his support of this work.

References and Notes

1. Ziegler, F.E. *Acc. Chem. Res.* **1977**, *10*, 227; Ziegler, F.E. *Chem. Rev.* **1988**, *88*, 1423; Blechert, S. *Synthesis* **1989**, 71.
2. Ireland, R.E. *Aldrichimica Acta* **1988**, *21*, 59; Kallmerten, J., Wittman, M.D. in *Studies in Natural Products Chemistry*; Rahman, A., Ed.; Elsevier, 1989; Vol. 3, (Part B), pp 233 - 286.
3. Recent examples: Funk, R.L., Abelman, M.M. *J. Org. Chem.* **1986**, *51*, 3247 (quadrone); Funk, R.L., Abelman, M.M., Munger Jr., J.D. *Tetrahedron* **1986**, *42*, 2831; Funk, R.L., Munger Jr., J.D. *J. Org. Chem.* **1986**, *50*, 707 (chrysanthemic acid); Ireland, R.E., Smith, M.G. *J. Am. Chem. Soc.* **1988**, *110*, 854 (streptolic acid); Danishefsky, S.J., Simoneau, B. *Pure & Appl. Chem.* **1988**, *60*, 1555 (ML236A); Heathcock, C.H., Finkelstein, B.L., Jarvi, E.T., Radel, P.A., Hadley, C.R. *J. Org. Chem.* **1988**, *53*, 1922 (vitamin E); Gilbert, J.C., Kelly, T.A. *Tetrahedron Lett.* **1989**, *30*, 4193 (trichodiene).
4. Hill, R.K. in *Asymmetric Synthesis;* Morrison, J.D., Ed.; Academic Press, 1984; Vol. 3; pp 503 - 572.
5. Pereyre, M., Quintard, J.-P., Rahm, A. *Tin in Organic Synthesis*, Butterworths & Co. Ltd, 1987.
6. Stille, J.K. *Angew. Chem.* **1986**, *98*, 504, *Angew. Chem. Int. Ed. Engl.* **1986**, *25*, 508; Stille, J.K. *Pure & Appl. Chem.* **1980**, *57*, 1771.
7. Yamamoto, Y. *Aldrichimica Acta* **1987**, *20*, 45; Yamamoto, Y. *Acc. Chem. Res.* **1987**, *20*, 243.
8. Wick, A.E., Felix, D., Steen, K., Eschenmoser, A. *Helv. Chim. Acta* **1964**, *47*, 2425.
9. Still, W.C. *J. Am. Chem. Soc.* **1978**, *100*, 1481.
10. Johnson, C.R., Kadow J.F. *J. Org. Chem.* **1987**, *52*, 1493.
11. Mitchell, T.N., Wickenkamp, R., Amamria, A., Dicke, R., Schneider, U. *J. Org. Chem.* **1987**, *52*, 4868.
12. Corey, E.J., Eckrich, T.M. *Tetrahedron Lett.* **1984**, *25*, 2415.
13. Ritter, K. *Synthesis* **1989**, 218.
14. Ireland, R., Mueller, R.H., Willard, A.K. *J. Am. Chem. Soc.* **1976**, *98*, 2868.
15. Gould, T.J., Balestra, M., Wittmann, M.D., Gary, J.A., Rossano, L.T., Kallmerten, J. *J. Org. Chem.* **1987**, *52*, 3889 and references therein; Barrish, J.C., Lee, H.L., Mitt, T., Pizzolato, G., Baggiolini, E.G., Uskokovic, M.R. *J. Org. Chem.* **1988**, *53*, 4282.
16. ^{1}H-NMR of **9 syn** ($CDCl_3$, 300 MHz): δ 0.75-0.90 (m; 6 H), 0.84 (t, J = 7.2 Hz; 9 H), 1.17-1.49 (m; 12 H), 1.63 (dd, J = 6.3, 1.2 Hz; 3 H; H-6), 2.57 (dd, J = 10.4, 8.7 Hz; 1 H; H-3), 3.71 (s; 3 H), 4.05 (d, J = 8.7 Hz; 1 H; H-2), 4.35, 4.59 (AB, J = 11.0 Hz; 2 H), 5.21 (qd, J = 15.0, 6.3 Hz; 1 H; H-5), 5.42 (ddd, J = 15.0, 10.4, 1.3 Hz; 1 H; H-4), 7.26-7.34 (m; 5 H).^{13}C-NMR of **9 syn** ($CDCl_3$, 75 MHz): δ 9.9, 13.7, 17.9, 27.4, 29.1, 37.3, 51.5, 72.3, 81.5, 120.9, 127.8, 128.2, 128.5, 129.9, 137.1, 173.6.
^{1}H-NMR of **9 anti** ($CDCl_3$, 300 MHz): δ 0.75-0.90 (m; 6 H), 0.84 (t, J = 7.2 Hz; 9 H), 1.17-1.51 (m; 12 H), 1.62 (dd, J = 6.4, 1.1 Hz; 3 H; H-6), 2.53 (dd, J = 11.1, 4.6 Hz; 1 H; H-3), 3.70 (s; 3 H), 4.10 (d, J = 4.6 Hz; 1 H; H-2), 4.30, 4.69 (AB, J = 11.0 Hz; 2 H), 5.22 (qd, J = 15.0, 6.4 Hz; 1 H; H-5), 5.61 (ddd, J = 15.0, 11.1, 1.5 Hz; 1 H; H-4), 7.25-7.36 (m; 5 H). ^{13}C-NMR of **9 anti** ($CDCl_3$, 75 MHz): δ 9.7, 13.7, 17.9, 27.4, 29.1, 36.5, 51.4, 72.4, 80.6, 121.3, 127.7, 128.2, 128.4, 129.5, 137.6, 172.8.
17. Doyle, M.P., Bagheri, V., Harn, N.K. *Tetrahedron Lett.* **1988**, *29*, 5119.
18. De Amici, M., De Micheli C., Carrea G., Spezia, S. *J. Org. Chem.* **1989**, *54*, 2646.
19. Midland, M.M., McDowell, D.C., Hatch, R.L., Tramontano, A. *J. Am. Chem. Soc.* **1980**, *102*, 867; Keinan, E., Greenspoon, N. in *The Chemistry of Enones*; Patai, S., Rappoport, Z., Ed.; J. Wiley, 1989; p 970.
20. Marshall, J.A., Gung, W.Y. *Tetrahedron Lett.* **1988**, *29*, 1657; Marshall, J.A., Gung, W.Y. *Tetrahedron Lett.* **1989**, *30*, 2183; Chan, P.C.-M., Chong, J.M. *J. Org. Chem.* **1988**, *53*, 5584.
21. Noyori, R., Kitamura, M. in *Modern Synthetic Methods 1989*; Sheffold, R., Ed.; Springer, 1989; pp 115 -198.

(Received in Germany 30 November 1989)