

# References for Problems

## Chapter 1

- 1a. W. S. Matthews, J. E. Bares, J. E. Bartmess, F. G. Bordwell, F. J. Cornforth, G. E. Drucker, Z. Margolin, R. J. McCallum, G. J. McCollum, and N. E. Vanier, *J. Am. Chem. Soc.*, **97**, 7006 (1975).
- b. H. D. Zook, W. L. Kelly, and I. Y. Posey, *J. Org. Chem.*, **33**, 3477 (1968).
- 2a. H. O. House and M. J. Umen, *J. Org. Chem.*, **38**, 1000 (1973).
- b. W. C. Still and M.-Y. Tsai, *J. Am. Chem. Soc.*, **102**, 3654 (1980).
- c. H. O. House and B. M. Trost, *J. Org. Chem.*, **30**, 1431 (1965); C. H. Heathcock, C. T. Buse, W. A. Kleschick, M. C. Pirrung, J. E. Sohn, and J. Lampe, *J. Org. Chem.*, **45**, 1066 (1980); L. Xie, K. Vanlandeghem, K. M. Isenberger, and C. Bernier, *J. Org. Chem.*, **68**, 641 (2003).
- d. D. Caine and T. L. Smith, Jr., *J. Am. Chem. Soc.*, **102**, 7568 (1980).
- e. M. F. Semmelhack, S. Tomoda, and K. M. Hurst, *J. Am. Chem. Soc.*, **102**, 7568 (1980); M. F. Semmelhack, S. Tomoda, H. Nagaoka, S. D. Boettger, and K. M. Hurst, *J. Am. Chem. Soc.*, **104**, 747 (1982).
- f. R. A. Lee, C. McAndrews, K. M. Patel, and W. Reusch, *Tetrahedron Lett.*, 965 (1973).
- g. R. H. Frazier, Jr., and R. L. Harlow, *J. Org. Chem.*, **45**, 5408 (1980).
- h. T. T. Tidwell, *J. Am. Chem. Soc.*, **92**, 1448 (1970); J. M. Jerkunica, S. Borcic, and D. E. Sunko, *Tetrahedron Lett.*, 4465 (1965).
- 3a. M. Gall and H. O. House, *Org. Synth.*, **52**, 39 (1972).
- b. P. S. Wharton and C. E. Sundin, *J. Org. Chem.*, **33**, 4255 (1968).
- c. B. W. Rockett and C. R. Hauser, *J. Org. Chem.*, **29**, 1394 (1964).
- d. J. Meier, *Bull. Soc. Chim. Fr.*, 290 (1962).
- e. M. E. Jung and C. A. McCombs, *Org. Synth.*, **VI**, 445 (1988).
- f,g. H. O. House, T. S. B. Sayer, and C. C. Yau, *J. Org. Chem.*, **43**, 2153 (1978).
- 4a. S. A. Monti and S.-S. Yuan, *Tetrahedron Lett.*, 3627 (1969); J. M. Harless and S. A. Monti, *J. Am. Chem. Soc.*, **96**, 4714 (1974).
- b. A. Wissner and J. Meinwald, *J. Org. Chem.*, **38**, 1697 (1973).
- c. W. J. Gensler and P. H. Solomon, *J. Org. Chem.*, **38**, 1726 (1973).
- d. H. W. Whitlock, Jr., *J. Am. Chem. Soc.*, **84**, 3412 (1962).
- e. C. H. Heathcock, R. A. Badger, and J. W. Patterson, Jr., *J. Am. Chem. Soc.*, **89**, 4133 (1967).
- f. E. J. Corey and D. S. Watt, *J. Am. Chem. Soc.*, **95**, 2302 (1973).
5. W. G. Kofron and L. G. Wideman, *J. Org. Chem.*, **37**, 555 (1972).
6. C. R. Hauser, T. M. Harris, and T. G. Ledford, *J. Am. Chem. Soc.*, **81**, 4099 (1959).
- 7a. N. Campbell and E. Ciganek, *J. Chem. Soc.*, 3834 (1956).
- b. F. W. Sum and L. Weiler, *J. Am. Chem. Soc.*, **101**, 4401 (1979).
- c. K. W. Rosemund, H. Herzberg, and H. Schutt, *Chem. Ber.*, **87**, 1258 (1954).
- d. T. Hudlicky, F. J. Koszyk, T. M. Kutchan, and J. P. Sheth, *J. Org. Chem.*, **45**, 5020 (1980).
- e. C. R. Hauser and W. R. Dunnivant, *Org. Synth.*, **IV**, 962 (1963).

- f. G. Opitz, H. Milderberger, and H. Suhr, *Liebigs Ann. Chem.*, **649**, 47 (1961).
- g. K. Wiesner, K. K. Chan, and C. Demerson, *Tetrahedron Lett.*, 2893 (1965).
- h. K. Shimo, S. Wakamatsu, and T. Inoue, *J. Org. Chem.*, **26**, 4868 (1961).
- i. G. R. Kieczykowski and R. H. Schlessinger, *J. Am. Chem. Soc.*, **100**, 1938 (1978).
- 8a. E. Wenkert and D. P. Strike, *J. Org. Chem.*, **27**, 1883 (1962).
- b. S. J. Etheredge, *J. Org. Chem.*, **31**, 1990 (1966).
- c. R. Deghenghi and R. Gaudry, *Tetrahedron Lett.*, 489 (1962).
- d. P. A. Grieco and C. C. Pogonowski, *J. Am. Chem. Soc.*, **95**, 3071 (1973).
- e. E. M. Kaiser, W. G. Kenyon, and C. R. Hauser, *Org. Synth.*, **V**, 559 (1973).
- f. J. Cason, *Org. Synth.*, **IV**, 630 (1963).
- g. S. A. Glickman and A. C. Cope, *J. Am. Chem. Soc.*, **67**, 1012 (1945).
- h. W. Steglich and L. Zechlin, *Chem. Ber.*, **111**, 3939 (1978).
- i. S. F. Brady, M. A. Ilton, and W. S. Johnson, *J. Am. Chem. Soc.*, **99**, 2882 (1968).
9. S. Masamune, *J. Am. Chem. Soc.*, **83**, 1009 (1961).
- 10a. L. A. Paquette, H.-S. Lin, D. T. Belmont, and J. P. Springer, *J. Org. Chem.*, **51**, 4807 (1986);  
L. A. Paquette, T. T. Belmont, and Y.-L. Hsu, *J. Org. Chem.*, **50**, 4667 (1985).
- b. R. K. Boeckman, Jr., D. K. Heckenden, and R. L. Chinn, *Tetrahedron Lett.*, **28**, 3551 (1987).
- c. D. Seebach, J. D. Aeby, M. Gander-Coquot, and R. Naef, *Helv. Chim. Acta*, **70**, 1194 (1987).
- d. F. E. Ziegler, S. I. Klein, U. K. Pati, and T.-F. Wang, *J. Am. Chem. Soc.*, **107**, 2730 (1985).
- e. M. E. Kuehne, *J. Org. Chem.*, **35**, 171 (1970).
- f. D. A. Evans, S. L. Bender, and J. Morris, *J. Am. Chem. Soc.*, **110**, 2506 (1988).
- g. K. Tomioka, Y.-S. Cho, F. Sato, and K. Koga, *J. Org. Chem.*, **53**, 4094 (1988).
- h. K. Tomioka, H. Kawasaki, K. Yasuda, and K. Koga, *J. Am. Chem. Soc.*, **110**, 3597 (1988).
- i. M. W. Carson, G. Kim, M. F. Hentemann, D. Trauner, and S. J. Danishefsky, *Angew. Chem. Int. Ed. Engl.*, **40**, 4450 (2001).
- j. J. E. Jung, H. Ho, and H.-D. Kim, *Tetrahedron Lett.*, **41**, 1793 (2000).
- 11a. S. G. Davies and H. J. Sangane, *Tetrahedron: Asymmetry*, **6**, 671 (1995); A. G. Myers, B. H. Yang, H. Chen, and J. L. Gleason, *J. Am. Chem. Soc.*, **116**, 9361 (1994); K. H. Ahn, A. Lim, and S. Lee, *Tetrahedron: Asymmetry*, **4**, 2435 (1993).
- b. D. Enders, H. Eichenauer, U. Baus, H. Schubert, and K. A. M. Kremer, *Tetrahedron*, **40**, 1345 (1984).
- 12a. T. Kometani, Y. Suzuki, H. Furuyama, and T. Honda, *J. Org. Chem.*, **48**, 31 (1983).
- b. R. A. Kjonaas and D. D. Patel, *Tetrahedron Lett.*, **25**, 5467 (1984).
- c. D. F. Taber and R. E. Ruckle, Jr., *J. Am. Chem. Soc.*, **108**, 7686 (1986).
- d. D. L. Snitman, M.-Y. Tsai, D. S. Watt, C. L. Edwards, and P. L. Stotter, *J. Org. Chem.*, **44**, 2838 (1979).
- e. A. G. Schultz and J. P. Dittami, *J. Org. Chem.*, **48**, 2318 (1983).
- 13a. K. F. McClure and M. Z. Axt, *Bioorg. Med. Chem. Lett.*, **8**, 143 (1998).
- b. T. Honda, N. Kimura, and M. Tsubuki, *Tetrahedron: Asymmetry*, **4**, 1475 (1993); T. Honda, F. Ishikawa, K. Kanai, S. Sato, D. Kato, and H. Tominaga, *Heterocycles*, **42**, 109 (1996).
- c. I. Vaulot, H.-J. Gais, N. Reuter, E. Schmitz, and R. K. L. Ossenkamp, *Eur. J. Org. Chem.*, 805 (1998); M. Majewski and R. Lazny, *J. Org. Chem.*, **60**, 5825 (1995).
- d. H. Pellissier, P.-Y. Michellys, and M. Santelli, *J. Org. Chem.*, **62**, 5588 (1997).
- e. K. Narasaka and Y. Ukagi, *Chem. Lett.*, 81 (1986).
14. J. G. Henkel and L. A. Spurlock, *J. Am. Chem. Soc.*, **95**, 8339 (1973).
15. M. S. Newman, V. De Vries, and R. Darlak, *J. Org. Chem.*, **31**, 2171 (1966).
16. P. A. Manis and M. W. Rathke, *J. Org. Chem.*, **45**, 4952 (1980).

## Chapter 2

- 1a. G. Ksander, J. E. McMurry, and N. Johnson, *J. Org. Chem.*, **42**, 1180 (1977).
- b. J. Zabicky, *J. Chem. Soc.*, 683 (1961).
- c. G. Stork, G. A. Kraus, and G. A. Garcia, *J. Org. Chem.*, **39**, 3459 (1974).
- d. H. Midorikawa, *Bull. Chem. Soc. Jpn.*, **27**, 210 (1954).
- e. R. A. Auerbach, D. S. Crumrine, D. L. Ellison, and H. O. House, *Org. Synth.*, **54**, 49 (1974).
- f. E. C. Du Feu, F. J. McQuillin, and R. Robinson, *J. Chem. Soc.*, 53 (1937).
- g. E. Buchta, G. Wolfrum, and H. Ziener, *Chem. Ber.*, **91**, 1552 (1958).

- h. L. H. Briggs and E. F. Orgias, *J. Chem. Soc. C*, 1885 (1970).
- i. J. A. Proffitt and D. S. Watt, and E. J. Corey, *J. Org. Chem.*, **40**, 127 (1975).
- j. U. Hengartner, and V. Chu, *Org. Synth.*, **58**, 83 (1978).
- k. E. Giacomini, M. A. Loreto, L. Pellacani, and P. A. Tardella, *J. Org. Chem.*, **45**, 519 (1980).
- l. N. Narasimhan and R. Ammanamanchi, *J. Org. Chem.*, **48**, 3945 (1983).
- m. M. P. Bosch, F. Camps, J. Coll, A. Guerro, T. Tatsuoka, and J. Meinwald, *J. Org. Chem.*, **51**, 773 (1986).
- n. T. A. Spencer, K. K. Schmiegel, and K. L. Williamson, *J. Am. Chem. Soc.*, **85**, 3785 (1963).
- 2a. M. W. Rathke and D. F. Sullivan, *J. Am. Chem. Soc.*, **95**, 3050 (1973).
- b. E. J. Corey, H. Yamamoto, D. K. Herron, and K. Achiwa, *J. Am. Chem. Soc.*, **92**, 6635 (1970).
- c. E. J. Corey and D. E. Cane, *J. Org. Chem.*, **36**, 3070 (1971).
- d. E. W. Yankee and D. J. Cram, *J. Am. Chem. Soc.*, **92**, 6328 (1970).
- e. W. G. Dauben, C. D. Poulter, and C. Suter, *J. Am. Chem. Soc.*, **92**, 7408 (1970).
- f. P. A. Grieco and K. Hiroi, *J. Chem. Soc., Chem. Commun.*, 1317 (1972).
- g. E. A. Couladouros and A. P. Mihou, *Tetrahedron Lett.*, **40**, 4861 (1999).
- h. I. Vlattas, I. T. Harrison, L. Tokes, J. H. Fried, and A. D. Cross, *J. Org. Chem.*, **33**, 4176 (1968).
- i. A. T. Nielsen and W. R. Carpenter, *Org. Synth.*, V, 288 (1973).
- j. M. L. Miles, T. M. Harris, and C. R. Hauser, *Org. Synth.*, V, 718 (1973).
- k. A. P. Beracierta and D. A. Whiting, *J. Chem. Soc., Perkin Trans. I*, 1257 (1978).
- l. T. Amatayakul, J. R. Cannon, P. Dampawan, T. Dechatiwongse, R. G. F. Giles, D. Huntrakul, K. Kusamran, M. Mokkhasamit, C. L. Raston, V. Reutrakul, and A. H. White, *Aust. J. Chem.*, **32**, 71 (1979).
- m. R. M. Coates, S. K. Shah, and R. W. Mason, *J. Am. Chem. Soc.*, **101**, 6765 (1979).
- n. K. A. Parker and T. H. Fedynyshyn, *Tetrahedron Lett.*, 1657 (1979).
- o. M. Miyashita and A. Yoshikoshi, *J. Am. Chem. Soc.*, **96**, 1917 (1974).
- p. E. J. Corey and S. Nozoe, *J. Am. Chem. Soc.*, **85**, 3527 (1963).
- q. L. Fitjer and U. Quabbeck, *Synth. Commun.*, **15**, 855 (1985).
- r. A. Padwa, L. Brodsky, and S. Clough, *J. Am. Chem. Soc.*, **94**, 6767 (1972).
- s. W. R. Roush, *J. Am. Chem. Soc.*, **102**, 1390 (1980).
- t. C. R. Johnson, K. Mori, and A. Nakanishi, *J. Org. Chem.*, **44**, 2065 (1979).
- u. T. Yanami, M. Miyashita, and A. Yoshikoshi, *J. Org. Chem.*, **45**, 607 (1980).
- v. D. A. Evans, T. Rovis, M. C. Kozlowski, C. W. Downey, and J. S. Tedrow, *J. Am. Chem. Soc.*, **122**, 9134 (2000).
- w. M. Yamaguchi, M. Tsukamoto, S. Tanaka, and I. Hirao, *Tetrahedron Lett.*, **25**, 5661 (1984); M. Yamaguchi, M. Tsukamoto, and I. Hirao, *Tetrahedron Lett.*, **26**, 1723 (1985).
- x. D. A. Evans, M. T. Bilodeau, T. C. Somers, J. Clardy, D. Cherry, and Y. Kato, *J. Org. Chem.*, **56**, 5750 (1991).
- 3a. K. D. Croft, E. L. Ghisalberti, P. R. Jefferies, and A. D. Stuart, *Aust. J. Chem.*, **32**, 2079 (1971).
- b. L. H. Briggs and G. W. White, *J. Chem. Soc., C*, 3077 (1971).
- c. D. F. Taber and B. P. Gunn, *J. Am. Chem. Soc.*, **101**, 3992 (1979).
- d. G. V. Kryshnal, V. V. Kulganek, V. F. Kucherov, and L. A. Yanovskaya, *Synthesis*, 107 (1979).
- e. S. F. Brady, M. A. Ilton, and W. S. Johnson, *J. Am. Chem. Soc.*, **90**, 2882 (1968).
- f. R. M. Coates and J. E. Shaw, *J. Am. Chem. Soc.*, **92**, 5657 (1970).
- g. K. Mitsuhashi and S. Shiotoni, *Chem. Pharm. Bull.*, **18**, 75 (1970).
- h. G. Wittig and H.-D. Frommeld, *Chem. Ber.*, **97**, 3548 (1964).
- i. R. J. Sundberg, P. A. Bukowick, and F. O. Holcombe, *J. Org. Chem.*, **32**, 2938 (1967).
- j. D. R. Howton, *J. Org. Chem.*, **10**, 277 (1945).
- k. M. Graff, A. Al Dilaimi, P. Seguinéau, M. Rambaud, and J. Villieras, *Tetrahedron Lett.*, **27**, 1577 (1986); T. Yamane and K. Ogasawara, *Synlett*, 925 (1996).
- l. Y. Chan and W. W. Epstein, *Org. Synth.*, **53**, 48 (1973).
- m. I. Fleming and M. Woolias, *J. Chem. Soc., Perkin Trans. I*, 827 (1979).
- n. F. Johnson, K. G. Paul, D. Favara, R. Ciabatti, and U. Guzzi, *J. Am. Chem. Soc.*, **104**, 2190 (1982).
- o. M. Ihara, M. Suzuki, K. Fukumoto, T. Kometani, and C. Kabuto, *J. Am. Chem. Soc.*, **110**, 1963 (1988).
- p. H. Hagiwara, T. Okabe, H. Ono, V. R. Kamat, T. Hoshi, T. Suzuki, and M. Ando, *J. Chem. Soc., Perkin Trans. I*, 895 (2002).
- q. S. P. Chavan and M. S. Venkatraman, *Tetrahedron Lett.*, **39**, 6745 (1998).

- r. M. Yamaguchi, M. Tsukamoto, S. Tanaka, and I. Hirao, *Tetrahedron Lett.*, **25**, 5661 (1984); M. Yamaguchi, M. Tsukamoto, and I. Hirao, *Tetrahedron Lett.*, **26**, 1723 (1985).
- s. D. J. Critcher, S. Connolly, and M. Wills, *J. Org. Chem.*, **62**, 6638 (1997).
- 4a. W. A. Mosher and R. W. Soeder, *J. Org. Chem.*, **36**, 1561 (1971).
- b. M. R. Roberts and R. H. Schlessinger, *J. Am. Chem. Soc.*, **101**, 7626 (1979).
- c. J. E. McMurry and T. E. Glass, *Tetrahedron Lett.*, 2575 (1971).
- d. D. J. Cram, A. Langemann, and F. Hauck, *J. Am. Chem. Soc.*, **81**, 5750 (1959).
- e. W. G. Dauben and J. Ipaktschi, *J. Am. Chem. Soc.*, **95**, 5088 (1973).
- f. T. J. Curphy and H. L. Kim, *Tetrahedron Lett.*, 1441 (1968).
- g. K. P. Singh and L. Mandell, *Chem. Ber.*, **96**, 2485 (1963).
- h. S. D. Lee, T. H. Chan, and K. S. Kwon, *Tetrahedron Lett.*, **25**, 3399 (1984).
- i. J. F. Lavallee and P. Deslongchamps, *Tetrahedron Lett.*, **29**, 6033 (1988).
- j. K. Aoyagi, H. Nakamura, and Y. Yamamoto, *J. Org. Chem.*, **64**, 4148 (1999).
5. T. T.何瓦思, G. P. Murphy, and T. A. Harris, *J. Am. Chem. Soc.*, **91**, 517 (1969).
- 6a. E. Vedejs, K. A. Snobel, and P. L. Fuchs, *J. Org. Chem.*, **38**, 1178 (1973).
- b. P. B. Dervan and M. A. Shippey, *J. Am. Chem. Soc.*, **98**, 1265 (1976).
- 7a. E. E. Schweizer and G. J. O'Neil, *J. Org. Chem.*, **30**, 2082 (1965); E. E. Schweizer, *J. Am. Chem. Soc.*, **86**, 2744 (1964).
- b. G. Buchi and H. Wuest, *Helv. Chim. Acta*, **54**, 1767 (1971).
- c. G. H. Posner, S.-B. Lu, and E. Asirvathan, *Tetrahedron Lett.*, **27**, 659 (1986).
- d. M. Mikolajczyk, M. Mikina, and A. Jankowiak, *J. Org. Chem.*, **65**, 5127 (2000); M. Mikolajczyk and M. Mikina, *J. Org. Chem.*, **59**, 6760 (1994).
- e. W. A. Kleschick and C. H. Heathcock, *J. Org. Chem.*, **43**, 1256 (1978).
- f. S. D. Darling, F. N. Muralidharan, and V. B. Muralidharan, *Tetrahedron Lett.*, 2761 (1979).
8. R. B. Woodward, F. Sondheimer, D. Taub, K. Heusler, and W. M. McLamore, *J. Am. Chem. Soc.*, **74**, 4223 (1952).
9. G. Stork, S. D. Darling, I. T. Harrison, and P. S. Wharton, *J. Am. Chem. Soc.*, **84**, 2018 (1962).
10. J. R. Pfister, *Tetrahedron Lett.*, **21**, 1281 (1980).
11. R. M. Jacobson, G. P. Lahm, and J. W. Clader, *J. Org. Chem.*, **45**, 395 (1980).
- 12a. A. I. Meyers and N. Nazarenko, *J. Org. Chem.*, **38**, 175 (1973).
- b. J. A. Marshall and D. J. Schaeffer, *J. Org. Chem.*, **30**, 3642 (1965); W. C. Still and F. L. Van Middlesworth, *J. Org. Chem.*, **42**, 1258 (1977).
- c. Y. Fukuda and Y. Okamoto, *Tetrahedron*, **58**, 2513 (2002).
- d. E. J. Corey, M. Ohno, R. B. Mitra, and P. A. Vatakencherry, *J. Am. Chem. Soc.*, **86**, 478 (1964).
- e. K. Makita, K. Fukumoto, and M. Ihara, *Tetrahedron Lett.*, **38**, 5197 (1997).
- 13a. R. V. Stevens and A. W. M. Lee, *J. Am. Chem. Soc.*, **101**, 7032 (1979).
- b. C. H. Heathcock, E. Kleinman, and E. S. Binkley, *J. Am. Chem. Soc.*, **100**, 3036 (1978).
- c. E. J. Corey and R. D. Balanson, *J. Am. Chem. Soc.*, **96**, 6516 (1974).
- 14a. M. Ertas and D. Seebach, *Helv. Chim. Acta*, **68**, 961 (1985).
- b. S. Masamune, W. Choy, F. A. J. Kerdesky, and B. Imperiali, *J. Am. Chem. Soc.*, **103**, 1566 (1981).
- c. C. H. Heathcock, C. T. Buse, W. A. Kleschick, M. C. Pirrung, J. E. Sohn, and J. Lampe, *J. Org. Chem.*, **45**, 1066 (1980).
- d. R. Noyori, K. Yokoyama, J. Sakata, I. Kuwajima, E. Nakamura, and M. Shimizu, *J. Am. Chem. Soc.*, **99**, 1265 (1977).
- e. D. A. Evans, E. Vogel, and J. V. Nelson, *J. Am. Chem. Soc.*, **101**, 6120 (1979); D. A. Evans, J. V. Nelson, E. Vogel, and T. R. Taber, *J. Am. Chem. Soc.*, **103**, 3099 (1981).
- f. C. T. Buse and C. H. Heathcock, *J. Am. Chem. Soc.*, **99**, 8109 (1977).
- g. R. Mahrwald, B. Costicella, and C. Gundogan, *Synthesis*, 262 (1998).
- h. C. Esteve, M. P. Ferrero, P. Romea, F. Urpi, and J. Vilarrasa, *Tetrahedron Lett.*, **40**, 5079, 5083 (1999).
- 15a. D. Enders, O. F. Prokopenko, G. Raabe, and J. Rumsink, *Synthesis*, 1095 (1996).
- b. M. T. Reetz and A. Jung, *J. Am. Chem. Soc.*, **105**, 4833 (1983).
- 16a,b,c,d. E. D. Bergmann, D. Ginsburg, and R. Pappo, *Org. React.*, **10**, 179 (1959).
- e. L. Mandell, J. U. Piper, and K. P. Singh, *J. Org. Chem.*, **28**, 3440 (1963).
- f. H. O. House, W. A. Kleschick, and E. J. Zaiko, *J. Org. Chem.*, **43**, 3653 (1978).
- g. J. E. McMurry and J. Melton, *Org. Synth.*, **56**, 36 (1977).
- h. D. F. Taber and B. P. Gunn, *J. Am. Chem. Soc.*, **101**, 3992 (1979).
- i. H. Feuer, A. Hirschfield, and E. D. Bergmann, *Tetrahedron*, **24**, 1187 (1968).

- j. A. M. Baradel, R. Longeray, J. Dreux, and J. Doris, *Bull. Soc. Chim. Fr.*, 255 (1970).
- k. H. H. Baer and K. S. Ong, *Can. J. Chem.*, **46**, 2511 (1968).
- l. A. Wettstein, K. Heusler, H. Ueberwasser, and P. Wieland, *Helv. Chim. Acta*, **40**, 323 (1957).
17. J. D. White and M. Kawasaki, *J. Am. Chem. Soc.*, **112**, 4991 (1990).
- 18a. C. Somoza, J. Darias, and E. A. Ruveda, *J. Org. Chem.*, **54**, 1539 (1989); (b) E. R. Koft, A. S. Kotnis, and T. A. Broadbent, *Tetrahedron Lett.*, **28**, 2799 (1987); M. Leclaire, R. Levet, and J.-Y. Lallemand, *Synth. Commun.*, **23**, 1923 (1993).
- 19a. J. Fried in *Heterocyclic Compounds*, Vol. 1., R. C. Elderfield, ed., John Wiley, New York, 1950, p. 358.
- b. R. Charpurlat, J. Heret, and J. Druex, *Bull. Soc. Chim. Fr.*, 2446, 2450 (1967).
- c. A. Miyashita, Y. Matsuoka, A. Numata, and T. Higashino, *Chem. Pharm. Bull.*, **44**, 448 (1996).
- d. M. L. Quesada, R. H. Schlessinger, and W. H. Parsons, *J. Org. Chem.*, **43**, 3968 (1978).
- 20a. M. T. Reetz and K. Kesseler, *J. Org. Chem.*, **50**, 5434 (1985).
- b. J. Mulzer, A. Mantoulidis, and E. Oehler, *J. Org. Chem.*, **65**, 7456 (2000).
- c. J. G. Solsono, P. Romea, F. Urpi, and J. Vilarrasa, *Org. Lett.*, **5**, 519 (2003).
- d. I. Paterson and R. D. Tillyer, *J. Org. Chem.*, **58**, 4182 (1993).
- e. F. Kuo and P. L. Fuchs, *J. Am. Chem. Soc.*, **109**, 1122 (1987).
- f. M.-H. Filippini, R. Faure, and J. Rodriguez, *J. Org. Chem.*, **60**, 6872 (1995).
21. G. Koch, O. Loiseleur, D. Fuentes, A. Jantsch and K.-H. Altmann, *Org. Lett.*, **4**, 3811 (2002).
22. D. J. Gustin, M. S. Van Nieuwenhze, and W. R. Roush, *Tetrahedron Lett.*, **36**, 3443 (1995).
- 23a. S. F. Martin and D. E. Guinn, *J. Org. Chem.*, **52**, 5588 (1987).
- b. A. Armstrong, P. A. Barsanti, T. J. Blench, and R. Ogilvie, *Tetrahedron*, **59**, 367 (2003).
- c. A. K. Ghosh and J.-H. Kim, *Tetrahedron Lett.*, **43**, 5621 (2002); A. K. Ghosh and J.-H. Kim, *Tetrahedron Lett.*, **42**, 1227 (2001).
- d. M. Arai, N. Morita, S. Aoyagi, and C. Kibayashi, *Tetrahedron Lett.*, **41**, 1199 (2000).
- e. D. A. Evans, R. L. Dow, T. L. Shih, J. M. Takacs, and R. Zahler, *J. Am. Chem. Soc.*, **112**, 5290 (1990).
- f. N. Murakami, W. Wang, M. Aoki, Y. Tsutsui, M. Sugimoto, and M. Kobayashi, *Tetrahedron Lett.*, **39**, 2349 (1998).
- g. M. T. Crimmins and B. W. King, *J. Am. Chem. Soc.*, **120**, 9084 (1998).
- h. A. B. Smith and B. M. Brandt, *Org. Lett.*, **3**, 1685 (2001).
24. N. Langlois and H. S. Wang, *Synth. Commun.*, **27**, 3133 (1997).
25. A. Bassan, W. Zou, E. Reyes, F. Himo, and A. Cordova, *Angew. Chem. Int. Ed. Engl.*, **44**, 7028 (2005).

## Chapter 3

- 1a. M. E. Kuehne and J. C. Bohnert, *J. Org. Chem.*, **46**, 3443 (1981).
- b. B. C. Barot and H. W. Pinnick, *J. Org. Chem.*, **46**, 2981 (1981).
- c. T. Mukaiyama, S. Shoda, and Y. Watanabe, *Chem. Lett.*, 383 (1977).
- d. H. Loibner and E. Zbiral, *Helv. Chim. Acta*, **59**, 2100 (1976).
- e. E. J. Prisbe, J. Smejkal, J. P. H. Verheyden, and J. G. Moffatt, *J. Org. Chem.*, **41**, 1836 (1976).
- f. B. D. MacKenzie, M. M. Angelo, and J. Wolinsky, *J. Org. Chem.*, **44**, 4042 (1979).
- g. A. I. Meyers, R. K. Smith, and C. E. Whitten, *J. Org. Chem.*, **44**, 2250 (1979).
- h. W. A. Bonner, *J. Org. Chem.*, **32**, 2496 (1967).
- i. B. E. Smith and A. Burger, *J. Am. Chem. Soc.*, **75**, 5891 (1953).
- j. W. D. Klobucar, L. A. Paquette, and J. F. Blount, *J. Org. Chem.*, **46**, 4021 (1981).
- k. G. Grethe, V. Toome, H. L. Lee, M. Uskokovic, and A. Brossi, *J. Org. Chem.*, **33**, 504 (1968).
- l. B. Neiss and W. Steglich, *Org. Synth.*, **63**, 183 (1984).
2. A. W. Friederang and D. S. Tarbell, *J. Org. Chem.*, **33**, 3797 (1968).
3. H. R. Hudson and G. R. de Spinoza, *J. Chem. Soc. Perkin Trans. 1*, 104 (1976).
- 4a. L. A. Paquette and M. K. Scott, *J. Am. Chem. Soc.*, **94**, 6760 (1972).
- b. P. N. Confalone, G. Pizzolato, E. G. Baggolini, D. Lollar, and M. R. Uskokovic, *J. Am. Chem. Soc.*, **99**, 7020 (1977).
- c. E. L. Eliel, J. K. Koskimies, and B. Lohri, *J. Am. Chem. Soc.*, **100**, 1614 (1978).
- d. H. Hagiwara, M. Numata, K. Konishi, and Y. Oka, *Chem. Pharm. Bull.*, **13**, 253 (1965).

- e. A. S. Kende and T. P. Demuth, *Tetrahedron Lett.*, 715 (1980).  
 f. P. A. Grieco, D. S. Clark, and G. P. Withers, *J. Org. Chem.*, **44**, 2945 (1979).  
 g. J. Yu, J. R. Falck, and C. Mioskowski, *J. Org. Chem.*, **57**, 3757 (1992).  
 h. J. Freedman, M. J. Vaal, and E. W. Huber, *J. Org. Chem.*, **56**, 670 (1991).  
 5a,b,c. D. Seebach, H.-O. Kalinowski, B. Bastani, G. Crass, H. Daum, H. Dorr, N. P. DuPreez, W. Langer, C. Nussler, H.-A. Oei, and M. Schmidt, *Helv. Chim. Acta*, **60**, 301 (1977).  
 d. G. L. Baker, S. J. Fritschel, J. R. Stille, and J. K. Stille, *J. Org. Chem.*, **46**, 2954 (1981).  
 e. M. D. Fryzuk and B. Bosnich, *J. Am. Chem. Soc.*, **99**, 6262 (1977).  
 f. S. Hanessian and R. Frenette, *Tetrahedron Lett.*, 3391 (1979).  
 g. K. G. Paul, F. Johnson, and D. Favara, *J. Am. Chem. Soc.*, **98**, 1285 (1976).  
 h. S. D. Burke, J. Hong, J. R. Lennox, and A. P. Mongin, *J. Org. Chem.*, **63**, 6952 (1998).  
 i. G. Dujardin, S. Rossignol, and E. Brown, *Synthesis*, 763 (1998).  
 6a. E. J. Corey, J.-L. Gras, and P. Ulrich, *Tetrahedron Lett.*, 809 (1976).  
 b. K. C. Nicolaou, S. P. Seitz, and M. R. Pavia, *J. Am. Chem. Soc.*, **103**, 1222 (1981).  
 c. E. J. Corey and A. Venkateswarlu, *J. Am. Chem. Soc.*, **94**, 6190 (1972).  
 d.-f. H. H. Meyer, *Liebigs Ann. Chem.*, 732 (1977).  
 7a. P. Henley-Smith, D. A. Whiting, and A. F. Wood, *J. Chem. Soc. Perkin Trans. 1*, 614 (1980).  
 b. P. Beak and L. G. Carter, *J. Org. Chem.*, **46**, 2363 (1981).  
 c. M. E. Jung and T. J. Shaw, *J. Am. Chem. Soc.*, **102**, 6304 (1980).  
 d. P. N. Swepston, S.-T. Lin, A. Hawkins, S. Humphrey, S. Siegel, and A. W. Cordes, *J. Org. Chem.*, **46**, 3754 (1981).  
 e. P. J. Maurer and M. J. Miller, *J. Org. Chem.*, **46**, 2835 (1981).  
 f. N. A. Porter, J. D. Byers, A. E. Ali, and T. E. Eling, *J. Am. Chem. Soc.*, **102**, 1183 (1980).  
 g. G. A. Olah, B. G. B. Gupta, R. Malhotra, and S. C. Narang, *J. Org. Chem.*, **45**, 1638 (1980).  
 8a. A. K. Bose, B. Lal, W. Hoffman, III, and M. S. Manhas, *Tetrahedron Lett.*, 1619 (1973).  
 b. J. B. Hendrickson and S. M. Schwartzman, *Tetrahedron Lett.*, 277 (1975).  
 c. J. F. King, S. M. Loosmore, J. D. Lock, and M. Aslam, *J. Am. Chem. Soc.*, **100**, 1637 (1978); C. N. Sukenic, and R. G. Bergman, *J. Am. Chem. Soc.*, **98**, 6613 (1976).  
 d. R. S. Freedlander, T. A. Bryson, R. B. Dunlap, E. M. Schulman, and C. A. Lewis, Jr., *J. Org. Chem.*, **46**, 3519 (1981).  
 e. A. Trzeciak and W. Bannwarth, *Synthesis*, 1433 (1996).  
 f. L. M. Beacham, III, *J. Org. Chem.*, **44**, 3100 (1979).  
 9a. J. Jacobus, M. Raban, and K. Mislow, *J. Org. Chem.*, **33**, 1142 (1968).  
 b. M. Schmid and R. Barner, *Helv. Chim. Acta*, **62**, 464 (1979).  
 c. V. Eswarakrishnan and L. Field, *J. Org. Chem.*, **46**, 4182 (1981).  
 d. R. F. Borch, A. J. Evans, and J. J. Wade, *J. Am. Chem. Soc.*, **99**, 1612 (1977).  
 e. H. S. Aaron and C. P. Ferguson, *J. Org. Chem.*, **33**, 684 (1968).  
 10. B. Koppenhoeffer and V. Schuring, *Org. Synth.*, **66**, 151, 160 (1987).  
 11a. M. Miyashita, A. Yoshikoshi, and P. A. Grieco, *J. Org. Chem.*, **42**, 3772 (1977).  
 b. E. J. Corey, L. O. Wiegel, D. Floyd, and M. G. Bock, *J. Am. Chem. Soc.*, **100**, 2916 (1978).  
 c. A. M. Felix, E. P. Heimer, T. J. Lambros, C. Tzougraki, and J. Meienhofer, *J. Org. Chem.*, **43**, 4194 (1978).  
 d. P. N. Confalone, G. Pizzolato, E. G. Baggionlini, D. Lollar, and M. R. Uskokovic, *J. Am. Chem. Soc.*, **97**, 5936 (1975).  
 e. A. B. Foster, J. Lehmann, and M. Stacey, *J. Chem. Soc.*, 4649 (1961).  
 12. B. E. Watkins and H. Rapoport, *J. Org. Chem.*, **47**, 4471 (1982).  
 13. C. Ahn, R. Correia, and P. DeShong, *J. Org. Chem.*, **67**, 1751 (2002).  
 14. R. M. Magid, O. S. Fruchey, W. L. Johnson, and T. G. Allen, *J. Org. Chem.*, **44**, 359 (1979).  
 15a. D. M. Simonovic, A. S. Rao, and S. C. Bhattacharyya, *Tetrahedron*, **19**, 1061 (1963).  
 b. G. Buchi, W. D. MacLeod, Jr., and J. Padilla, *J. Am. Chem. Soc.*, **86**, 4438 (1964).  
 c. P. Doyle, I. R. Maclean, W. Parker, and R. A. Raphael, *Proc. Chem. Soc.*, 239 (1963).  
 d. J. C. Sheehan and K. R. Henery-Logan, *J. Am. Chem. Soc.*, **84**, 2983 (1962).  
 e. E. J. Corey, M. Ohno, R. B. Mitra, and P. A. Vatakencherry, *J. Am. Chem. Soc.*, **86**, 478 (1964).  
 16a. R. B. Woodward, R. A. Olofson, and H. Mayer, *Tetrahedron Suppl.*, **8**, 321 (1966); R. B. Woodward and R. A. Olofson, *J. Am. Chem. Soc.*, **83**, 1007 (1961).  
 b. B. Belleau and G. Malek, *J. Am. Chem. Soc.*, **90**, 1651 (1968).  
 17a. E. J. Corey, K. C. Nicolaou, and L. S. Melvin, Jr., *J. Am. Chem. Soc.*, **97**, 654 (1975).  
 b. J. Huang and J. Meinwald, *J. Am. Chem. Soc.*, **103**, 861 (1981).  
 c. P. Beak and L. G. Carter, *J. Org. Chem.*, **46**, 2363 (1981).

18. T. Mukaiyama, S. Shoda, T. Nakatsuka, and K. Narasaka, *Chem. Lett.*, 605 (1978).
19. R. U. Lemieux, K. B. Hendrik, R. V. Stick, and K. James, *J. Am. Chem. Soc.*, **97**, 4056 (1975).
- 20a. T. Mukaiyama, R. Matsueda, and M. Suzuki, *Tetrahedron Lett.*, 1901 (1970).
- b. E. J. Corey and D. A. Clark, *Tetrahedron Lett.*, 2875 (1979).
- 21a. J. Y. Lee and B. H. Kim, *Tetrahedron*, **52**, 571 (1996).
- b. J. Y. Lee and B. H. Kim, *Tetrahedron Lett.*, **36**, 3361 (1995); I. Fleming and S. K. Ghosh, *J. Chem. Soc., Chem. Commun.*, 2287 (1994).
- 22a. E. M. Acton, R. N. Goerner, H. S. Uh, K. J. Ryan, D. W. Henry, C. E. Cass, and G. A. LePage, *J. Med. Chem.*, **22**, 518 (1979).
- b. E. G. Gros, *Carbohydr. Res.*, **2**, 56 (1966).
- c. S. Hanessian and G. Rancourt, *Can. J. Chem.*, **55**, 1111 (1977).
- d. R. E. Schmidt and A. Gohl, *Chem. Ber.*, **112**, 1689 (1979).

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References for Problems

## Chapter 4

- 1a. N. Kharasch and C. M. Buess, *J. Am. Chem. Soc.*, **71**, 2724 (1949).
- b. A. J. Sisti, *J. Org. Chem.*, **33**, 3953 (1968).
- c. H. C. Brown and G. Zweifel, *J. Am. Chem. Soc.*, **83**, 1241 (1961).
- d. F. W. Fowler, A. Hassner, and L. A. Levy, *J. Am. Chem. Soc.*, **89**, 2077 (1967).
- e. A. Hassner and F. W. Fowler, *J. Org. Chem.*, **33**, 2686 (1968).
- f. A. Padwa, T. Blacklock, and A. Tremper, *Org. Synth.*, **57**, 83 (1977).
- g. I. Ryu, S. Murai, I. Niwa, and N. Sonoda, *Synthesis*, 874 (1977).
- h. R. A. Amos and J. A. Katzenellenbogen, *J. Org. Chem.*, **43**, 560 (1978).
- i. H. C. Brown and G. J. Lynch, *J. Org. Chem.*, **46**, 531 (1981).
- j. R. C. Cambie, R. C. Hayward, P. S. Rutledge, T. Smith-Palmer, B. E. Swedlund, and P. D. Woodgate, *J. Chem. Soc. Perkin Trans. 1*, 180 (1979).
- k. A. B. Holmes, K. Russell, E. S. Stern, M. E. Stubbs, and N. K. Wellard, *Tetrahedron Lett.*, **25**, 4163 (1984).
- l. N. S. Zefirov, T. N. Velikokhat'ko, and N. K. Sandovaya, *Zh. Org. Khim. (Engl. Transl.)*, **19**, 1407 (1983).
- m. F. B. Gonzalez and P. A. Bartlett, *Org. Synth.*, **64**, 175 (1985).
2. D. J. Pasto and J. A. Gontarz, *J. Am. Chem. Soc.*, **93**, 6902 (1971).
3. D. J. Pasto and J. A. Gontarz, *J. Am. Chem. Soc.*, **93**, 6902 (1971).
4. R. Gleiter and G. Mueller, *J. Org. Chem.*, **53**, 3912 (1988).
5. G. Stork and R. Borch, *J. Am. Chem. Soc.*, **86**, 935 (1964).
6. T. Hori and K. B. Sharpless, *J. Org. Chem.*, **43**, 1689 (1978).
- 7a. E. Kloster-Jensen, E. Kovats, A. Eschenmoser, and E. Heilbronner, *Helv. Chim. Acta*, **39**, 1051 (1956).
- b. P. N. Rao, *J. Org. Chem.*, **36**, 2426 (1971).
- c. R. A. Moss and E. Y. Chen, *J. Org. Chem.*, **46**, 1466 (1981).
- d. J. M. Jerkunica and T. G. Traylor, *Org. Synth.*, **53**, 94 (1973).
- e. G. Zweifel and C. C. Whitney, *J. Am. Chem. Soc.*, **89**, 2753 (1967).
- f. W. I. Fanta and W. F. Erman, *J. Org. Chem.*, **33**, 1656 (1968).
- g. W. E. Billups, J. H. Cross, and C. V. Smith, *J. Am. Chem. Soc.*, **95**, 3438 (1973).
- h. G. W. Kabalka and E. E. Gooch, III, *J. Org. Chem.*, **45**, 3578 (1980).
- i. E. J. Corey, G. Weiss, Y. B. Xiang, and A. K. Singh, *J. Am. Chem. Soc.*, **109**, 4717 (1987).
- j. W. Oppolzer, H. Hauth, P. Pfaffli, and R. Wenger, *Helv. Chim. Acta*, **60**, 1801 (1977).
- k. G. H. Posner and P. W. Tang, *J. Org. Chem.*, **43**, 4131 (1978).
- l. A. V. Bayquen and R. W. Read, *Tetrahedron*, **52**, 13467 (1996).
- m. T. Fukuyama and G. Liu, *J. Am. Chem. Soc.*, **118**, 7426 (1996).
- 8a. E. J. Corey and H. Estreicher, *J. Am. Chem. Soc.*, **100**, 6294 (1978).
- b. E. J. Corey and H. Estreicher, *Tetrahedron Lett.*, 1113 (1980).
- c. G. A. Olah and M. Nohima, *Synthesis*, 785 (1973).
9. D. J. Pasto and F. M. Klein, *Tetrahedron Lett.*, 963 (1967).
10. H. J. Reich, J. M. Renga, and J. L. Reich, *J. Am. Chem. Soc.*, **97**, 5434 (1975).
11. H. C. Brown, G. J. Lynch, W. J. Hammar, and L. C. Liu, *J. Org. Chem.*, **44**, 1910 (1979).
- 12a. R. Lavilla, O. Coll, M. Nicolas, and J. Bosch, *Tetrahedron Lett.*, **39**, 5089 (1998).

- b. A. Garofalo, M. B. Hursthouse, K. M. A. Malik, H. F. Olivio, S. M. Roberts, and V. Sik, *J. Chem. Soc. Perkin Trans. I*, 1311 (1994).
- c. H. Imagawa, T. Shigaraki, T. Suzuki, H. Takao, H. Yamada, T. Sugihara, and M. Nichizawa, *Chem. Pharm. Bull.*, **46**, 1341 (1998).
- d. A. G. Schultz and S. J. Kirmich, *J. Org. Chem.*, **61**, 5626 (1996).
- e. I. Fleming and N. J. Lawrence, *J. Chem. Soc. Perkin Trans. I*, 3309 (1992); 2679 (1998).
- f. R. Bittman, H.-S. Byun, K. C. Reddy, P. Samadder, and G. Arthur, *J. Med. Chem.*, **40**, 1391 (1997).
- g. P. A. Bartlett and J. Myerson, *J. Am. Chem. Soc.*, **100**, 3950 (1978).
- h. S. Terashima, M. Hayashi, and K. Koga, *Tetrahedron Lett.*, 2733 (1980).
- i. H. Bernsmann, R. Froehlich, and P. Metz, *Tetrahedron Lett.*, **41**, 4347 (2000).
- 13a. D. A. Evans, J. E. Ellman, and R. L. Dorow, *Tetrahedron Lett.*, **28**, 1123 (1987).
- b. K. C. Nicolaou, R. L. Magolda, W. J. Sipio, W. E. Barnette, Z. Lysenko, and M. M. Joullie, *J. Am. Chem. Soc.*, **102**, 3784 (1980).
- c. K. C. Nicolaou, W. E. Barnette, and R. L. Magolda, *J. Am. Chem. Soc.*, **103**, 3472 (1981).
- d. S. Knapp, A. T. Levorse, and J. A. Potenza, *J. Org. Chem.*, **53**, 4773 (1988).
- e. T. H. Jones and M. S. Blum, *Tetrahedron Lett.*, **22**, 4373 (1981).
- 14a. W. T. Smith and G. L. McLeod, *Org. Synth.*, **IV**, 345 (1963).
- b. K. E. Harding, T. H. Marman, and D. Nam, *Tetrahedron Lett.*, **29**, 1627 (1988).
15. A. Toshimitsu, K. Terao, and S. Uemura, *J. Org. Chem.*, **51**, 1724 (1986).
- 16a. W. Oppolzer and P. Dudfield, *Tetrahedron Lett.*, **26**, 5037 (1985).
- b. D. A. Evans, J. A. Ellman, and R. L. Dorow, *Tetrahedron Lett.*, **28**, 1123 (1987).
17. T. W. Bell, *J. Am. Chem. Soc.*, **103**, 1163 (1981).
- 18a. H. C. Brown and B. Singaram, *J. Am. Chem. Soc.*, **106**, 1797 (1984).
- b. S. Masamune, B. M. Kim, J. S. Petersen, T. Sato, S. J. Veenstra, and T. Imai, *J. Am. Chem. Soc.*, **107**, 4549 (1985).
19. C. F. Palmer, K. D. Parry, S. M. Roberts, and V. Sik, *J. Chem. Soc. Perkin Trans. I*, 1021 (1992); C. F. Palmer and R. McCague, *J. Chem. Soc. Perkin Trans. I*, 2977 (1998); A. Toyota, A. Nishimura, and C. Kaneko, *Heterocycles*, **45**, 2105 (1997).
- 20a. M. Noguchi, H. Okada, M. Watanabe, K. Okuda, and O. Nakamura, *Tetrahedron*, **52**, 6581 (1996).
- b. R. Madsen, C. Roberts, and B. Fraser-Reid, *J. Org. Chem.*, **60**, 7920 (1995).
21. M. E. Jung and U. Karama, *Tetrahedron Lett.*, **40**, 7907 (1999).
22. B. Fraser and P. Perlmutter, *J. Chem. Soc., Perkin Trans. I*, 2896 (2002).
23. M. J. Kurth and E. G. Brown, *J. Am. Chem. Soc.*, **109**, 6844 (1987); M. J. Kurth, R. L. Beard, M. Olmstead, and J. G. Macmillan, *J. Am. Chem. Soc.*, **111**, 3712 (1989); M. J. Kurth, E. G. Brown, E. J. Lewis, and J. C. McKew, *Tetrahedron Lett.*, **29**, 1517 (1988).
24. S. Bedford, G. Fenton, D. W. Knight, and D. E. Shaw, *J. Chem. Soc., Perkin Trans. I*, 1505 (1996).

## Chapter 5

- 1a. W. R. Roush, *J. Am. Chem. Soc.*, **102**, 1390 (1980).
- b. H. C. Brown, S. C. Kim, and S. Krishnamurthy, *J. Org. Chem.*, **45**, 1 (1980).
- c. G. W. Kabalka, D. T. C. Yang, and J. D. Baker, Jr., *J. Org. Chem.*, **41**, 574 (1976).
- d. J. K. Whitesell, R. S. Matthews, M. A. Minton, and A. M. Helbling, *J. Am. Chem. Soc.*, **103**, 3468 (1981).
- e. K. S. Kim, M. W. Spatz, and F. Johnson, *Tetrahedron Lett.*, 331 (1979).
- f. M.-H. Rei, *J. Org. Chem.*, **44**, 2760 (1979).
- g. R. O. Hutchins, D. Kandasamy, F. Dux, III, C. A. Maryanoff, D. Rolstein, B. Goldsmith, W. Burgoyne, F. Cistone, J. Dalessandro, and J. Puglis, *J. Org. Chem.*, **43**, 2259 (1978).
- h. H. Lindlar, *Helv. Chim. Acta*, **35**, 446 (1952).
- i. E. Vedejs, R. A. Buchanan, R. Conrad, G. P. Meier, M. J. Mullins, and Y. Watanabe, *J. Am. Chem. Soc.*, **109**, 5878 (1987).
- j. C. B. Jackson and G. Pattenden, *Tetrahedron Lett.*, **26**, 3393 (1985).
2. D. C. Wigfield and D. J. Phelps, *J. Am. Chem. Soc.*, **96**, 543 (1974).
- 3a. E. J. Corey, T. K. Schaaf, W. Huber, U. Koelliker, and N. M. Weinshenker, *J. Am. Chem. Soc.*, **92**, 397 (1970).
- b. E. J. Corey and R. Noyori, *Tetrahedron Lett.*, 311 (1970).
- c. R. F. Borch, *Org. Synth.*, **52**, 124 (1972).

- d. D. Seyferth and V. A. Mai, *J. Am. Chem. Soc.*, **92**, 7412 (1970).  
 e. R. V. Stevens and J. T. Lai, *J. Org. Chem.*, **37**, 2138 (1972).  
 f. M. J. Robins and J. S. Wilson, *J. Am. Chem. Soc.*, **103**, 932 (1981).  
 g. G. R. Pettit and J. R. Dias, *J. Org. Chem.*, **36**, 3207 (1971).  
 h. P. A. Grieco, T. Oguri, and S. Gilman, *J. Am. Chem. Soc.*, **102**, 5886 (1980).  
 i. M. F. Semmelhack, S. Tomoda, and K. M. Hurst, *J. Am. Chem. Soc.*, **102**, 7567 (1980).  
 j. H. C. Brown and P. Heim, *J. Org. Chem.*, **38**, 912 (1973).  
 k. R. O. Hutchins and N. R. Natale, *J. Org. Chem.*, **43**, 2299 (1978).  
 l. M. R. Detty and L. A. Paquette, *J. Am. Chem. Soc.*, **99**, 821 (1977).  
 m. C. A. Bunnell and P. L. Fuchs, *J. Am. Chem. Soc.*, **99**, 5184 (1977).  
 n. Y.-J. Wu and D. J. Burnell, *Tetrahedron Lett.*, **29**, 4369 (1988).  
 o. P. W. Collins, E. Z. Dajani, R. Pappo, A. F. Gasiecki, R. G. Bianchi, and E. M. Woods, *J. Med. Chem.*, **26**, 786 (1983).  
 4a. F. A. Carey, D. H. Ball, and L. Long, *Carbohydr. Res.*, **3**, 205 (1966).  
 b. D. J. Cram and R. A. Abd Elhafez, *J. Am. Chem. Soc.*, **74**, 5828 (1952).  
 c. R. N. Rej, C. Taylor, and G. Eadon, *J. Org. Chem.*, **45**, 126 (1980).  
 d. M. C. Dart and H. B. Henbest, *J. Chem. Soc.*, 3563 (1960).  
 e. E. Piers, W. de Waal, and R. W. Britton, *J. Am. Chem. Soc.*, **93**, 5113 (1971).  
 f. A. L. J. Beckwith and C. Easton, *J. Am. Chem. Soc.*, **100**, 2913 (1978).  
 g. D. Horton and W. Weckerle, *Carbohydr. Res.*, **44**, 227 (1975).  
 h. R. A. Holton and R. M. Kennedy, *Tetrahedron Lett.*, **28**, 303 (1987).  
 i. H. Iida, N. Yamazaki, and C. Kibayashi, *J. Org. Chem.*, **51**, 1069, 3769 (1986).  
 j. D. A. Evans and M. M. Morrisey, *J. Am. Chem. Soc.*, **106**, 3866 (1984).  
 k. N. A. Porter, C. B. Ziegler, Jr., F. F. Khouri, and D. H. Roberts, *J. Org. Chem.*, **50**, 2252 (1985).  
 l. G. Stork and D. E. Kahne, *J. Am. Chem. Soc.*, **105**, 1072 (1983).  
 m. Y. Yamamoto, K. Matsuoaka, and H. Nemoto, *J. Am. Chem. Soc.*, **110**, 4475 (1988).  
 n. G. Palmisano, B. Danieli, G. Lesma, D. Passerella, and L. Toma, *J. Org. Chem.*, **56**, 2380 (1991).  
 o. D. A. Evans, S. J. Miller, and M. D. Ennis, *J. Org. Chem.*, **58**, 471 (1993).  
 p. A. G. Schultz and N. J. Green, *J. Am. Chem. Soc.*, **113**, 4931 (1991).  
 q. R. Frenette, M. Monette, M. A. Bernstein, R. N. Young, and T. R. Verhoeven, *J. Org. Chem.*, **56**, 3083 (1991).  
 5a. D. Lenoir, *Synthesis*, 553 (1977).  
 b. J. A. Marshall and A. E. Greene, *J. Org. Chem.*, **36**, 2035 (1971).  
 c. B. M. Trost, Y. Nishimura, and K. Yamamoto, *J. Am. Chem. Soc.*, **101**, 1328 (1979); J. E. McMurry, A. Andrus, G. M. Ksander, J. H. Musser, and M. A. Johnson, *J. Am. Chem. Soc.*, **101**, 1330 (1979).  
 d. R. E. Ireland and C. S. Wilcox, *J. Org. Chem.*, **45**, 197 (1980).  
 e. P. G. Gassman and T. J. Atkins, *J. Am. Chem. Soc.*, **94**, 7748 (1972).  
 f. A. Gopalan and P. Magnus, *J. Am. Chem. Soc.*, **102**, 1756 (1980).  
 g. R. M. Coates, S. K. Shah, and R. W. Mason, *J. Am. Chem. Soc.*, **101**, 6765 (1979); Y.-K. Han and L. A. Paquette, *J. Org. Chem.*, **44**, 3731 (1979).  
 h. L. P. Kuhn, *J. Am. Chem. Soc.*, **80**, 5950 (1958).  
 i. R. P. Hatch, J. Shringarpure, and S. M. Weinreb, *J. Org. Chem.*, **43**, 4172 (1978).  
 j. T. Shono, Y. Matsumura, S. Kashimura, and H. Kyutoko, *Tetrahedron Lett.*, 1205 (1978).  
 6a,b. K. E. Wiegers and S. G. Smith, *J. Org. Chem.*, **43**, 1126 (1978).  
 c. D. C. Wigfield and F. W. Gowland, *J. Org. Chem.*, **45**, 653 (1980).  
 7. D. Caine and T. L. Smith, Jr., *J. Org. Chem.*, **43**, 755 (1978).  
 8. P. E. A. Dear and F. L. M. Pattison, *J. Am. Chem. Soc.*, **85**, 622 (1963).  
 9a. S. Danishefsky, M. Hirama, K. Gombatz, T. Harayama, E. Berman, and P. F. Schuda, *J. Am. Chem. Soc.*, **101**, 7020 (1979).  
 b. A. S. Kende, M. L. King, and D. P. Curran, *J. Org. Chem.*, **46**, 2826 (1981).  
 c. A. P. Kozikowski and A. Ames, *J. Am. Chem. Soc.*, **103**, 3923 (1981).  
 d. E. J. Corey, S. G. Pyre, and W. Su, *Tetrahedron Lett.*, **24**, 4883 (1983).  
 e. T. Rosen and C. Heathcock, *J. Am. Chem. Soc.*, **107**, 3731 (1985).  
 f. T. Fujisawa and T. Sato, *Org. Synth.*, **66**, 121 (1987).  
 g. H. J. Liu and M. G. Kulkarni, *Tetrahedron Lett.*, **26**, 4847 (1985).  
 h. D. A. Evans, S. J. Miller, and M. D. Ennis, *J. Org. Chem.*, **58**, 471 (1993).  
 i. D. L. J. Clive, K. S. K. Murthy, A. G. H. Wee, J. S. Prasad, G. V. J. da Silva, M. Majewski, P. C. Anderson, C. F. Evans, R. D. Haugen, L. D. Heerze, and J. R. Barrie, *J. Am. Chem. Soc.*, **112**, 3018 (1990).

- 10a. H. C. Brown and W. C. Dickason, *J. Am. Chem. Soc.*, **92**, 709 (1970).  
 b. D. Seyferth, H. Yamazaki, and D. L. Alleston, *J. Org. Chem.*, **28**, 703 (1963).  
 c. G. Stork and S. D. Darling, *J. Am. Chem. Soc.*, **82**, 1512 (1960).
- 11a. R. F. Borch, *Org. Synth.*, **52**, 124 (1972).  
 b. R. F. Borch, M. D. Bernstein, and H. D. Durst, *J. Am. Chem. Soc.*, **93**, 2897 (1971).
12. S.-K. Chung and F.-F. Chung, *Tetrahedron Lett.*, 2473 (1979).
- 13a. D. F. Taber, *J. Org. Chem.*, **41**, 2649 (1976).  
 b. D. R. Briggs and W. B. Whalley, *J. Chem. Soc., Perkin Trans. I*, 1382 (1976).  
 c. J. R. Flisak and S. S. Hall, *J. Am. Chem. Soc.*, **112**, 7299 (1990).
14. R. Yoneda, S. Harusawa, and T. Kurihara, *J. Org. Chem.*, **56**, 1827 (1991).
15. S. Kaneko, N. Nakajima, M. Shikano, T. Katoh, and S. Terashima, *Tetrahedron*, **54**, 5485 (1998).
- 16a. N. J. Leonard and S. Gelfand, *J. Am. Chem. Soc.*, **77**, 3272 (1955).  
 b. P. S. Wharton and D. H. Bohlen, *J. Org. Chem.*, **26**, 3615 (1961); W. R. Benn and R. M. Dodson, *J. Org. Chem.*, **29**, 1142 (1964).  
 c. G. Lardelli and O. Jeger, *Helv. Chim. Acta*, **32**, 1817 (1949).  
 d. R. J. Peterson and P. S. Skell, *Org. Synth.*, **V**, 929 (1973).
- 17a. N. M. Yoon, C. S. Pak, H. C. Brown, S. Krishnamurthy, and T. P. Stocky, *J. Org. Chem.*, **38**, 2786 (1973).  
 b. D. J. Dawson and R. E. Ireland, *Tetrahedron Lett.*, 1899 (1968).  
 c. R. O. Hutchins, C. A. Milewski, and B. A. Maryanoff, *J. Am. Chem. Soc.*, **95**, 3662 (1973).  
 d. M. J. Kornet, P. A. Thio, and S. I. Tan, *J. Org. Chem.*, **33**, 3637 (1968).  
 e. C. T. West, S. J. Donnelly, D. A. Kooistra, and M. P. Doyle, *J. Org. Chem.*, **38**, 2675 (1973).  
 f. M. R. Johnson and B. Rickborn, *J. Org. Chem.*, **35**, 1041 (1970).  
 g. N. Akubult and M. Balci, *J. Org. Chem.*, **53**, 3338 (1988).
18. H. Iida, N. Yamazaki, and C. Kibayashi, *J. Org. Chem.*, **51**, 3769 (1986).
- 19a. H. C. Brown, G. G. Pai, and P. K. Jadhav, *J. Am. Chem. Soc.*, **106**, 1531 (1984).  
 b. E. J. Corey, R. K. Bakshi, S. Shibata, C.-P. Chen, and V. K. Singh, *J. Am. Chem. Soc.*, **109**, 7925 (1987).  
 c. M. Srebnik, P. V. Ramachandran, and H. C. Brown, *J. Org. Chem.*, **53**, 2916 (1988).
- 20a. L. A. Paquette, T. J. Nitz, R. J. Ross, and J. P. Springer, *J. Am. Chem. Soc.*, **106**, 1446 (1984).  
 b. L. N. Mander and M. M. McLachlan, *J. Am. Chem. Soc.*, **125**, 2400 (2003).  
 c. S. Bhattacharyya and D. Mukherjee, *Tetrahedron Lett.*, **23**, 4175 (1982).
21. J. A. Marshall, *Acc. Chem. Res.*, **13**, 213 (1980); J. A. Marshall and K. E. Flynn, *J. Am. Chem. Soc.*, **106**, 723 (1984); J. A. Marshall, J. C. Peterson, and L. Lebioda, *J. Am. Chem. Soc.*, **106**, 6006 (1984).
- 22a. J. P. Guidot, T. Le Gall, and C. Mioskowski, *Tetrahedron Lett.*, **35**, 6671 (1994).  
 b. M. Schwaebe and R. D. Little, *J. Org. Chem.*, **61**, 3240 (1996).  
 c. T. Kan, S. Hosokawa, S. Naja, M. Oikawa, S. Ito, F. Matsuda, and H. Shirahama, *J. Org. Chem.*, **59**, 5532 (1994).  
 d. E. J. Enholm, H. Satici, and A. Trivellas, *J. Org. Chem.*, **54**, 5841 (1989).  
 e. E. J. Enholm and A. Trievellas, *Tetrahedron Lett.*, **35**, 1627 (1994).  
 f. J. E. Baldwin, S. C. M. Turner, and M. G. Moloney, *Tetrahedron Lett.*, **33**, 1517 (1992).
- 23a. R. N. Bream, S. V. Ley, B. McDermott, and P. A. Procopiou, *J. Chem. Soc., Perkin Trans. I*, 2237 (2002).  
 b. L. H. P. Teixeira, E. J. Barreiro, and C. A. M. Fraga, *Synth. Commun.*, **27**, 3241 (1997).

## Chapter 6

- 1a. B. M. Trost, S. A. Godleski, and J. P. Genet, *J. Am. Chem. Soc.*, **100**, 3930 (1978).  
 b. M. E. Jung and C. A. McCombs, *J. Am. Chem. Soc.*, **100**, 5207 (1978).  
 c. L. E. Overman, and P. J. Jessup, *J. Am. Chem. Soc.*, **100**, 5179 (1978).  
 d. C. Cupas, W. E. Watts, and P. v. R. Schleyer, *Tetrahedron Lett.*, 2503 (1964).  
 e. T. C. Jain, C. M. Banks, and J. E. McCloskey, *Tetrahedron Lett.*, 841 (1970).  
 f. G. Buchi and J. E. Powell, Jr., *J. Am. Chem. Soc.*, **89**, 4559 (1967).  
 g. M. Raban, F. B. Jones, Jr., E. H. Carlson, E. Banucci, and N. A. LeBel, *J. Org. Chem.*, **35**, 1497 (1970).  
 h. H. Yamamoto and H. L. Sham, *J. Am. Chem. Soc.*, **101**, 1609 (1979).  
 i. H. O. House, T. S. B. Sayer, and C.-C. Yau, *J. Org. Chem.*, **43**, 2153 (1978).

- j. M. C. Pirrung, *J. Am. Chem. Soc.*, **103**, 82 (1981).  
 k. M. Sevrin and A. Krief, *Tetrahedron Lett.*, 187 (1978).  
 l. L. A. Paquette, G. D. Crouse, and A. K. Sharma, *J. Am. Chem. Soc.*, **102**, 3972 (1980).  
 m. N.-K. Chan and G. Saucy, *J. Org. Chem.*, **42**, 3828 (1977).  
 n,o. J. A. Marshall and J. Lebreton, *J. Org. Chem.*, **53**, 4141 (1988).  
 p. F. A. J. Kerdesky, R. J. Ardecky, M. V. Lakshmikathan, and M. P. Cava, *J. Am. Chem. Soc.*, **103**, 1992 (1981).  
 q. B. B. Snider and R. A. H. F. Hui, *J. Org. Chem.*, **50**, 5167 (1985).  
 r. L. Lambs, N. P. Singh, and J.-F. Biellmann, *J. Org. Chem.*, **57**, 6301 (1992).  
 s. M. T. Reetz and E. H. Lauterbach, *Tetrahedron Lett.*, **32**, 4481 (1991).  
 t. B. Coates, D. Montgomery, and P. J. Stevenson, *Tetrahedron Lett.*, **32**, 4199 (1991).  
 u. K. Honda, S. Inoue, and K. Sato, *J. Org. Chem.*, **57**, 428 (1992).  
 v. D. Kim, S. K. Ahn, H. Bae, W. J. Choi, and H. S. Kim, *Tetrahedron Lett.*, **38**, 4437 (1997).  
 w. K. Tanaka, T. Imase, and S. Iwata, *Bull. Chem. Soc. Jpn.*, **69**, 2243 (1996).  
 2a. W. Oppolzer and M. Petržilka, *J. Am. Chem. Soc.*, **98**, 6722 (1976).  
 b. A. Padwa and N. Kamigata, *J. Am. Chem. Soc.*, **99**, 1871 (1977).  
 c. H. W. Gschwend, A. O. Lee, and H.-P. Meier, *J. Org. Chem.*, **38**, 2169 (1973).  
 d. J. L. Gras and M. Bertrand, *Tetrahedron Lett.*, 4549 (1979).  
 e. T. Kometani, M. Tsubuki, Y. Shiratori, H. Nemoto, M. Ihara, K. Fukumoto, F. Satoh, and H. Inoue, *J. Org. Chem.*, **42**, 2672 (1977).  
 3a. K. C. Brannock, A. Bell, R. D. Burpitt, and C. A. Kelly, *J. Org. Chem.*, **29**, 801 (1964).  
 b. K. Ogura, S. Furukawa, and G. Tsuchihashi, *J. Am. Chem. Soc.*, **102**, 2125 (1980).  
 c. E. Vedejs, M. J. Arco, D. W. Powell, J. M. Renga, and S. P. Singer, *J. Org. Chem.*, **43**, 4831 (1978).  
 d. J. J. Tufariello and J. J. Tegeler, *Tetrahedron Lett.*, 4037 (1976).  
 e. L. A. Paquette, *J. Org. Chem.*, **29**, 2851 (1964).  
 f. M. E. Monk and Y. K. Kim, *J. Am. Chem. Soc.*, **86**, 2213 (1964).  
 g. B. Cazes and S. Julia, *Bull. Soc. Chim. Fr.*, 925 (1977).  
 h. D. L. Boger and D. D. Mullican, *Org. Synth.*, **65**, 98 (1987).  
 4a. P. E. Eaton and U. R. Chakraborty, *J. Am. Chem. Soc.*, **100**, 3634 (1978).  
 b. H. Hogeweijn and B. J. Nusse, *J. Am. Chem. Soc.*, **100**, 3110 (1978).  
 c. T. Oida, S. Tanimoto, T. Sugimoto, and M. Okano, *Synthesis*, 131 (1980).  
 d. J. N. Labovitz, C. A. Henrick, and V. L. Corbin, *Tetrahedron Lett.*, 4209 (1975).  
 e. W. Steglich and L. Zechlin, *Chem. Ber.*, **111**, 3939 (1978).  
 f. F. D. Lewis and R. J. DeVoe, *J. Org. Chem.*, **45**, 948 (1980).  
 g. S. P. Tanis and K. Nakanishi, *J. Am. Chem. Soc.*, **101**, 4398 (1979).  
 h. S. Danishefsky, M. P. Prisbylla, and S. Hiner, *J. Am. Chem. Soc.*, **100**, 2918 (1978).  
 i. T. Hudlicky, F. J. Kosyk, T. M. Kutchan, and J. P. Sheth, *J. Org. Chem.*, **45**, 5020 (1980).  
 j. G. Li, Z. Li, and X. Fang, *Synth. Commun.*, **26**, 2569 (1996).  
 k. C. Chen and D. J. Hart, *J. Org. Chem.*, **55**, 6236 (1990).  
 l. S. Chackalamannil, R. J. Davis, Y. Wang, T. Asberom, D. Doller, J. Wong, D. Leone, and A. T. McPhail, *J. Org. Chem.*, **64**, 1932 (1999).  
 5a. R. Schug and R. Huisgen, *J. Chem. Soc., Chem. Commun.*, 60 (1975).  
 b. N. Shimizu, M. Ishikawa, K. Ishikura, and S. Nishida, *J. Am. Chem. Soc.*, **96**, 6456 (1974).  
 c. W. L. Howard and N. B. Loretta, *Org. Synth.*, **V**, 25 (1973).  
 d. J. Wolinsky and P. B. Login, *J. Org. Chem.*, **35**, 3205 (1970).  
 6a. S. Danishefsky, M. Hirama, N. Fitsch, and J. Clardy, *J. Am. Chem. Soc.*, **101**, 7013 (1979).  
 b. D. A. Evans, C. A. Bryan, and C. L. Sims, *J. Am. Chem. Soc.*, **94**, 2891 (1972).  
 7. J. C. Gilbert and P. D. Selliah, *J. Org. Chem.*, **58**, 6255 (1993).  
 8. B. Bichan and M. Winnik, *Tetrahedron Lett.*, 3857 (1974).  
 9a. R. A. Carboni and R. V. Lindsey, Jr., *J. Am. Chem. Soc.*, **81**, 4342 (1969).  
 b. L. A. Carpino, *J. Am. Chem. Soc.*, **84**, 2196 (1962); **85**, 2144 (1963).  
 10a. S. Hanessian, P. J. Roy, M. Petrini, P. J. Hodges, R. Di Fabio, and G. Carganico, *J. Org. Chem.*, **55**, 5766 (1990).  
 b. W. R. Roush and B. B. Brown, *J. Am. Chem. Soc.*, **115**, 2268 (1993).  
 c. J. W. Coe and W. R. Roush, *J. Org. Chem.*, **54**, 915 (1989).  
 11a. D. L. J. Clive, G. Chittattu, N. J. Curtis, and S. M. Menchen, *J. Chem. Soc., Chem. Commun.*, 770 (1978).  
 b. B. W. Metcalf, P. Bey, C. Danzin, M. J. Jung, P. Casara, and J. P. Veveri, *J. Am. Chem. Soc.*, **100**, 2551 (1978).

- c. T. Cohen, Z. Kosarych, K. Suzuki, and L.-C. Yu, *J. Org. Chem.*, **50**, 2965 (1985).
- d. T. Cohen, M. Bhupathy, and J. R. Matz, *J. Am. Chem. Soc.*, **105**, 520 (1983).
- e. R. G. Shea, J. N. Fitzner, J. E. Farkhauser, A. Spaltenstein, P. A. Carpino, R. M. Peevey, D. V. Pratt, B. J. Tenge, and P. B. Hopkins, *J. Org. Chem.*, **51**, 5243 (1986).
- f. R. L. Funk, P. M. Novak, and M. M. Abelman, *Tetrahedron Lett.*, **29**, 1493 (1988).
- g. C. H. Cummins and R. M. Coates, *J. Org. Chem.*, **51**, 1383 (1986).
- h. K. Ogura, S. Furukawa, and G. Tsuchihashi, *J. Am. Chem. Soc.*, **102**, 2125 (1980).
- i. H. F. Schmitthenner and S. M. Weinreb, *J. Org. Chem.*, **43**, 3372 (1980).
- j. R. A. Gibbs and W. H. Okamura, *J. Am. Chem. Soc.*, **110**, 4062 (1988).
- k. E. Vedejs, J. D. Rodgers, and S. J. Wittenberger, *J. Am. Chem. Soc.*, **110**, 4822 (1988).
- l. J. Ahman, T. Jarevang, and P. I. Somfai, *J. Org. Chem.*, **61**, 8148 (1996).
- m. E. Vedejs and M. Gingras, *J. Am. Chem. Soc.*, **116**, 579 (1994).
- 12a. N. Ono, A. Kanimura, A. Kaji, *Tetrahedron Lett.*, **27**, 1595 (1986).
- b. R. V. C. Carr, R. V. Williams, and L. A. Paquette, *J. Org. Chem.*, **48**, 4976 (1983).
- c. C. H. DePuy and P. R. Story, *J. Am. Chem. Soc.*, **82**, 627 (1960).
- d. S. Ranganathan, D. Ranganathan, and R. Iyengar, *Tetrahedron*, **32**, 961 (1976).
- 13a. D. J. Faulkner and M. R. Peterson, *J. Am. Chem. Soc.*, **95**, 553 (1973).
- b. N. A. LeBel, N. D. Ojha, J. R. Menke, and R. J. Newland, *J. Org. Chem.*, **37**, 2896 (1972).
- c. G. Buchi and H. Wuest, *J. Am. Chem. Soc.*, **96**, 7573 (1974).
- d. C. A. Henrick, F. Schaub, and J. B. Siddall, *J. Am. Chem. Soc.*, **94**, 5374 (1972).
- e. R. E. Ireland and R. H. Mueller, *J. Am. Chem. Soc.*, **94**, 5897 (1972).
- f. E. J. Corey, R. B. Mitra, and H. Uda, *J. Am. Chem. Soc.*, **86**, 485 (1964).
- g. R. E. Ireland, P. A. Aristoff, and C. F. Hoyng, *J. Org. Chem.*, **44**, 4318 (1979).
- h. W. Sucrow, *Angew. Chem. Int. Ed. Engl.*, **7**, 629 (1968).
- i. O. P. Vig, K. L. Matta, and I. Raj, *J. Indian Chem. Soc.*, **41**, 752 (1964).
- j. W. Nagata, S. Hirai, T. Okumura, and K. Kawata, *J. Am. Chem. Soc.*, **90**, 1650 (1968).
- k. H. O. House, J. Lubinkowski, and J. J. Good, *J. Org. Chem.*, **40**, 86 (1975).
- l. L. A. Paquette, G. D. Grouse, and A. K. Sharma, *J. Am. Chem. Soc.*, **102**, 3972 (1980).
- m. R. L. Funk and G. L. Bolton, *J. Org. Chem.*, **49**, 5021 (1984).
- n. A. P. Kozikowski and C.-S. Li, *J. Org. Chem.*, **52**, 3541 (1987).
- o. B. M. Trost and A. C. Lavoie, *J. Am. Chem. Soc.*, **105**, 5075 (1983).
- p. A. P. Marchand, S. C. Suri, A. D. Earlywine, D. R. Powell, and D. van der Helm, *J. Org. Chem.*, **49**, 670 (1984).
- q. M. Kodoma, Y. Shiobara, H. Sumitomo, K. Fukuzumi, H. Minami, and Y. Miyamoto, *J. Org. Chem.*, **53**, 1437 (1988).
- r. K. M. Werner, J. M. de los Santos, and S. M. Weinreb, *J. Org. Chem.*, **64**, 686 (1999).
- s. D. Perez, G. Bures, F. Guittan, and L. Castedo, *J. Org. Chem.*, **61**, 1650 (1996).
- t. A. K. Mapp and C. H. Heathcock, *J. Org. Chem.*, **64**, 23 (1999).
- 14a. L. A. Paquette, S. K. Huber, and R. C. Thompson, *J. Org. Chem.*, **58**, 6874 (1993).
- b. R. L. Funk, T. Olmstead, M. Parvez, and J. B. Stallmann, *J. Org. Chem.*, **58**, 5873 (1993).
- 15a. J. J. Turfariello, A. S. Milowsky, M. Al-Nuri, and S. Goldstein, *Tetrahedron Lett.*, **28**, 263 (1987).
- b. G. H. Posner, A. Haas, W. Harrison, and C. M. Kinter, *J. Org. Chem.*, **52**, 4836 (1987).
- c. F. E. Ziegler, A. Nangia, and G. Schulte, *J. Am. Chem. Soc.*, **109**, 3987 (1987).
- d. M. P. Edwards, S. V. Ley, S. G. Lister, B. D. Palmer, and D. J. Williams, *J. Org. Chem.*, **49**, 3503 (1984).
- e. R. E. Ireland and M. D. Varney, *J. Org. Chem.*, **48**, 1829 (1983).
- f. D. J.-S. Tsai and M. M. Midland, *J. Am. Chem. Soc.*, **107**, 3915 (1985).
- g. E. Vedejs, J. M. Dolphin, and H. Mastalerz, *J. Am. Chem. Soc.*, **105**, 127 (1983).
- h. T. Zoller, D. Uguen, A. DeCian, J. Fischer, and S. Sable, *Tetrahedron Lett.*, **38**, 3409 (1997).
- i. L. Grimaud, J.-P. Ferezou, J. Prunet, and J. Y. Lallemand, *Tetrahedron*, **53**, 9253 (1997).
- j. P. M. Wovkulich, K. Shankaran, J. Kliegiel, and M. R. Uskokovic, *J. Org. Chem.*, **58**, 832 (1993).
- k. P. A. Grieco and M. D. Kaufman, *Tetrahedron Lett.*, **40**, 1265 (1999); P. Grieco and Y. Dai, *J. Am. Chem. Soc.*, **120**, 5128 (1998).
- l. M. E. Jung and B. T. Vu, *J. Org. Chem.*, **61**, 4427 (1996).
16. S. Cossu, S. Battaggia, and O. De Lucchi, *J. Org. Chem.*, **62**, 4162 (1997).
- 17a. K. Nomura, K. Okazaki, H. Hori, and E. Yoshii, *Chem. Pharm. Bull.*, **34**, 3175 (1996).
- b. Y. Tamura, M. Sasho, K. Nakagawa, T. Tsugoshi, and Y. Kita, *J. Org. Chem.*, **49**, 473 (1984).
18. S. D. Burke, D. M. Armistead, and K. Shankaran, *Tetrahedron Lett.*, **27**, 6295 (1986).
- 19a. C. Siegel and E. R. Thornton, *Tetrahedron Lett.*, **29**, 5225 (1988).

- b. D. P. Curran, B. H. Kim, J. Daugherty, and T. A. Heffner, *Tetrahedron Lett.*, **29**, 3555 (1988).  
c. H. Waldmann, *J. Org. Chem.*, **53**, 6133 (1988).

- 20a. T.-Z. Wang, E. Pinard, and L. A. Paquette, *J. Am. Chem. Soc.*, **118**, 1309 (1996).  
b. L. Morency and L. Barriault, *Tetrahedron Lett.*, **45**, 6105 (2004).  
c. L. Barriault, P. J. A. Ang, and R. M. A. Lavigne, *Org. Lett.*, **6**, 1317 (2004).  
d. G. A. Kraus and S. H. Woo, *J. Org. Chem.*, **52**, 4841 (1987).  
21. D. A. Evans, D. M. Barnes, J. S. Johnson, T. Lectka, P. von Matt, S. J. Miller, J. A. Murry, R. D. Norcross, E. A. Shaughnessy, and K. R. Campos, *J. Am. Chem. Soc.*, **121**, 7582 (1999).  
22. T. B. H. McMurry, A. Work, and B. McKenna, *J. Chem. Soc., Perkin Trans. I*, 811 (1991).  
23. K. Mori, T. Tashiro, and S. Sano, *Tetrahedron Lett.*, **41**, 5243 (2000); T. Tashiro, M. Bando, and K. Mori, *Synthesis*, 1852 (2000).  
24. A. S. Raw and E. B. Jang, *Tetrahedron Lett.*, **56**, 3285 (2000).

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References for Problems

## Chapter 7

- 1a. H. Neumann and D. Seebach, *Tetrahedron Lett.*, 4839 (1976).  
b. P. Canonne, G. Foscolos, and G. Lemay, *Tetrahedron Lett.*, **21**, 155 (1980).  
c. T. L. Shih, M. Wyvratt, and H. Mrozik, *J. Org. Chem.*, **52**, 2029 (1987).  
d. G. M. Rubottom and C. Kim, *J. Org. Chem.*, **48**, 1550 (1983).  
e. S. L. Buchwald, B. T. Watson, R. T. Lum, and W. A. Nugent, *J. Am. Chem. Soc.*, **109**, 7137 (1987); P. D. Brewer, J. Tagat, C. A. Hergueter, and P. Helquist, *Tetrahedron Lett.*, 4573 (1977).  
f. T. Okazoe, K. Takai, K. Oshima, and K. Utimoto, *J. Org. Chem.*, **52**, 4410 (1987).  
g. J. W. Frankenfeld and J. J. Werner, *J. Org. Chem.*, **34**, 3689 (1969).  
h. E. R. Burkhardt and R. D. Rieke, *J. Org. Chem.*, **50**, 416 (1985).  
i. G. Veeresa and A. Datta, *Tetrahedron*, **54**, 15673 (1998).  
2. R. W. Herr and C. R. Johnson, *J. Am. Chem. Soc.*, **92**, 4979 (1970).  
3a. J. S. Sawyer, A. Kucerovy, T. L. Macdonald, and G. J. McGarvey, *J. Am. Chem. Soc.*, **110**, 842 (1988).  
b. T. Cohen and J. R. Matz, *J. Am. Chem. Soc.*, **102**, 6900 (1980).  
c. C. R. Johnson and J. R. Medlich, *J. Org. Chem.*, **53**, 4131 (1988).  
d. B. M. Trost and T. N. Nanninga, *J. Am. Chem. Soc.*, **107**, 1293 (1985).  
e. T. Morwick, *Tetrahedron Lett.*, **21**, 3227 (1980).  
f. R. F. Cunio and F. J. Clayton, *J. Org. Chem.*, **41**, 1480 (1976).  
4a. J. J. Fitt and H. W. Gschwend, *J. Org. Chem.*, **45**, 4258 (1980).  
b. S. Akiyama and J. Hooz, *Tetrahedron Lett.*, 4115 (1973).  
c. K. P. Klein and C. R. Hauser, *J. Org. Chem.*, **32**, 1479 (1967).  
d. B. M. Graybill and D. A. Shirley, *J. Org. Chem.*, **31**, 1221 (1966).  
e. M. M. Midland, A. Tramontano, and J. R. Cable, *J. Org. Chem.*, **45**, 28 (1980).  
f. W. Fuhrer and H. W. Gschwend, *J. Org. Chem.*, **44**, 1133 (1979).  
g. D. F. Taber and R. W. Korsmeyer, *J. Org. Chem.*, **43**, 4925 (1978).  
h. B. A. Feit, U. Melamed, R. R. Schmidt, and H. Speer, *Tetrahedron*, **37**, 2143 (1981).  
i. R. M. Carlson, *Tetrahedron Lett.*, 111 (1978).  
j. R. J. Sundberg, R. Broome, C. P. Walters, and D. Schnur, *J. Heterocycl. Chem.*, **18**, 807 (1981).  
k. J. J. Eisch and J. N. Shah, *J. Org. Chem.*, **56**, 2955 (1991).  
l. G. P. Crowther, R. J. Sundberg, and A. M. Sarapeshkar, *J. Org. Chem.*, **49**, 4657 (1984).  
5a. M. P. Dreyfuss, *J. Org. Chem.*, **28**, 3269 (1963).  
b. P. J. Pearce, D. H. Richards, and N. F. Scilly, *Org. Synth.*, **VI**, 240 (1988).  
c. U. Schollkopf, H. Kuppers, H.-J. Traencker, and W. Pitteroff, *Liebigs Ann. Chem.*, **704**, 120 (1967); A. Duchene, D. Mouko-Mpegna, J. P. Quintard, *Bull. Soc. Chim. Fr.*, 787 (1985).  
d. J. V. Hay and T. M. Harris, *Org. Synth.*, **VI**, 478 (1988).  
e. F. Sato, M. Inoue, K. Oguro, and M. Sato, *Tetrahedron Lett.*, 4303 (1979).  
f. J. C. H. Hwa and H. Sims, *Org. Synth.*, **V**, 608 (1973).  
6a. J. H. Rigby and C. Senanyake, *J. Am. Chem. Soc.*, **109**, 3147 (1987).  
b. K. Takai, Y. Kataoka, T. Okazoe, and K. Utimoto, *Tetrahedron Lett.*, **29**, 1065 (1988).  
c. E. Nakamura, S. Aoki, K. Sekiya, H. Oshino, and I. Kuwajima, *J. Am. Chem. Soc.*, **109**, 8056 (1987).  
d. H. A. Whaley, *J. Am. Chem. Soc.*, **93**, 3767 (1971).  
7. J. Barluenga, F. J. Fananas, and M. Yus, *J. Org. Chem.*, **44**, 4798 (1979).

- 8a,b. W. C. Still and J. H. MacDonald, III, *Tetrahedron Lett.*, **21**, 1031 (1980).
- c. E. Casadevall and Y. Pouet, *Tetrahedron Lett.*, 2841 (1976).
9. P. Beak, J. E. Hunter, Y. M. Jan, and A. P. Wallin, *J. Am. Chem. Soc.*, **109**, 5403 (1987).
10. C. J. Kowalski, and M. S. Haque, *J. Org. Chem.*, **50**, 5140 (1985).
11. C. Fehr, J. Galindo, and R. Perret, *Helv. Chim. Acta*, **70**, 1745 (1987).
- 12a. M. P. Cooke, Jr., and I. N. Houpis, *Tetrahedron Lett.*, **26**, 4987 (1985).
- b. E. Piers and P. C. Marais, *Tetrahedron Lett.*, **29**, 4053 (1988).
- 13a. C. Phillips, R. Jacobson, B. Abrahams, H. J. Williams, and C. R. Smith, *J. Org. Chem.*, **45**, 1920 (1980).
- b. T. Cohen and J. R. Matz, *J. Am. Chem. Soc.*, **102**, 6900 (1980).
- c. T. R. Govindachari, P. C. Parthasarathy, H. K. Desai, and K. S. Ramachandran, *Indian J. Chem.*, **13**, 537 (1975).
- d. W. C. Still, *J. Am. Chem. Soc.*, **100**, 1481 (1978).
- e. E. J. Corey and D. R. Williams, *Tetrahedron Lett.*, 3847 (1977).
- f. T. Okazoe, K. Takai, K. Oshima, and K. Utimoto, *J. Org. Chem.*, **52**, 4410 (1987).
- g. M. A. Adams, A. J. Duggan, J. Smolanoff, and J. Meinwald, *J. Am. Chem. Soc.*, **101**, 5364 (1979).
- h. S. O. de Silva, M. Watanabe, and V. Snieckus, *J. Org. Chem.*, **44**, 4802 (1979).
14. M. Kitamura, S. Suga, K. Kawai, and R. Noyori, *J. Am. Chem. Soc.*, **108**, 6071 (1986); K. Soai, A. Ookawa, T. Kaba, and K. Ogawa, *J. Am. Chem. Soc.*, **109**, 7111 (1987); M. Kitamura, S. Okada, and R. Noyori, *J. Am. Chem. Soc.*, **111**, 4028 (1989); T. Rasmussen and P.-O. Norrby, *J. Am. Chem. Soc.*, **125**, 5130 (2003).
15. W.-L. Cheng, Y.-J. Shaw, S.-M. Yeh, P. P. Kanakamma, Y.-H. Chen, C. Chen, J.-C. Shieh, S.-J. Yiin, G.-H. Lee, Y. Wang, and T.-Y Luh, *J. Org. Chem.*, **64**, 532 (1999).
- 17a. R. F. W. Jackson, I. Rilatt, and P. J. Murry, *Chem. Commun.*, 1242 (2003).
- b. M. I. Calaza, M. R. Paleo, and F. J. Sardina, *J. Am. Chem. Soc.*, **123**, 2095 (2001).

## Chapter 8

- 1a. C. Huynh, F. Derguini-Boumechal, and G. Linstrumelle, *Tetrahedron Lett.*, 1503 (1979).
- b. N. J. LaLima, Jr., and A. B. Levy, *J. Org. Chem.*, **43**, 1279 (1978).
- c. A. Cowell and J. K. Stille, *J. Am. Chem. Soc.*, **102**, 4193 (1980).
- d. T. Sato, M. Kawashima, and T. Fujisawa, *Tetrahedron Lett.*, 2375 (1981).
- e. H. P. Dang and G. Linstrumelle, *Tetrahedron Lett.*, 191 (1978).
- f. B. M. Trost and D. P. Curran, *J. Am. Chem. Soc.*, **102**, 5699 (1980).
- g. D. J. Pasto, S.-K. Chou, E. Fritzen, R. H. Shults, A. Waterhouse, and G. F. Hennion, *J. Org. Chem.*, **43**, 1389 (1978).
- h. B. H. Lipshutz, J. Kozlowski, and R. S. Wilhelm, *J. Am. Chem. Soc.*, **104**, 2305 (1982).
- i. P. A. Grieco and C. V. Srinivasan, *J. Org. Chem.*, **46**, 2591 (1981).
- j. C. Iwata, K. Suzuki, S. Aoki, K. Okamura, M. Yamashita, I. Takahashi, and T. Tanaka, *Chem. Pharm. Bull.*, **34**, 4939 (1988).
- k. A. Alexakis, G. Cahiez, and J. F. Normant, *Org. Synth.*, **VII**, 290 (1990).
- l. J. Tsuji, Y. Kobayashi, H. Kataoka, and T. Takahashi, *Tetrahedron Lett.*, **21**, 1475 (1980).
- m. W. A. Nugent and R. J. McKinney, *J. Org. Chem.*, **50**, 5370 (1985).
- n. R. M. Wilson, K. A. Schnapp, R. K. Merwin, R. Ranganathan, D. L. Moats, and T. T. Conrad, *J. Org. Chem.*, **51**, 4028 (1986).
- o. L. N. Pridgen, *J. Org. Chem.*, **47**, 4319 (1982).
- p. R. Casas, C. Cave, and J. d'Angelo, *Tetrahedron Lett.*, **36**, 1039 (1995).
- q. N. Miyaura, K. Yamada, and A. Suzuki, *Tetrahedron Lett.*, 3437 (1979).
- r. F. K. Steffy, J. P. Godschalk, and J. K. Stille, *J. Am. Chem. Soc.*, **106**, 4833 (1984).
- 2a. B. H. Lipshutz, M. Koerner, and D. A. Parker, *Tetrahedron Lett.*, **28**, 945 (1987).
- b. B. H. Lipshutz, R. S. Wilhelm, J. A. Kozlowski, and D. Parker, *J. Org. Chem.*, **49**, 3928 (1984).
- c. J. P. Marino, R. Fernandez de la Pradilla, and E. Laborde, *J. Org. Chem.*, **52**, 4898 (1987).
- d. C. R. Johnson and D. S. Dhanoa, *J. Org. Chem.*, **52**, 1885 (1987).
- 3a. H. Urata, A. Fujita, and T. Fuchikami, *Tetrahedron Lett.*, **29**, 4435 (1988).
- b. Y. Itoh, H. Aoyama, T. Hirao, A. Mochizuki, and T. Saegusa, *J. Am. Chem. Soc.*, **101**, 494 (1979).
- c. P. G. M. Wuts, M. L. Obrzut, and P. A. Thompson, *Tetrahedron Lett.*, **25**, 4051 (1984).
- d. K. Kokubo, K. Matsumasa, M. Miura, and M. Nomura, *J. Org. Chem.*, **61**, 6941 (1996).

- e. S. T. Diver and A. J. Giessert, *Synthesis*, 466 (2004).
- 4a. R. J. Anderson, V. L. Corbin, G. Cotterrel, G. R. Cox, C. A. Henrick, F. Schaub, and J. B. Siddall, *J. Am. Chem. Soc.*, **97**, 1197 (1975).
- b. P. de Mayo, L. K. Sydnes, and G. Wenska, *J. Org. Chem.*, **45**, 1549 (1980).
- c. Y. Yamamoto, H. Yatagai, and K. Maruyama, *J. Org. Chem.*, **44**, 1744 (1979).
- d. H. Shostarez and L. A. Paquette, *J. Am. Chem. Soc.*, **103**, 722 (1981).
- e. W. G. Dauben, G. H. Beasley, M. D. Broadhurst, B. Muller, D. J. Peppard, P. Pesnelle, and C. Suter, *J. Am. Chem. Soc.*, **97**, 4973 (1975).
- f. L. Watts, J. D. Fitzpatrick, and R. Pettit, *J. Am. Chem. Soc.*, **88**, 623 (1966).
- g. J. I. Kim, B. A. Patel, and R. F. Heck, *J. Org. Chem.*, **46**, 1067 (1981).
- h. J. A. Marshall, W. F. Huffman, and J. A. Ruth, *J. Am. Chem. Soc.*, **94**, 4691 (1972).
- i. H.-A. Hasseberg and H. Gerlach, *Helv. Chim. Acta*, **71**, 957 (1988).
- j. R. Alvarez, M. Herrero, S. Lopez, and A. R. de Lera, *Tetrahedron*, **54**, 6793 (1998).
- k. T. K. Chakraborty and D. Thippeswamy, *Synlett*, 150 (1999).
- l. S. Jinno, T. Okita, and K. Inoyue, *Bioorg. Med. Chem. Lett.*, **9**, 1029 (1999).
- m. J. Thibonnet, M. Abarbi, A. Duchene, and J.-L. Parrain, *Synlett*, 141 (1999).
- n. G. Giambastiani and G. Poli, *J. Org. Chem.*, **63**, 9608 (1998).
- o. N. Miyaura, K. Yamada, H. Sugino, and A. Suzuki, *J. Am. Chem. Soc.*, **107**, 972 (1985).
- p. S. Nakamura, Y. Hirata, T. Kurosaki, M. Anada, O. Kataoka, S. Kitagaki, and S. Hashimoto, *Angew. Chem. Int. Ed. Engl.*, **42**, 5351 (2003).
5. B. O'Connor and G. Just, *J. Org. Chem.*, **52**, 1801 (1987); G. Just and B. O'Connor, *Tetrahedron Lett.*, **26**, 1799 (1985).
6. B. H. Lipshutz, R. S. Wilhelm, J. A. Kozlowski, and D. Parker, *J. Org. Chem.*, **49**, 3928 (1984); E. C. Ashby, R. N. DePriest, A. Tuncay, and S. Srivasta, *Tetrahedron Lett.*, **23**, 5251 (1982).
- 7a. C. G. Chavdarian and C. H. Heathcock, *J. Am. Chem. Soc.*, **97**, 3822 (1975).
- b. E. J. Corey and J. G. Smith, *J. Am. Chem. Soc.*, **101**, 1038 (1977).
- c. G. Mehta and K. S. Rao, *J. Am. Chem. Soc.*, **108**, 8015 (1986).
- d. W. A. Nugent and F. W. Hobbs, Jr., *Org. Synth.*, **66**, 52 (1988).
- e. G. F. Cooper, D. L. Wren, D. Y. Jackson, C. C. Beard, E. Galeazzi, A. R. Van Horn, and T. T. Li, *J. Org. Chem.*, **58**, 4280 (1993).
- f. R. K. Dieter, J. W. Dieter, C. W. Alexander, and N. S. Bhinderwala, *J. Org. Chem.*, **61**, 2930 (1996).
- g. C. R. Johnson and T. D. Penning, *J. Am. Chem. Soc.*, **110**, 4726 (1988).
- h. T. Hudlicky and H. F. Olivo, *J. Am. Chem. Soc.*, **114**, 9694 (1992).
- 8a. C. M. Lentz and G. H. Posner, *Tetrahedron Lett.*, 3769 (1978).
- b. A. Marfat, P. R. McGuirk, R. Kramer, and P. Helquist, *J. Am. Chem. Soc.*, **99**, 253 (1977).
- c. L. A. Paquette and Y.-K. Han, *J. Am. Chem. Soc.*, **103**, 1831 (1981).
- d. A. Alexakis, J. Berlan, and Y. Besace, *Tetrahedron Lett.*, **27**, 1047 (1986).
- e. M. Sletzinger, T. R. Verhoeven, R. P. Volante, J. M. McNamara, E. G. Corley, and T. M. H. Liu, *Tetrahedron Lett.*, **26**, 2951 (1985).
- 9a. E. J. Corey and E. Hamanaka, *J. Am. Chem. Soc.*, **89**, 2758 (1967).
- b. Y. Kitagawa, A. Itoh, S. Hashimoto, H. Yamamoto, and H. Nozaki, *J. Am. Chem. Soc.*, **99**, 3864 (1977).
- c. B. M. Trost and R. W. Warner, *J. Am. Chem. Soc.*, **105**, 5940 (1983).
- d. S. Brandt, A. Marfat, and P. Helquist, *Tetrahedron Lett.*, 2193 (1979).
- e. A. Fürstner and H. Weinritt, *J. Am. Chem. Soc.*, **120**, 2817 (1998).
- f. Y. Matsuya, T. Kawaguchi, and H. Nemoto, *Org. Lett.*, **5**, 2939 (2003).
10. R. H. Grubbs and R. A. Grey, *J. Am. Chem. Soc.*, **95**, 5765 (1973).
11. H. L. Goering, E. P. Seitz, Jr., and C. C. Tseng, *J. Org. Chem.*, **46**, 5304 (1981).
12. A. Marfat, P. R. McGuirk, and P. Helquist, *J. Org. Chem.*, **44**, 1345 (1979).
13. N. Cohen, W. F. Eichel, R. J. Lopresti, C. Neukom, and G. Saucy, *J. Org. Chem.*, **41**, 3505 (1976).
- 14a. R. J. Linderman, A. Godfrey, and K. Horne, *Tetrahedron Lett.*, **28**, 3911 (1987).
- b. H. Schostarez and L. A. Paquette, *J. Am. Chem. Soc.*, **103**, 722 (1981).
- c. Y. Yamamoto, S. Yamamoto, H. Yatagai, Y. Ishihara, and K. Maruyama, *J. Org. Chem.*, **47**, 119 (1982).
- d. T. Kawabata, P. A. Grieco, H.-L. Sham, H. Kim, J. Y. Law, and S. Tu, *J. Org. Chem.*, **52**, 3346 (1987).
- 15a. A. Minato, K. Suzuki, K. Tamao, and M. Kumada, *Tetrahedron Lett.*, **25**, 83 (1984).
- b. E. R. Larson and R. A. Raphael, *Tetrahedron Lett.*, 5041 (1979).
- c. M. C. Pirrung and S. A. Thompson, *J. Org. Chem.*, **53**, 227 (1988).
- d. J. Just and B. O'Connor, *Tetrahedron Lett.*, **29**, 753 (1988).
- e. M. F. Semmelhack and A. Yamashita, *J. Am. Chem. Soc.*, **102**, 5924 (1980).
- f. A. M. Echavarren and J. K. Stille, *J. Am. Chem. Soc.*, **110**, 4051 (1988).

- g. K. Nakamura, H. Okubo, and M. Yamaguchi, *Synlett*, 549 (1999).
- h. A. F. Littke, L. Schwarz, and G. C. Fu, *J. Am. Chem. Soc.*, **124**, 6343 (2002).
- i. W. A. Moradi and S. Buchwald, *J. Am. Chem. Soc.*, **123**, 7996 (2001).
- j. M. Palucki and S. L. Buchwald, *J. Am. Chem. Soc.*, **119**, 11108 (1997).
- k. H. Tang, K. Menzel, and G. C. Fu, *Angew. Chem. Int. Ed. Engl.*, **42**, 5079 (2003).
- l. Y. Urawa and K. Ogura, *Tetrahedron Lett.*, **44**, 271 (2003).
- 16a. J. E. Backvall, S. E. Bystrom, and R. E. Nordberg, *J. Org. Chem.*, **49**, 4619 (1984).
- b. M. F. Semmelhack and C. Bodurow, *J. Am. Chem. Soc.*, **106**, 1496 (1984).
- c. D. Valentine, Jr., J. W. Tilley, and R. A. LeMahieu, *J. Org. Chem.*, **46**, 4614 (1981).
- d. A. S. Kende, B. Roth, P. J. SanFilippo, and T. J. Blacklock, *J. Am. Chem. Soc.*, **104**, 5808 (1982).
17. E. J. Corey, F. J. Hannon, and N. W. Boaz, *Tetrahedron*, **45**, 545 (1989).
- 18a. P. A. Bartlett, J. D. Meadows, and E. Ottow, *J. Am. Chem. Soc.*, **106**, 5304 (1984).
- b. M. Larcheveque and Y. Petit, *Tetrahedron Lett.*, **28**, 1993 (1987).
- c. B. M. Trost and J. D. Oslo, *J. Am. Chem. Soc.*, **121**, 3057 (1999).
19. P. Compain, J. Gore, and J. M. Vatele, *Tetrahedron*, **52**, 10405 (1996); H. D. Doan, J. Gore, and J.-M. Vatele, *Tetrahedron Lett.*, **40**, 6765 (1999).
20. T. Kitamura and M. Mori, *Org. Lett.*, **3**, 1161 (2001).

## Chapter 9

- 1a. A. Suzuki, N. Miyaura, S. Abiko, M. Itoh, H. C. Brown, J. A. Sinclair, and M. M. Midland, *J. Am. Chem. Soc.*, **95**, 3080 (1973).
- b. H. Yatagai, Y. Yamamoto, and K. Maruyama, *J. Am. Chem. Soc.*, **102**, 4548 (1980); Y. Yamamoto, H. Yatagai, H. Naruta, and K. Maruyama, *J. Am. Chem. Soc.*, **102**, 7107 (1980).
- c. R. Mohan and J. A. Katzenellenbogen, *J. Org. Chem.*, **49**, 1238 (1984).
- d. H. C. Brown and T. Imai, *J. Am. Chem. Soc.*, **105**, 6285 (1983).
- e. H. C. Brown, N. G. Bhat, and J. B. Campbell, Jr., *J. Org. Chem.*, **51**, 3398 (1986).
- 2a. H. C. Brown, M. M. Rogic, H. Nambu, and M. W. Rathke, *J. Am. Chem. Soc.*, **91**, 2147 (1969); H. C. Brown, H. Nambu, and M. M. Rogic, *J. Am. Chem. Soc.*, **91**, 6852 (1969).
- b. H. C. Brown and R. A. Coleman, *J. Am. Chem. Soc.*, **91**, 4606 (1969).
- c. G. Zweifel, R. P. Fisher, J. T. Snow, and C. C. Whitney, *J. Am. Chem. Soc.*, **93**, 6309 (1971).
- d. H. C. Brown and M. W. Rathke, *J. Am. Chem. Soc.*, **89**, 2738 (1967).
- e. H. C. Brown and M. M. Rogic, *J. Am. Chem. Soc.*, **91**, 2146 (1969); H. C. Brown, H. Nambu, and M. M. Rogic, *J. Am. Chem. Soc.*, **91**, 6852 (1969).
3. See the references to Scheme 9.1.
- 4a. H. C. Brown, H. D. Lee, and S. U. Kulkarni, *J. Org. Chem.*, **51**, 5282 (1986).
- b. J. A. Sikorski, N. G. Bhat, T. E. Cole, K. K. Wang, and H. C. Brown, *J. Org. Chem.*, **51**, 4521 (1986).
- c. S. U. Kulkarni, H. D. Lee, and H. C. Brown, *J. Org. Chem.*, **45**, 4542 (1980).
- d. M. C. Welch and T. A. Bryson, *Tetrahedron Lett.*, **29**, 521 (1988).
- 5a. A. Pelter, K. J. Gould, and C. R. Harrison, *Tetrahedron Lett.*, 3327 (1975).
- b. A. Pelter and R. A. Drake, *Tetrahedron Lett.*, **29**, 4181 (1988).
- c. L. E. Overman and M. J. Sharp, *J. Am. Chem. Soc.*, **110**, 612 (1988).
- d. H. C. Brown and S. U. Kulkarni, *J. Org. Chem.*, **44**, 2422 (1979).
- 6a. W. R. Roush, M. A. Adam, and D. J. Harris, *J. Org. Chem.*, **50**, 2000 (1985).
- b. S. J. Danishefsky, S. DeNinno, and P. Lartey, *J. Am. Chem. Soc.*, **109**, 2082 (1987).
- c. Y. Nishigaiichi, N. Ishida, M. Nishida, and A. Takuwa, *Tetrahedron Lett.*, **37**, 3701 (1996).
- d. D. A. Heerding, C. Y. Hong, N. Kado, G. C. Look, and L. E. Overman, *J. Org. Chem.*, **58**, 6947 (1993).
- 7a,b. H. C. Brown and N. G. Bhat, *J. Org. Chem.*, **53**, 6009 (1988).
- c,d. H. C. Brown, D. Basavaiah, S. U. Kulkarni, N. Bhat, and J. V. N. Vara Prasad, *J. Org. Chem.*, **53**, 239 (1988).
- 8a. J. A. Marshall, S. L. Crooks, and B. S. DeHoff, *J. Org. Chem.*, **53**, 1616 (1988); J. A. Marshall and W. Y. Gung, *Tetrahedron Lett.*, **29**, 1657 (1988).
- b. B. M. Trost and T. Sato, *J. Am. Chem. Soc.*, **107**, 719 (1985).
- 9a. W. E. Fristad, D. S. Dime, T. R. Bailey, and L. A. Paquette, *Tetrahedron Lett.*, 1999 (1979).
- b. E. Piers and H. E. Morton, *J. Org. Chem.*, **45**, 4263 (1980).
- c. J. C. Bottaro, R. N. Hanson, and D. E. Seitz, *J. Org. Chem.*, **46**, 5221 (1981).

- d. Y. Yamamoto and A. Yanagi, *Heterocycles*, **16**, 1161 (1981).
- e. M. B. Anderson and P. L. Fuchs, *Synth. Commun.*, **17**, 621 (1987); B. A. Narayanan and W. H. Bunelle, *Tetrahedron Lett.*, **28**, 6261 (1987).
- f. A. Hosomi, M. Sato, and H. Sakurai, *Tetrahedron Lett.*, 429 (1979).
10. P. A. Grieco and W. F. Fobare, *Tetrahedron Lett.*, **27**, 5067 (1986).
11. E. J. Corey and W. L. Seibel, *Tetrahedron Lett.*, **27**, 905 (1986).
- 12a. E. Moret and M. Schlosser, *Tetrahedron Lett.*, **25**, 4491 (1984).
- b. L. K. Truesdale, D. Swanson, and R. C. Sun, *Tetrahedron Lett.*, **26**, 5009 (1985).
- c. R. L. Funk and G. L. Bolton, *J. Org. Chem.*, **49**, 5021 (1984).
- d. L. E. Overman, T. C. Malone, and G. P. Meier, *J. Am. Chem. Soc.*, **105**, 6993 (1983).
- 13a. H. C. Brown, T. Imai, M. C. Desai, and B. Singaran, *J. Am. Chem. Soc.*, **107**, 4980 (1985).
- b,c. H. C. Brown, R. K. Bakshi, and B. Singaran, *J. Am. Chem. Soc.*, **110**, 1529 (1988).
- d. H. C. Brown, M. Srebnik, R. R. Bakshi, and T. E. Cole, *J. Am. Chem. Soc.*, **109**, 5420 (1987).
14. K. K. Wang and K.-H. Chu, *J. Org. Chem.*, **49**, 5175 (1984).
- 15a. W. R. Roush, J. A. Straub, and M. S. Van Nieuwenhze, *J. Org. Chem.*, **56**, 1636 (1991).
- b. L. A. Paquette and G. D. Maynard, *J. Am. Chem. Soc.*, **114**, 5018 (1992).
- c. C. Y. Hong, N. Kado, and L. E. Overman, *J. Am. Chem. Soc.*, **115**, 11028 (1993).
- d. P. V. Ramachandran, G.-M. Chen, and H. C. Brown, *Tetrahedron Lett.*, **38**, 2417 (1997).
- e. A. B. Charette, C. Mellon, and M. Motamed, *Tetrahedron Lett.*, **36**, 8561 (1995).
- f. C. Masse, M. Yang, J. Solomon, and J. S. Panek, *J. Am. Chem. Soc.*, **120**, 4123 (1998).
16. I. Chataigner, J. Lebreton, F. Zammattio, and J. Villieras, *Tetrahedron Lett.*, **38**, 3719 (1997).
17. J. A. Marshall, B. M. Seletsky, and G. P. Luke, *J. Org. Chem.*, **59**, 3413 (1994); J. A. Marshall, J. A. Jablonowski, and G. P. Luke, *J. Org. Chem.*, **59**, 7825 (1994).
18. K. Maruyama, Y. Ishiara, and Y. Yamamoto, *Tetrahedron Lett.*, **22**, 4235 (1981); Y. Yamamoto, H. Nemoto, R. Kikuchi, H. Komatsu, and I. Suzuki, *J. Am. Chem. Soc.*, **112**, 8598 (1990). For allylic boron additions to this compound see: R. W. Hoffmann, W. Ladner, and K. Ditrich, *Liebigs Ann. Chem.*, 883 (1989).
19. J. A. Marshall and S. Beaudoin, *J. Org. Chem.*, **59**, 7833 (1994).

## Chapter 10

- 1a. S. Julia and A. Ginebreda, *Synthesis*, 682 (1977).
- b. D. S. Breslow, E. I. Edwards, R. Leone, and P. V. R. Schleyer, *J. Am. Chem. Soc.*, **90**, 7097 (1968).
- c. D. J. Burton and J. L. Hahnfeld, *J. Org. Chem.*, **42**, 828 (1977).
- d. D. Seyforth and S. P. Hopper, *J. Org. Chem.*, **37**, 4070 (1972).
- e. G. L. Closs, L. E. Closs, and W. A. Boll, *J. Am. Chem. Soc.*, **85**, 3796 (1963).
- f. L. G. Mueller and R. G. Lawton, *J. Org. Chem.*, **44**, 4741 (1979).
- g. F. G. Bordwell and M. W. Carlson, *J. Am. Chem. Soc.*, **92**, 3377 (1970).
- h. A. Burger and G. H. Harness, *J. Am. Chem. Soc.*, **65**, 2382 (1943).
- i. E. Schmitz, D. Habish, and A. Stark, *Angew. Chem. Int. Ed. Engl.*, **2**, 548 (1963).
- j. R. Zurfluh, E. N. Wall, J. B. Sidall, and J. A. Edwards, *J. Am. Chem. Soc.*, **90**, 6224 (1968).
- k. M. Nishizawa, H. Takenaka, and Y. Hayashi, *J. Org. Chem.*, **51**, 806 (1986).
- l. H. Nishiyama, K. Sakuta, and K. Itoh, *Tetrahedron Lett.*, **25**, 223 (1984).
- m. H. Seto, M. Sakaguchi, and Y. Fujimoto, *Chem. Pharm. Bull.*, **33**, 412 (1985).
- n. D. F. Taber and E. H. Petty, *J. Org. Chem.*, **47**, 4808 (1982).
- o. B. Iddon, D. Price, H. Suschitzsky, and D. J. C. Scopes, *Tetrahedron Lett.*, **24**, 413 (1983).
- p. A. Chu and L. N. Mander, *Tetrahedron Lett.*, **29**, 2727 (1988).
- q. G. E. Keck and D. F. Kachinsky, *J. Org. Chem.*, **51**, 2487 (1986).
- r. W. A. Thaler and B. Franzus, *J. Org. Chem.*, **29**, 2226 (1964).
- s. B. B. Snider, *J. Org. Chem.*, **41**, 3061 (1976).
- t. D. H. R. Barton, J. Guilhem, Y. Herve, P. Potier, and J. Thierry, *Tetrahedron Lett.*, **28**, 1413 (1987).
- u. A. M. Gomez, G. O. Danelon, S. Valverde, and J. C. Lopez, *J. Org. Chem.*, **63**, 9626 (1998).
- v. S. D. Burke and D. N. Deaton, *Tetrahedron Lett.*, **32**, 4651 (1991).
- w. J. A. Wendt and J. Aube, *Tetrahedron Lett.*, **37**, 1531 (1996).
- x. G. Mehta, S. Karmarkar, and S. K. Chattopadhyay, *Tetrahedron*, **60**, 5013 (2004).
- 2a. K. B. Wiberg, B. L. Furtek, and L. K. Olli, *J. Am. Chem. Soc.*, **101**, 7675 (1979).
- b. A. E. Greene and J.-P. Depres, *J. Am. Chem. Soc.*, **101**, 4003 (1979).

- c. R. A. Moss and E. Y. Chen, *J. Org. Chem.*, **46**, 1466 (1981).
- d. B. M. Trost, R. M. Cory, P. H. Scudder, and H. B. Neubold, *J. Am. Chem. Soc.*, **95**, 7813 (1973).
- e. T. J. Nitz, E. M. Holt, B. Rubin, and C. H. Stammer, *J. Org. Chem.*, **46**, 2667 (1981).
- f. L. N. Mander, J. V. Turner, and B. G. Colmbe, *Aust. J. Chem.*, **27**, 1985 (1974).
- g. P. J. Jessup, C. B. Petty, J. Roos, and L. E. Overman, *Org. Synth.*, **59**, 1 (1979).
- h. H. Durr, H. Nickels, L. A. Pacala, and M. Jones, Jr., *J. Org. Chem.*, **45**, 973 (1980).
- i. G. A. Scheisher and J. D. White, *J. Org. Chem.*, **45**, 1864 (1980).
- j. M. B. Groen and F. J. Zeelen, *J. Org. Chem.*, **43**, 1961 (1978).
- k. R. C. Gadwood, R. M. Lett, and J. E. Wissinger, *J. Am. Chem. Soc.*, **108**, 6343 (1986).
- l. V. B. Rao, C. F. George, S. Wolff, and W. C. Agosta, *J. Am. Chem. Soc.*, **107**, 5732 (1985).
- m. Y. Araki, T. Endo, M. Tanji, J. Nagasawara, and Y. Ishido, *Tetrahedron Lett.*, **28**, 5853 (1987).
- n. G. Stork, P. M. Sher, and H.-L. Chen, *J. Am. Chem. Soc.*, **108**, 6384 (1986).
- o. E. J. Corey and M. Kang, *J. Am. Chem. Soc.*, **106**, 5384 (1984).
- p. G. E. Keck, D. F. Kachensky, and E. J. Enholm, *J. Org. Chem.*, **50**, 4317 (1985).
- q. A. De Mesmaeker, P. Hoffmann, and B. Ernst, *Tetrahedron Lett.*, **30**, 57 (1989).
- r. A. K. Singh, R. K. Bakshi, and E. J. Corey, *J. Am. Chem. Soc.*, **109**, 6187 (1987).
- s. S. Danishfsky and J. S. Panek, *J. Am. Chem. Soc.*, **109**, 917 (1987).
- t. M. Handa, T. Sunazaka, A. Sugawara, Y. Harigara, O. Yoshihiro, K. Otoguro, and S. Omura, *J. Antibiotics*, **56**, 730 (2003).
- 3a. T. J. Lee, A. Bunge, and H. F. Schaefer, III, *J. Am. Chem. Soc.*, **107**, 137 (1985); M. Rubio, J. Stalring, A. Bernhardsson, R. Lindh, and B. O. Roos, *Theoretical Chem. Acc.*, **105**, 15 (2000); R. Kakkar, R. Garg, and P. Preeti, *Theochem*, **617**, 141 (2000).
- b. R. Noyori and M. Yamakawa, *Tetrahedron Lett.*, **21**, 2851 (1980).
- c. S. Matzinger, T. Bally, E. V. Patterson, and R. J. McMahon, *J. Am. Chem. Soc.*, **118**, 1535 (1996); P. R. Schreiner, W. L. Karney, P. v. R. Schleyer, W. T. Borden, T. P. Hamilton, and H. F. Schaefer, III, *J. Org. Chem.*, **61**, 7030 (1996).
- d. C. Boehme and G. Frenking, *J. Am. Chem. Soc.*, **118**, 2039 (1996).
4. C. D. Poulter, E. C. Friedrich, and S. Winstein, *J. Am. Chem. Soc.*, **91**, 6892 (1969).
5. P. L. Barili, G. Berti, B. Macchia, F. Macchia, and L. Monti, *J. Chem. Soc. C*, 1168 (1970).
- 6a. R. K. Hill and D. A. Cullison, *J. Am. Chem. Soc.*, **95**, 2923 (1973).
- b. A. B. Smith, III, B. H. Toder, S. J. Brancha, and R. K. Dieter, *J. Am. Chem. Soc.*, **103**, 1996 (1981).
- c. M. C. Pirrung and J. A. Werner, *J. Am. Chem. Soc.*, **108**, 6060 (1986).
7. E. W. Warnhoff, C. M. Wong, and W. T. Tai, *J. Am. Chem. Soc.*, **90**, 514 (1968).
- 8a. S. A. Godleski, P. v. R. Schleyer, E. Osawa, Y. Inamoto, and Y. Fujikura, *J. Org. Chem.*, **41**, 2596 (1976).
- b. P. E. Eaton, Y. S. Or, and S. J. Branca, *J. Am. Chem. Soc.*, **103**, 2134 (1981).
- c. G. H. Posner, K. A. Babia, G. L. Loomis, W. J. Frazee, R. D. Mittal, and I. L. Karle, *J. Am. Chem. Soc.*, **102**, 7498 (1980).
- d. T. Hudlicky, F. J. Koszyk, T. M. Kutchan, and J. P. Sheth, *J. Org. Chem.*, **45**, 5020 (1980).
- e. L. A. Paquette and Y.-K. Han, *J. Am. Chem. Soc.*, **103**, 1835 (1981).
- f. L. A. Paquette and R. W. Houser, *J. Am. Chem. Soc.*, **91**, 3870 (1969).
- g. L. A. Paquette, S. Nakatani, T. M. Zydowski, S. D. Edmondson, L.-Q. Sun, and R. Skerlj, *J. Org. Chem.*, **64**, 3244 (1999).
- 9a. Y. Ito, S. Fujii, M. Nakatsuka, F. Kawamoto, and T. Saegusa, *Org. Synth.*, **59**, 113 (1979).
- b. P. Nedenskov, H. Heide, and N. Clauson-Kass, *Acta Chem. Scand.*, **16**, 246 (1962).
- c. L.-F. Tietze, *J. Am. Chem. Soc.*, **96**, 946 (1974).
- d. E. G. Breitholle and A. G. Fallis, *J. Org. Chem.*, **43**, 1964 (1978).
- e. E. Y. Chen, *J. Org. Chem.*, **49**, 3245 (1984).
- f. G. Mehta and K. S. Rao, *J. Org. Chem.*, **50**, 5537 (1985).
- g. T. V. Rajan Babu, *J. Org. Chem.*, **53**, 4522 (1988).
- h. W. D. Klobucar, L. A. Paquette, and J. P. Blount, *J. Org. Chem.*, **46**, 4021 (1981).
- i. F. E. Ziegler, S. I. Klein, U. K. Pati, and T.-F. Wang, *J. Am. Chem. Soc.*, **107**, 2730 (1985).
- j. T. Hudlicky, F. J. Koszyk, D. M. Dochwat, and G. L. Cantrell, *J. Org. Chem.*, **46**, 2911 (1981).
- k. R. E. Ireland, W. C. Dow, J. D. Godfrey, and S. Thaisrivongs, *J. Org. Chem.*, **49**, 1001 (1984).
- l. C. P. Chuang and D. J. Hart, *J. Org. Chem.*, **48**, 1782 (1983).
- m. P. Wender, T. W. von Geldern, and B. H. Levine, *J. Am. Chem. Soc.*, **110**, 4858 (1988).
- 10a. S. D. Larsen and S. A. Monti, *J. Am. Chem. Soc.*, **99**, 8015 (1977).
- b. S. A. Monti and J. M. Harless, *J. Am. Chem. Soc.*, **99**, 2690 (1977).
- c. F. T. Bond and C.-Y. Ho, *J. Org. Chem.*, **41**, 1421 (1976).

## Chapter 11

1a. L. Friedman and H. Shechter, *J. Org. Chem.*, **26**, 2522 (1961).b. E. C. Taylor, F. Kienzle, R. L. Robey, and A. McKillop, *J. Am. Chem. Soc.*, **92**, 2175 (1970).c. J. Koo, *J. Am. Chem. Soc.*, **75**, 1889 (1953).d. E. C. Taylor, R. Kienzle, R. L. Robey, A. McKillop, and J. D. Hunt, *J. Am. Chem. Soc.*, **93**, 4845 (1971).e. G. A. Ropp and E. C. Coyner, *Org. Synth.*, **IV**, 727 (1963).f. M. Shiratsuchi, K. Kawamura, T. Akashi, M. Fujii, H. Ishihama, and Y. Uchida, *Chem. Pharm. Bull.*, **35**, 632 (1987).g. D. C. Furlano and K. D. Kirk, *J. Org. Chem.*, **51**, 4073 (1986).h. C. K. Bradsher, F. C. Brown, and H. K. Porter, *J. Am. Chem. Soc.*, **76**, 2357 (1954).i. F. A. Macias, D. Marin, D. Chincilla, and J. M. G. Molinillo, *Tetrahedron Lett.*, **43**, 6417 (2002).2a. E. C. Taylor, E. C. Bingham, and D. K. Johnson, *J. Org. Chem.*, **42**, 362 (1977); G. S. Lal, *J. Org. Chem.*, **58**, 2791 (1993).b. P. Studt, *Liebigs Ann. Chem.*, 2105 (1978).c. T. Jojima, H. Takeshiba, and T. Kinoto, *Bull. Chem. Soc. Jpn.*, **52**, 2441 (1979).d. R. W. Bost and F. Nicholson, *J. Am. Chem. Soc.*, **57**, 2368 (1935).e. H. Durr, H. Nickels, L. A. Pacala, and M. Jones, Jr., *J. Org. Chem.*, **45**, 973 (1980).

- 3a. C. L. Perrin and G. A. Skinner, *J. Am. Chem. Soc.*, **93**, 3389 (1971).  
 b. R. A. Rossi and J. F. Bunnett, *J. Am. Chem. Soc.*, **94**, 683 (1972).  
 c. M. Jones, Jr., and R. H. Levin, *J. Am. Chem. Soc.*, **91**, 6411 (1969).  
 d. Y. Naruta, Y. Nishigaichi, and K. Maruyama, *J. Org. Chem.*, **53**, 1192 (1988).  
 e. S. P. Khanapure, R. T. Reddy, and E. R. Biehl, *J. Org. Chem.*, **52**, 5685 (1987).  
 f. G. Buchi and J. C. Leung, *J. Org. Chem.*, **51**, 4813 (1986).
- 4a. M. P. Doyle, J. F. Dellaria, Jr., B. Siegfried, and S. W. Bishop, *J. Org. Chem.*, **42**, 3494 (1977).  
 b. T. Cohen, A. G. Dietz, Jr., and J. R. Miser, *J. Org. Chem.*, **42**, 2053 (1977).  
 c. M. P. Doyle, B. Siegfried, R. C. Elliot, and J. F. Dellaria, Jr., *J. Org. Chem.*, **42**, 2431 (1977).  
 d. G. D. Figuly and J. C. Martin, *J. Org. Chem.*, **45**, 3728 (1980).  
 e. E. McDonald and R. D. Wylie, *Tetrahedron*, **35**, 1415 (1979).  
 f. M. P. Doyle, B. Siegfried, and J. F. Dellaria, Jr., *J. Org. Chem.*, **42**, 2426 (1977).  
 g. P. H. Gore and I. M. Khan, *J. Chem. Soc., Perkin Trans. 1*, 2779 (1979).  
 h. A. A. Leon, G. Daub, and I. R. Silverman, *J. Org. Chem.*, **49**, 4544 (1984).  
 i. S. R. Wilson and L. A. Jacob, *J. Org. Chem.*, **51**, 4833 (1986).  
 j. S. A. Khan, M. A. Munawar, and M. Siddiq, *J. Org. Chem.*, **53**, 1799 (1988).  
 k. J. R. Beadle, S. H. Korzeniowski, D. E. Rosenberg, B. J. Garcia-Slanga, and G. W. Gokel, *J. Org. Chem.*, **49**, 1594 (1984).  
 l. B. L. Zenitz and W. H. Hartung, *J. Org. Chem.*, **11**, 444 (1946).  
 m. T. F. Buckley, III, and H. Rapoport, *J. Am. Chem. Soc.*, **102**, 3056 (1980).  
 n. G. A. Olah and J. A. Olah, *J. Am. Chem. Soc.*, **98**, 1839 (1976).  
 o. E. J. Corey, S. Barcza, and G. Klotmann, *J. Am. Chem. Soc.*, **91**, 4782 (1969).  
 p. E. C. Taylor, F. Kienzle, R. L. Robey, and A. McKillop, *J. Am. Chem. Soc.*, **92**, 2175 (1970).  
 q. M. Essiz, G. Guillaumet, J.-J. Brunet, and P. Caubere, *J. Org. Chem.*, **45**, 240 (1980).  
 r. S. P. Khanapure, L. Crenshaw, R. T. Reddy, and E. R. Biehl, *J. Org. Chem.*, **53**, 4915 (1988).  
 12a. J. H. Boyer and R. S. Burkis, *Org. Synth.*, **V**, 1067 (1973).  
 b. H. P. Schultz, *Org. Synth.*, **IV**, 364 (1963); F. D. Gunstone and S. H. Tucker, *Org. Synth.*, **IV**, 160 (1963).  
 c. D. H. Hey and M. J. Perkins, *Org. Synth.*, **V**, 51 (1973).  
 d. K. Rorig, J. D. Johnston, R. W. Hamilton, and T. J. Telinski, *Org. Synth.*, **IV**, 576 (1963).  
 e. K. G. Rutherford and W. Redmond, *Org. Synth.*, **V**, 133 (1973).  
 f. M. M. Robinson and B. L. Robinson, *Org. Synth.*, **IV**, 947 (1963).  
 g. R. Adams, W. Reifschneider, and A. Ferretti, *Org. Synth.*, **VI**, 21 (1988).  
 h. G. H. Cleland, *Org. Synth.*, **VI**, 21 (1988).  
 13a. R. E. Ireland, C. A. Lipinski, C. J. Kowalski, J. W. Tilley, and D. M. Walba, *J. Am. Chem. Soc.*, **96**, 3333 (1974).  
 b. J. J. Korst, J. D. Johnston, K. Butler, E. J. Bianco, L. H. Conover, and R. B. Woodward, *J. Am. Chem. Soc.*, **90**, 439 (1968).  
 c. K. A. Parker and J. Kallmerten, *J. Org. Chem.*, **45**, 2614, 2620 (1980).  
 d. F. A. Carey and R. M. Giuliano, *J. Org. Chem.*, **46**, 1366 (1981).  
 e. R. B. Woodward and T. R. Hoye, *J. Am. Chem. Soc.*, **99**, 8007 (1977).  
 f. E. C. Horning, J. Koo, M. S. Fish, and G. N. Walker, *Org. Synth.*, **IV**, 408 (1963); J. Koo, *Org. Synth.*, **V**, 550 (1973).  
 14a. M. J. Piggott and D. Wege, *Austr. J. Chem.*, **53**, 749 (2000).  
 b. D. Perez, E. Guitian, and L. Castedo, *J. Org. Chem.*, **57**, 5911 (1992).  
 15. H. C. Bell, J. R. Kalman, J. T. Pinhey, and S. Sternhell, *Tetrahedron Lett.*, 3391 (1974).  
 16. B. Chauncy and E. Gellert, *Austr. J. Chem.*, **22**, 993 (1969); R. I. Duclos, Jr., J. S. Tung, and H. Rapoport, *J. Org. Chem.*, **49**, 5243 (1984).  
 17. W. G. Miller and C. U. Pittman, Jr., *J. Org. Chem.*, **39**, 1955 (1974).  
 18. W. Nagata, K. Okada, and T. Aoki, *Synthesis*, 365 (1979).  
 19. T. J. Doyle, M. Hendrix, D. Van Derveer, S. Javanmard, and J. Haseltine, *Tetrahedron*, **53**, 11153 (1997).  
 20. T. P. Smyth and B. W. Corby, *Org. Process Res. Dev.*, **1**, 264 (1997).

## Chapter 12

- 1a. Y. Butsugan, S. Yoshida, M. Muto, and T. Bito, *Tetrahedron Lett.*, 1129 (1971).  
 b. E. J. Corey and H. E. Ensley, *J. Am. Chem. Soc.*, **97**, 6908 (1975).  
 c. R. G. Gaughan and C. D. Poulter, *J. Org. Chem.*, **44**, 2441 (1979).

- d. E. Vedejs, D. A. Engler, and J. E. Telschow, *J. Org. Chem.*, **43**, 188 (1978).  
 e. K. Akashi, R. E. Palermo, and K. B. Sharpless, *J. Org. Chem.*, **43**, 2063 (1978).  
 f. A. Hassner, R. H. Reuss, and H. W. Pinnick, *J. Org. Chem.*, **40**, 3427 (1975).  
 g. R. N. Mirrington and K. J. Schmalzl, *J. Org. Chem.*, **37**, 2877 (1972).  
 h. K. B. Sharpless and R. F. Lauer, *J. Org. Chem.*, **39**, 429 (1974).  
 i. J. A. Marshall and R. C. Andrews, *J. Org. Chem.*, **50**, 1602 (1985).  
 j. R. H. Schlessinger, J. J. Wood, A. J. Poos, R. A. Nugent, and W. H. Parsons, *J. Org. Chem.*, **48**, 1146 (1983).  
 k. R. K. Boeckman, Jr., J. E. Starett, Jr., D. G. Nickell, and P.-E. Sum, *J. Am. Chem. Soc.*, **108**, 5549 (1986).  
 l. E. J. Corey and Y. B. Xiang, *Tetrahedron*, **29**, 995 (1988).  
 m. D. J. Plata and J. Kallmerten, *J. Am. Chem. Soc.*, **110**, 4041 (1988).  
 n. B. E. Rossiter, T. Katsuki, and K. B. Sharpless, *J. Am. Chem. Soc.*, **103**, 464 (1981).  
 o. J. Mulzer, A. Angermann, B. Schubert, and C. Seitzl, *J. Org. Chem.*, **51**, 5294 (1986).  
 p. R. H. Schlessinger and R. A. Nugent, *J. Am. Chem. Soc.*, **104**, 1116 (1982).  
 q. H. Niwa, T. Mori, T. Hasegawa, and K. Yamada, *J. Org. Chem.*, **51**, 1015 (1986).  
 2a. J. P. McCormick, W. Tomasik, and M. W. Johnson, *Tetrahedron Lett.*, **22**, 607 (1981).  
 b. H. C. Brown, J. H. Kawakami, and S. Ikegami, *J. Am. Chem. Soc.*, **92**, 6914 (1970).  
 c. R. M. Scarborough, Jr., B. H. Toder, and A. B. Smith, III, *J. Am. Chem. Soc.*, **102**, 3904 (1980).  
 d. B. Rickborn and R. M. Gerkin, *J. Am. Chem. Soc.*, **90**, 4193 (1968).  
 e. J. A. Marshall and R. A. Ruden, *J. Org. Chem.*, **36**, 594 (1971).  
 f. G. A. Kraus and B. Roth, *J. Org. Chem.*, **45**, 4825 (1980).  
 g. T. Sakan and K. Abe, *Tetrahedron Lett.*, 2471 (1968).  
 h. K. J. Clark, G. I. Fray, R. H. Jaeger, and R. Robinson, *Tetrahedron*, **6**, 217 (1959).  
 i. T. Kawabata, P. Grieco, H.-L. Sham, H. Kim, J. Y. Jaw, and S. Tu, *J. Org. Chem.*, **52**, 3346 (1987).  
 j. P. T. Lansbury, J. P. Galbo, and J. P. Springer, *Tetrahedron Lett.*, **29**, 147 (1988).  
 k. J. P. Marino, R. F. de La Pradilla, and E. Laborde, *J. Org. Chem.*, **52**, 4898 (1987).  
 l. J. E. Toth, P. R. Hamann, and P. L. Fuchs, *J. Org. Chem.*, **53**, 4694 (1988).  
 3. E. L. Eliel, S. H. Schroeter, T. J. Brett, F. J. Biros, and J.-C. Richer, *J. Am. Chem. Soc.*, **88**, 3327 (1966).  
 4. E. E. Royals and J. C. Leffingwell, *J. Org. Chem.*, **31**, 1937 (1966).  
 5. W. W. Epstein and F. W. Sweat, *Chem. Rev.*, **67**, 247 (1967).  
 6a. D. P. Higley and R. W. Murray, *J. Am. Chem. Soc.*, **96**, 3330 (1974).  
 b. R. Criegee and P. Gunther, *Chem. Ber.*, **96**, 1564 (1963).  
 c. W. P. Keaveny, M. G. Berger, and J. J. Pappas, *J. Org. Chem.*, **32**, 1537 (1967).  
 7a. S. Isoe, S. B. Hyeon, H. Ichikawa, S. Katsumura, and T. Sakan, *Tetrahedron Lett.*, 5561 (1968).  
 b. Y. Ogata, Y. Sawaki, and M. Shiroyama, *J. Org. Chem.*, **42**, 4061 (1977).  
 c. F. G. Bordwell and A. C. Knipe, *J. Am. Chem. Soc.*, **93**, 3416 (1971).  
 d. B. M. Trost, P. R. Bernstein, and P. C. Funfschilling, *J. Am. Chem. Soc.*, **101**, 4378 (1979).  
 e. C. S. Foote, S. Mazur, P. A. Burns, and D. Lerdal, *J. Am. Chem. Soc.*, **95**, 586 (1973).  
 f. J. P. Marino, K. E. Pfitzner, and R. A. Olofson, *Tetrahedron*, **27**, 4181 (1971).  
 g. M. A. Avery, C. Jennings-White, and W. K. M. Chong, *Tetrahedron Lett.*, **28**, 4629 (1987).  
 h. S. Horvat, P. Karallas, and J. M. White, *J. Chem. Soc., Perkin Trans. 2*, 2151 (1998).  
 8a. P. N. Confalone, C. Pizzolato, D. L. Confalone, and M. R. Uskokovic, *J. Am. Chem. Soc.*, **102**, 1954 (1980).  
 b. J. K. Whitesell, R. S. Matthews, M. A. Minton, and A. M. Helbling, *J. Am. Chem. Soc.*, **103**, 3468 (1981).  
 c. F. A. J. Kerdesky, R. J. Ardecky, M. V. LakshmiKanthan, and M. P. Cava, *J. Am. Chem. Soc.*, **103**, 1992 (1981).  
 d. R. Fujimoto, Y. Kishi, and J. F. Blount, *J. Am. Chem. Soc.*, **102**, 7154 (1980).  
 e. S. P. Tanis and K. Nakanishi, *J. Am. Chem. Soc.*, **101**, 4398 (1979).  
 f. R. B. Miller and R. D. Nash, *J. Org. Chem.*, **38**, 4424 (1973).  
 g. R. Grewe and I. Hinrichs, *Chem. Ber.*, **97**, 443 (1964).  
 h. W. Nagata, S. Hirai, K. Kawata, and T. Okumura, *J. Am. Chem. Soc.*, **89**, 5046 (1967).  
 i. W. G. Dauben, M. Lorber, and D. S. Fullerton, *J. Org. Chem.*, **34**, 3587 (1969).  
 j. E. E. van Tamelen, M. Shamma, A. W. Burgstahler, J. Wolinsky, R. Tamm, and P. E. Aldrich, *J. Am. Chem. Soc.*, **80**, 5006 (1958).  
 k. S. D. Burke, C. W. Murtishaw, J. O. Saunders, J. A. Oplinger, and M. S. Dike, *J. Am. Chem. Soc.*, **106**, 4558 (1984).  
 l. B. M. Trost, P. G. McDougal, and K. J. Haller, *J. Am. Chem. Soc.*, **106**, 383 (1984).

9. B. M. Trost and K. Hiroi, *J. Am. Chem. Soc.*, **97**, 6911 (1975).
- 10a. F. Delay and G. Ohloff, *Helv. Chim. Acta*, **62**, 2168 (1979).
- b. S. Danishefsky, R. Zamboni, M. Kahn, and S. J. Etheridge, *J. Am. Chem. Soc.*, **103**, 3460 (1981).
- c. R. Noyori, T. Sato, and Y. Hayakawa, *J. Am. Chem. Soc.*, **100**, 2561 (1978).
- d. J. K. Whitesell and R. S. Matthews, *J. Org. Chem.*, **43**, 1650 (1978).
- e. R. C. Cambie, M. P. Hay, L. Larsen, C. E. F. Rickard, P. S. Rutledge, and P. D. Woodgate, *Aust. J. Chem.*, **44**, 821 (1991).
- f. T. K. M. Shing, C. M. Lee, and H. Y. Lo, *Tetrahedron Lett.*, **42**, 8361 (2001).
- g. P. A. Wender and T. P. Mucciaro, *J. Am. Chem. Soc.*, **114**, 5878 (1992).
- 11a. I. Saito, R. Nagata, K. Yubo, and Y. Matsuura, *Tetrahedron Lett.*, **24**, 4439 (1983).
- b. J. R. Wiseman and S. Y. Lee, *J. Org. Chem.*, **51**, 2485 (1986).
- c. H. Nishiyama, M. Matsumoto, H. Arai, H. Sakaguchi, and K. Itoh, *Tetrahedron Lett.*, **27**, 1599 (1986).
- 12a. R. E. Ireland, P. G. M. Wuts, and B. Ernst, *J. Am. Chem. Soc.*, **103**, 3205 (1981).
- b. R. M. Scarborough, Jr., B. H. Tober, and A. B. Smith, III, *J. Am. Chem. Soc.*, **102**, 3904 (1980).
- c. P. F. Hudrik, A. M. Hudrik, G. Nagendrappa, T. Yimenu, E. T. Zellers, and E. Chin, *J. Am. Chem. Soc.*, **102**, 6894 (1980).
- d. T. Wakamatsu, K. Akasaka, and Y. Ban, *J. Org. Chem.*, **44**, 2008 (1979).
- e. D. A. Evans, C. E. Sacks, R. A. Whitney, and N. G. Mandel, *Tetrahedron Lett.*, 727 (1978).
- f. F. Bourelle-Wargnier, M. Vincent, and J. Chuche, *J. Org. Chem.*, **45**, 428 (1980).
- g. J. A. Zalikowski, K. E. Gilbert, and W. T. Borden, *J. Org. Chem.*, **45**, 346 (1980).
- h. E. Vogel, W. Klug, and A. Breuer, *Org. Synth.*, **55**, 86 (1976).
- i. L. D. Spicer, M. W. Bullock, M. Garber, W. Groth, J. J. Hand, D. W. Long, J. L. Sawyer, and R. S. Wayne, *J. Org. Chem.*, **33**, 1350 (1968).
- j. B. E. Rossiter, T. Katsuki, and K. B. Sharpless, *J. Am. Chem. Soc.*, **103**, 464 (1981).
- k. L. A. Paquette and Y.-K. Han, *J. Am. Chem. Soc.*, **103**, 1831 (1981).
- l. M. Muelbacher and C. D. Poulter, *J. Org. Chem.*, **53**, 1026 (1988).
- m. P. T. W. Cheng and S. McLean, *Tetrahedron Lett.*, **29**, 3511 (1988).
- n. A. B. Smith, III, and R. E. Richmond, Jr., *J. Am. Chem. Soc.*, **105**, 575 (1983).
- o. E. J. Corey and Y. B. Xiang, *Tetrahedron Lett.*, **29**, 995 (1988).
- p. T. Tanaka, K. Murakami, A. Kanda, D. Patra, S. Yamamoto, N. Satoh, S.-W. Kim, S. M. Abdur Rahman, H. Ohno, and C. Iwata, *J. Org. Chem.*, **66**, 7107 (2001).
- q. R. K. Boeckman, Jr., J. E. Starrett, Jr., D. G. Nickell, and P.-E. Sum, *J. Am. Chem. Soc.*, **108**, 5549 (1986).
13. Y. Gao and K. B. Sharpless, *J. Org. Chem.*, **53**, 4081 (1988).
14. C. W. Jefford, Y. Wang, and G. Bernardinelli, *Helv. Chim. Acta*, **71**, 2042 (1988).
15. R. W. Murray, M. Singh, B. L. Williams, and H. M. Moncrief, *J. Org. Chem.*, **61**, 1830 (1996).
- 16a. M. Chini, P. Crotti, L. A. Flippin, and F. Macchia, *J. Org. Chem.*, **55**, 4265 (1990).
- b. B. Myrboh, H. Illa, and H. Junjappa, *Synthesis*, 126 (1981); T. Yamauchi, K. Nakao, and K. Fujii, *J. Chem. Soc., Perkin Trans. 1*, 1433 (1987).
- c. R. M. Goodman and Y. Kishi, *J. Am. Chem. Soc.*, **120**, 9392 (1998).
- 17a. J. Moulines, A.-M. Lamidey and V. Desvernes-Breuil, *Synth. Commun.*, **31**, 749 (2001).
- b. M. G. Bolster, B. J. M. Jansen, and A. de Groot, *Tetrahedron*, **57**, 5663 (2001).
18. S. Arseniyadis, R. B. Alves, D. V. Yashunsky, Q. Wang, and P. Potier, *Tetrahedron Lett.*, **36**, 1027 (1995); C. Unaleroglu, V. Aviyente, and S. Arseniyadis, *J. Org. Chem.*, **67**, 2447 (2002).
- 19a. K. D. Eom, J. V. Raman, H. Kim, and J. K. Cha, *J. Am. Chem. Soc.*, **125**, 5415 (2003).
- b. Y. Yamano and M. Ito, *Chem. Pharm. Bull.*, **49**, 1662 (2001).

## Chapter 13

- 1a. T. Hylton and V. Boekelheide, *J. Am. Chem. Soc.*, **90**, 6887 (1968).
- b. B. W. Erickson, *Org. Synth.*, **54**, 19 (1974); E. J. Corey, B. W. Erickson, and R. Noyori, *J. Am. Chem. Soc.*, **93**, 1724 (1971).
- c. H. Paulsen, V. Sinnwell, and P. Stadler, *Angew. Chem. Int. Ed. Engl.*, **11**, 149 (1972).
- d. S. Torii, K. Uneyama, and M. Isihara, *J. Org. Chem.*, **39**, 3645 (1974).
- e. J. A. Marshall and A. E. Greene, *J. Org. Chem.*, **36**, 2035 (1971).
- f. E. Leete, M. R. Chedekel, and G. B. Bodem, *J. Org. Chem.*, **37**, 4465 (1972).
- g. H. Yamamoto and H. L. Sham, *J. Am. Chem. Soc.*, **101**, 1609 (1979).

i. T. Takahashi, K. Kitamura, and J. Tsuji, *Tetrahedron Lett.*, **24**, 4695 (1983).2a. S. Danishefsky and T. Kitahara, *J. Am. Chem. Soc.*, **96**, 7807 (1974).

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References for Problemsb. P. S. Wharton, C. E. Sundin, D. W. Johnson, and H. C. Kluender, *J. Org. Chem.*, **37**, 34 (1972).c. E. J. Corey, B. W. Erickson, and R. Noyori, *J. Am. Chem. Soc.*, **93**, 1724 (1971).d. R. E. Ireland and J. A. Marshall, *J. Org. Chem.*, **27**, 1615 (1962).e. W. S. Johnson, T. J. Brocksom, P. Loew, D. H. Rich, L. Werthemann, R. A. Arnold, T. Li, and D. J. Faulkner, *J. Am. Chem. Soc.*, **92**, 4463 (1970).f. L. Birladeanu, T. Hanafusa, and S. Winstein, *J. Am. Chem. Soc.*, **88**, 2315 (1966); T. Hanafusa, L. Birladeanu, and S. Winstein, *J. Am. Chem. Soc.*, **87**, 3510 (1965).g. H. Takayanagi, Y. Kitano, and Y. Morinaka, *J. Org. Chem.*, **59**, 2700 (1994).3a. A. B. Smith, III, and W. C. Agosta, *J. Am. Chem. Soc.*, **96**, 3289 (1974).b. R. S. Cooke and U. H. Andrews, *J. Am. Chem. Soc.*, **96**, 2974 (1974).c. L. A. Hulshof and H. Wynberg, *J. Am. Chem. Soc.*, **96**, 2191 (1974).d. S. D. Burke, C. W. Murtiashaw, M. S. Dike, S. M. S. Strickland, and J. O. Saunders, *J. Org. Chem.*, **46**, 2400 (1981).e. K. C. Nicolaou, M. R. Pavia, and S. P. Seitz, *J. Am. Chem. Soc.*, **103**, 1224 (1981).f. J. Cossy, B. Gille, S. BouzBouz, and V. Bellosta, *Tetrahedron Lett.*, **38**, 4069 (1997).4a. E. M. Acton, R. N. Goerner, H. S. Uh, K. J. Ryan, D. W. Henry, C. E. Cass, and G. A. LePage, *J. Med. Chem.*, **22**, 518 (1979).b. E. G. Gros, *Carbohd. Res.*, **2**, 56 (1966).c. S. Hanessian and G. Rancourt, *Can. J. Chem.*, **55**, 1111 (1977).d. R. R. Schmidt and A. Gohl, *Chem. Ber.*, **112**, 1689 (1979).5a. S. F. Martin and T. Chou, *J. Org. Chem.*, **43**, 1027 (1978).b. W. C. Still and M.-Y. Tsai, *J. Am. Chem. Soc.*, **102**, 3654 (1980).c. J. C. Bottaro and G. A. Berchtold, *J. Org. Chem.*, **45**, 1176 (1980).d. A. S. Kende and T. P. Demuth, *Tetrahedron Lett.*, **21**, 715 (1980).e. J. A. Marshall and P. G. M. Wuts, *J. Org. Chem.*, **43**, 1086 (1978).6a. R. Bonjouklian and R. A. Ruden, *J. Org. Chem.*, **42**, 4095 (1977).b. L. A. Paquette, R. E. Moerck, B. Harirchian, and P. D. Magnus, *J. Am. Chem. Soc.*, **100**, 1597 (1978).c. P. S. Wharton, C. E. Sundin, D. W. Johnson, and H. C. Kluender, *J. Org. Chem.*, **37**, 34 (1972).d. M. E. Ochoa, M. S. Arias, R. Aguilar, I. Delgado, and J. Tamariz, *Tetrahedron*, **55**, 14535 (1999).e. S. Danishefsky, T. Kitahara, C. F. Yan, and J. Morris, *J. Am. Chem. Soc.*, **101**, 6996 (1979).f. B. M. Trost, J. Ippen, and W. C. Vladuchick, *J. Am. Chem. Soc.*, **99**, 8116 (1977).7a. E. J. Corey, E. J. Trybulski, L. S. Melvin, K. C. Nicolaou, J. A. Sechrist, R. Leltt, P. W. Sheldrake, J. R. Falck, D. J. Brunelle, M. F. Haslanger, S. Kim, and S. Yoo, *J. Am. Chem. Soc.*, **100**, 4618 (1978).b. K. G. Paul, F. Johnson, and D. Favara, *J. Am. Chem. Soc.*, **98**, 1285 (1976).c. P. N. Confalone, G. Pizzolato, E. G. Baggolini, D. Lollar, and M. R. Uskokovic, *J. Am. Chem. Soc.*, **97**, 5936 (1975).d. E. Baer, J. M. Gosheintz, and H. O. L. Fischer, *J. Am. Chem. Soc.*, **61**, 2607 (1939).e. J. L. Coke and A. B. Richon, *J. Org. Chem.*, **41**, 3516 (1976).f. J. R. Dyer, W. E. McGonigal, and K. C. Rice, *J. Am. Chem. Soc.*, **87**, 654 (1965).g. E. J. Corey and S. Nozoe, *J. Am. Chem. Soc.*, **85**, 3527 (1963).h. R. Jacobson, R. J. Taylor, H. J. Williams, and L. R. Smith, *J. Am. Chem. Soc.*, **47**, 1140 (1925).8a. R. B. Miller and E. S. Behare, *J. Am. Chem. Soc.*, **96**, 8102 (1974).b. G. Buchi, W. Hofheinz, and J. V. Paukstelis, *J. Am. Chem. Soc.*, **91**, 6473 (1969).c. M. Brown, *J. Org. Chem.*, **33**, 162 (1968).d. E. J. Corey, R. B. Mitra, and H. Uda, *J. Am. Chem. Soc.*, **86**, 485 (1964).9a. E. Piers, R. W. Britton, and W. de Waal, *J. Am. Chem. Soc.*, **93**, 5113 (1971); K. J. Schmalzl and R. N. Mirrington, *Tetrahedron Lett.*, 3219 (1970); N. Fukamiya, M. Kato, and A. Yoshikoshi, *J. Chem. Soc., Chem. Commun.*, 1120 (1971); N. Fukamiya, M. Kato, and A. Yoshikoshi, *J. Chem. Soc. Perkin Trans. 1*, 1843 (1973); G. Frater, *Helv. Chim. Acta*, **57**, 172 (1974); K. Yamada, Y. Kyotani, S. Manabe, and M. Suzuki, *Tetrahedron*, **35**, 293 (1979); M. E. Jung, C. A. McCombs, Y. Takeda, and Y. G. Pan, *J. Am. Chem. Soc.*, **103**, 6677 (1981); S. C. Welch, J. M. Gruber, and P. A. Morrison, *J. Org. Chem.*, **50**, 2676 (1985); S. C. Welch, C. Chou, J. M. Gruber, and J. M. Assercq, *J. Org. Chem.*, **50**, 2668 (1985); H. Hagiwara, A. Okano, and H. Uda, *J. Chem. Soc., Chem. Commun.*, 1047 (1985); G. Stork and N. H. Baird, *Tetrahedron Lett.*, **26**, 5927 (1985); K. V. Bhaskar and G. S. R. S. Rao, *Tetrahedron Lett.*, **30**, 225 (1989); H. Hagiwara, A. Okano, and H. Uda, *J. Chem. Soc. Perkin Trans. 1*, 2109 (1990); G. S. R. S. Rao and K. V. Bhaskar, *J. Chem. Soc. Perkin Trans. 1*, 2813 (1993).

- b. S. Archambaud, K. Aphecetche-Julienne, and A. Guingant, *Synlett*, 139 (2005); Y. Wu, X. Shen, Y.-Q. Yang, Q. Hu, and J.-H. Huang, *J. Org. Chem.*, **69**, 3857 (2004); Y. G. Suh, J.-K. Jung, S.-Y. Seo, K.-H. Min, D.-Y. Shin, Y.-S. Lee, S. H. Kim and H.-J. Park, *J. Org. Chem.*, **67**, 4127 (2002); D. Kim, J. Lee, P. J. Shim, J. I. Lim, T. Doi and S. Kim *J. Org. Chem.*, **67**, 772 (2002); D. Kim, J. Lee, P. J. Shim, J. I. Lim, H. Jo, and S. Kim *J. Org. Chem.*, **67**, 764 (2002); B. M. Trost and M. L. Crawley, *J. Am. Chem. Soc.*, **124**, 9328 (2002); Y. Wang, and D. Romo, *Org. Lett.*, **4**, 3231 (2002); R. K. Haynes, W. W.-L Lam, L. L. Yeung, I. D. Williams, A. C. Ridley, S. M. Starling, S. C. Vonwiller, T. W. Hambley, P. Lelandais, *J. Org. Chem.*, **62**, 4552 (1997); P. Ducray, B. Rousseau, and C. Mioskowski, *J. Org. Chem.*, **64**, 3800 (1999); A. B. Argade, R. D. Haugwitz, R. Devraj, J. Kozlowski, P. Fanwick, and M. Cushman, *J. Org. Chem.*, **63**, 273 (1998); K. Tomioka, K. Ishikawa, and T. Nakaik, *Synlett*, 901 (1995); V. Bernades, N. Kann, A. Riera, A. Moyano, M. A. Pericas, and A. E. Greene, *J. Org. Chem.*, **60**, 6670 ((1995); A. J. Carnell, G. Cay, G. Gorins, A. Kompany-Saeid R. McCague, H. F. Olivo, S. M. Roberts, and A. J. Willets, *J. Chem. Soc. Perkin Trans. 1*, 3431 (1994); G. Solladie and O. Lohse, *J. Org. Chem.*, **58**, 4555 (1993); D. F. Taber, L. J. Silverberg, and E. D. Robinson, *J. Am. Chem. Soc.*, **113**, 6639 (1991); J. Nokami, M. Ohkura, Y. Dan-oh, and Y. Sakamoto, *Tetrahedron Lett.*, **32**, 2409 (1991); S. Hatakeyama, K. Sugawara, M. Kawamura, and S. Takano, *Synlett*, 691 (1990); B. N. Trost, J. Lynch, P. Renaut, and D. H. Steinman, *J. Am. Chem. Soc.*, **108**, 284 (1986); K. Ueno, H. Suemune, S. Saeki, and K. Sakai, *Chem. Pharm. Bull.*, **33**, 4021 (1985); K. Nakatani and S. Isoe, *Tetrahedron Lett.*, **26**, 2209 (1985); H. J. Gais and T. Lied, *Angew. Chem. Int. Ed. Engl.*, **23**, 145 (1984); M. Honda, K. Hirata, H. Sueoka, T. Katsuki, and T. Yamaguchi, *Tetrahedron Lett.*, **22**, 2679 (1981); T. Kitahara and K. Mori, *Tetrahedron*, **40**, 2935 (1984); K. H. Marx, P. Raddatz, and E. Winterfeldt, *Liebigs Ann. Chem.*, 474 (1984); C. Le Drian, and A. E. Greene, *J. Am. Chem. Soc.*, **104**, 5473 (1982); A. E. Greene, C. Le Drian, and P. Crabbe, *J. Am. Chem. Soc.*, **102**, 7583 (1980); P. A. Bartlett and F. R. Green, III, *J. Am. Chem. Soc.*, **100**, 4858 (1978); E. J. Corey and P. Carpinio, *Tetrahedron Lett.*, **31**, 7555 (1990); E. J. Corey, R. H. Wollenberg, and D. R. Williams, *Tetrahedron Lett.*, **26**, 2243 (1977); E. J. Corey, and R. H. Wollenberg, *Tetrahedron Lett.*, **25**, 4705 (1976).
- c. E. Herrmann, H. J. Gais, B. Rosenstock, G. Raabe, and H. J. Lindner, *Eur. J. Org. Chem.*, 275 (1998); W. Oppolzer, J. Z. Xu, and C. Stone, *Helv. Chim. Acta*, **74**, 465 (1991); K. Mori and M. Tsuji, *Tetrahedron*, **44**, 2835 (1988); D. H. Hua, M. J. Coulter, and I. Badejo, *Tetrahedron Lett.*, **28**, 5465 (1987); J. P. Marino, C. C. Silveira, J. V. Comassetto, and N. Petragnani, *J. Org. Chem.*, **52**, 4140 (1987); J. P. Marino, C. C. Silveira, J. V. Comassetto, and N. Petragnani, *J. Brazil. Chem. Soc.*, **7**, 145 (1996); M. C. Pirrung and S. A. Thomson, *Tetrahedron Lett.*, **27**, 2703 (1986); M. C. Pirrung and S. A. Thomson, *J. Org. Chem.*, **53**, 227 (1988); D. F. Taber and J. L. Schuchardt, *J. Am. Chem. Soc.*, **107**, 5289 (1985); D. F. Taber and J. L. Schuchardt, *Tetrahedron*, **43**, 5677 (1987); D. E. Cane and P. J. Thomas, *J. Am. Chem. Soc.*, **106**, 5295 (1984); T. Ohtsuka, H. Shirahama, and T. Matsumoto, *Tetrahedron Lett.*, **24**, 3851 (1983); L. A. Paquette, G. D. Annis, and H. Schostarez, *J. Am. Chem. Soc.*, **104**, 6646 (1982); W. H. Parsons, R. H. Schlessinger and M. L. Quesada, *J. Am. Chem. Soc.*, **102**, 889 (1979); W. H. Parsons and R. H. Schlessinger, *Bull. Soc. Chim. Fr.*, 327 (1980); S. Danishefsky, M. Hirama, K. Gombatz, T. Harayama, E. Berman and P. F. Schuda, *J. Am. Chem. Soc.*, **100**, 6536 (1978); S. Danishefsky, M. Hirama, K. Gombatz, T. Harayama, E. Berman, and P. F. Schuda, *J. Am. Chem. Soc.*, **101**, 7020 (1979).
- 10a. R. E. Ireland, R. H. Mueller, and A. K. Willard, *J. Am. Chem. Soc.*, **98**, 2868 (1976).
- b. W. A. Kleschick, C. T. Buse, and C. H. Heathcock, *J. Am. Chem. Soc.*, **99**, 247 (1977); P. Fellmann and J. E. Dubois, *Tetrahedron Lett.*, **34**, 1349 (1978).
- c. B. M. Trost, S. A. Godleski, and J. P. Genet, *J. Am. Chem. Soc.*, **100**, 3930 (1978).
- d. M. Mousseron, M. Mousseron, J. Neyrolles, and Y. Beziat, *Bull. Chim. Soc. Fr.* 1483 (1963); Y. Beziat and M. Mousseron-Canet, *Bull. Chim. Soc. Fr.*, 1187 (1968); N. A. Ross and R. A. Bartsch, *J. Org. Chem.*, **68**, 360 (2003); S. A. Babu, M. Yasuda, I. Shibata, and A. Baba, *Org. Lett.*, **6**, 4475 (2004).
- e. G. Stork and V. Nair, *J. Am. Chem. Soc.*, **101**, 1315 (1979).
- 11a. R. D. Cooper, V. B. Jigajimmi, and R. H. Wightman, *Tetrahedron Lett.*, **25**, 5215 (1984).
- b. C. E. Adams, F. J. Walker, and K. B. Sharpless, *J. Org. Chem.*, **50**, 420 (1985).
- c. G. Grethe, J. Sereno, T. H. Williams, and M. R. Uskokovic, *J. Org. Chem.*, **48**, 5315 (1983).
- 12a. T. Taniguchi, M. Takeuchi, and K. Ogasawara, *Tetrahedron: Asymmetry*, **9**, 1451 (1998).
- b. J. A. Marshall, Z.-H. Lu, and B. A. Johns, *J. Org. Chem.*, **63**, 817 (1998).
- c. A. B. Smith, III, B. S. Freeze, M. Xian, and T. Hirose, *Org. Lett.*, **7**, 1825 (2005).
- d. P. V. Ramachandran, B. Prabhudas, J. S. Chandra, M. V. R. Reddy, and H. C. Brown, *Tetrahedron Lett.*, **45**, 1011 (2004).
- e. W. R. Roush, L. Banfi, J. C. Park, and L. K. Hoong, *Tetrahedron Lett.*, **30**, 6457 (1989).

- 13a. H. Albrecht, G. Bonnet, D. Enders, and G. Zimmermann, *Tetrahedron Lett.*, 3175 (1980).
- b. A. I. Meyers, G. Knaus, K. Kamata, and M. E. Ford, *J. Am. Chem. Soc.*, **98**, 567 (1976).
- c. S. Hashimoto and K. Koga, *Tetrahedron Lett.*, 573 (1978).
- d. B. M. Trost, D. O'Krongly, and J. L. Balletire, *J. Am. Chem. Soc.*, **102**, 7595 (1980); J. A. Tucker, K. N. Houk, and B. M. Trost, *J. Am. Chem. Soc.*, **112**, 5465 (1990); C. Siegel, and E. R. Thornton, *Tetrahedron: Asymmetry*, **2**, 1413 (1991); J. F. Maddaluno, N. Gresh, and C. Giessner-Prettre, *J. Org. Chem.*, **59**, 793 (1999).
- e. A. I. Meyers, R. K. Smith, and C. E. Whitten, *J. Org. Chem.*, **44**, 2250 (1979).
- f. W. R. Roush, T. G. Marron, and L. A. Pfeifer, *J. Org. Chem.*, **62**, 474 (1997).
- g. D. Zuev and L. A. Paquette, *Org. Lett.*, **2**, 679 (2000).
- h. M. T. Crimmins and J. She, *Synlett*, 1371 (2004).
14. G. E. Keck, A. Palani, and S. F. McHardy, *J. Org. Chem.*, **59**, 3113 (1994); N. Nakajima, K. Uoto, O. Yonemitsu, and T. Hata, *Chem. Pharm. Bull.*, **39**, 64 (1991); K. C. Nicolaou, M. R. Pavia, and S. P. Seitz, *J. Am. Chem. Soc.*, **103**, 1224 (1981).
15. S. Hanessian and R. Schaum, *Tetrahedron Lett.*, **38**, 163 (1997).
- 16a. R. A. Holton, C. Somoza, H.-B. Kim, F. Liang, R. J. Biediger, P. D. Boatman, M. Shindo, C. C. Smith, S. Kim, H. Nadizadeh, Y. Suzuki, C. Tao, P. Va, S. Tang, K. K. Murthi, L. N. Gentile, and J. H. Lin, *J. Am. Chem. Soc.*, **116**, 1597 (1994); R. A. Holton, H.-B. Kim, C. Somoza, F. Liang, R. J. Biediger, P. D. Boatman, M. Shindo, C. C. Smith, S. Kim, H. Nadizadeh, Y. Suzuki, C. Tao, P. Vu, S. Tank, P. Zhang, K. K. Murthi, L. N. Gentile, and J. H. Lin, *J. Am. Chem. Soc.*, **116**, 1599 (1994).
- b. K. C. Nicolaou, P. G. Nanternet, H. Ueno, R. K. Guy, E. A. Coulouros, and E. J. Sorenson, *J. Am. Chem. Soc.*, **117**, 624 (1995); K. C. Nicolaou, J.-J. Liu, Z. Yang, H. Ueno, E. J. Sorenson, C. F. Claiborne, R. K. Guy, C.-K. Hwang, M. Nakada, and P. G. Nanternet, *J. Am. Chem. Soc.*, **117**, 645 (1995); K. C. Nicolaou, H. Ueno, J.-J. Liu, P. G. Nanternet, Z. Yang, J. Renaud, K. Paulvannan, and R. Chadha, *J. Am. Chem. Soc.*, **117**, 653 (1995).
- c. S. J. Danishefsky, J. J. Masters, W. B. Young, J. T. Link, L. B. Snyder, T. V. Magne, D. K. Jung, R. C. A. Isaacs, W. G. Bornmann, C. A. Alaimo, C. A. Coburn, and M. J. Di Grandi, *J. Am. Chem. Soc.*, **118**, 2843 (1996).
- d. P. A. Wender, N. F. Badham, S. P. Conway, P. E. Floreancig, T. E. Glass, C. Granicher, J. B. Houze, J. Janichen, D. Lee, D. G. Marquess, P. L. McGrane, W. Meng, T. P. Mucciaro, M. Mulebach, M. G. Natchus, H. Paulsen, D. B. Rawlins, J. Satkofsky, A. J. Shuker, J. C. Sutton, R. E. Taylor, and K. Tomooka, *J. Am. Chem. Soc.*, **119**, 2755 (1997); P. A. Wender, N. F. Badham, S. P. Conway, P. E. Floreancig, T. E. Glass, J. B. Houze, N. E. Krauss, D. Lee, D. G. Marquessk, P. L. McGrane, W. Meng, M. G. Natchus, A. J. Shuker, J. C. Sutton, and R. E. Taylor, *J. Am. Chem. Soc.*, **119**, 2757 (1997).
- e. T. Mukaiyama, I. Shiina, H. Iwadare, M. Saitoh, T. Nishimura, N. Ohkawa, H. Sakoh, K. Nishimura, Y. Tani, M. Hasegawa, K. Yamada, and K. Saitoh, *Chem. Eur. J.*, **5**, 121 (1999).
- f. K. Morihara, R. Hara, S. Kawahara, T. Nishimori, N. Nakamura, H. Kusama, and I. Kuwajima, *J. Am. Chem. Soc.*, **120**, 12980 (1998); H. Kusama, R. Hara, S. Kawahara, T. Nishimori, H. Kashima, N. Nakamura, K. Morihara, and I. Kuwajima, *J. Am. Chem. Soc.*, **122**, 3811 (2000).

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