Regio- and Diastereoselective Decarboxylative Coupling of Heteroaromatic Alkanes

Shelli R. Waetzig and Jon A. Tunge*

Department of Chemistry, University of Kansas, Lawrence, KS 66045

Supporting Information

Table of Contents

General Experimental	S-1
Table 1: Impact of catalyst loading on elimination	S-3
Spectral Characterization of 2a	S-4
Spectral Characterization of 2b	S-5
Spectral Characterization of 2c	S-6
Spectral Characterization of 2d	S-7
Spectral Characterization of 2e	S-8
Spectral Characterization of 2f	S-9
Spectral Characterization of 2g	S-10
Spectral Characterization of 2h	S-11
Spectral Characterization of 2i	S-12
Spectral Characterization of 2j	S-13
Spectral Characterization of 2k	S-14
Spectral Characterization of 2l	S-15
Spectral Characterization of 2m	S-16
Spectral Characterization of 2n	S-17
Spectral Characterization of 2o	S-18
Spectral Characterization of 2p	S-19
Spectral Characterization of 2q	S-20
X-ray crystal structure for 4g	S-21

Experimental:

General Information:

All reactions were run in flame-dried glassware under Ar atmosphere using standard Schlenk techniques. CH₂Cl₂, Toluene and THF were dried over activated alumina. Commercially available reagents were used without additional purification unless otherwise stated. Compound purification was effected by flash chromatography using 230x400 mesh, 60 Å porosity, silica obtained from Sorbent Technologies. ¹H NMR and ¹³C NMR spectra were obtained on a Bruker Avance 400 or a Bruker Avance 500 DRX spectrometer and referenced to residual protio solvent signals (some spectra were taken using a QNP Cryoprobe). Structural assignments are based on ¹H, ¹³C, DEPT-135, COSY, HSQC and IR spectroscopies.

Procedure for the synthesis of allyl-2-benzoxazole propanoates: This was prepared using a modification of a procedure by Cherney.¹ Dimethyl malonate (13.8 mmol) was added to 2-aminophenol (4.6 mmol). The mixture was heated to 160° C for 5 hours, at which time p-TsOH (0.46 mmol) was added to the reaction. This solution was stirred at 160° C for 12 hours. The mixture was cooled to room temperature and directly purified on silica gel using 95:5 hexane/ethyl acetate as the eluent. The resulting methyl-2-benzoxazol-2-yl acetate was then treated with LiOH according to the procedure by Cherney and let stir at room temperature overnight.¹ The crude acid was treated with 1.1 equivalents of the appropriate allylic alcohol, 1.0 equivalents of DCC, and 0.10 equivalents of DMAP in CH₂Cl₂.² The solutions were stirred at room temperature overnight. The reactions were filtered and washed with H₂O and brine, dried over MgSO₄, and concentrated. The allyl-2-benzoxazol-2-yl acetates were purified on silica gel using 90:10 hexane/ethyl acetate. Alkylation of the α -position was accomplished using ^tBuOK and the corresponding alkylating agent.³

Procedure for the synthesis of allyl-2-benzothiazole propanoates: A mixture of the appropriate allyl cyanoacetate⁴ was mixed with 2-aminothiophenol⁵ and heated at 120° C overnight.⁶ The crude reaction was purified directly on silica gel. The resulting ester was alkylated with ^tBuOK and the appropriate alkylating agent.³

Procedure for the synthesis of allyl-2-benzimidazole propanoates: Benzimidazolyl acetonitrile was hydrolyzed to the corresponding acid according to Copeland and Day.⁷ Coupling of the acid was achieved using cinnamyl alcohol, DCC, Et₃N and cat. DMAP after heating at reflux in CH₂Cl₂ overnight.² The benzimidazole nitrogen was then alkylated with MeI according to Das and coworkers.⁸ Alkylation was achieved with ^tBuOK and the appropriate alkylating agent.³

Procedure for the synthesis of allyl-2-pyridin-2-yl propanoates: These substrates were synthesized by the DCC/DMAP catalyzed coupling of 2-pyridyl acetic acid hydrochloride with the appropriate allylic alcohol.² Alkylation was achieved with ^tBuOK and the appropriate alkylating reagent.³

Procedure for the synthesis of cinnamyl 2-(4,5-diphenyloxazol-2-yl)-3-phenylpropanoate: The methyl 2-(4,5-diphenyloxazol-2-yl)acetate was synthesized in a procedure described by Davies.⁹ The ester was hydrolyzed using LiOH.¹ The crude acid

¹ Cherney, R. J. PCT Intl. App. # WO 2004098516, **2004**.

² Kim, H. Y.; Lantrip, D. A.; Fuchs, P. L. *Org. Lett.* **2001**, 3, 2137.

³ Lee, H.-S.; Park, J.-S.; Kim, B. M.; Gellman, S. H. *J. Org. Chem.* **2003**, 68, 1575.

⁴ Kobayashi, T.; Inoue, T.; Nishino, S.; Fujihara, Y.; Oizumi, K.; Kimura, T. *Chem. Pharm. Bull.* **1995**, 43, 797.

⁵ 2-aminothiophenol was purified via distillation and stored under Ar atmosphere.

⁶ Abbotto, A.; Bradamante, S.; Facchetti, A.; Pagani, G. A. *J. Org. Chem.* **2002**, 67, 5753.

⁷ Copeland, R. A. B.; Day, A. R. *J. Amer. Chem. Soc.* **1943**, 65, 1072.

⁸ Das, J.; Laxman Rao, C. V.; Sastry, T. V. R. S.; Roshaiiah, M.; Gowri Sankar, P.; Khadeer, A.; Sitaram Kumar, M.; Mallik, A.; Selvakumar, N.; Iqbal, J.; Trehan, S. *Bioorg. Med. Chem. Lett.* **2005**, 15, 337.

⁹ Davies, H. M.; Townsend, R. J. *J. Org. Chem.* **2001**, 66, 6595.

was coupled with cinnamyl alcohol using DCC/DMAP catalyzed reaction.² Alkylation was achieved using ^tBuOK and benzyl bromide.³

Procedure for the bromocyclization of 2g: 2g (0.06 M in C₆H₆) was treated with bromine (1 equiv., 0.07 M solution in CH₂Cl₂) in at 0° C. The reaction was then stirred at room temperature for 15 min and then filtered. The filtrate was recrystallized from CH₂Cl₂/pentane.¹⁰

General Procedure for Palladium-catalyzed decarboxylation reaction: In a dried Schlenk tube under argon, Pd(PPh₃)₃ (0.013 mmol) was added to substrates **1** (0.25 mmol) in toluene. The reactions of the cinnamyl esters were run at 0.05 M substrate concentration and 80° C for the specified time. The reactions of the alkyl substituted allyl esters were run at 0.025 M substrate concentration at 100° C for the specified time. After such time, the reactions were cooled to room temperature, concentrated *in vacuo* and directly purified via flash chromatography on silica gel.

Table of Effect of Catalyst Loading on Elimination:

[1j]	mol % cat.	Temp. °C	2j	3j
0.05	0.5 ^a	80	11	89
0.05	1	80	49	51
0.05	5	80	58	42
0.05	10	80	59	41

^a Reaction only went to 42% completion after 16 h.

¹⁰ Szychowski, J.; Wrobel, J. T.; Leniewski, A. *Bull. Acad. Pol. Sci., Ser. Sci. Chim.* **1980**, 28, 9.

Spectral Characterization of Compounds:

2a: (2-(3-phenylpent-4-en-2-yl)benzoxazole): white solid: 98:2 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 1.49 (d, 3H: $J = 7.0$ Hz, R_2CHCH_3), 3.53 (dq, 1H: $J = 7.0, 9.1$ Hz, R_2CHCH_3), 3.86 (t, 1H: $J = 9.1$ Hz, R_2CHPh), 5.15 (dd, 1H: $J = 1.5, 10.1$ Hz, H_A), 5.19 (dd, 1H: $J = 1.5, 17.0$ Hz, H_B), 6.10 (ddd, 1H: $J = 9.1, 10.0, 17.0$ Hz, $\text{RCH}=\text{CH}_2$), 7.11 (m, 1H: Ar CH), 7.13 (s, 2H: overlapping Ar CH's), 7.19 (d, 1H: $J = 1.5$ Hz, Ar CH), 7.24 (m, 2H: overlapping Het Ar CH's), 7.41 (m, 1H: Het Ar CH's), 7.60 (m, 1H: Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 16.9 (R_2CHCH_3), 40.0 (R_2CHCH_3), 55.3 (R_2CHPh), 111.1 (Het Ar CH), 118.1 ($\text{RCH}=\text{CH}_2$), 120.5 (Het Ar CH), 124.9 (Het Ar CH), 125.2 (Het Ar CH), 127.5 (Ar CH), 128.6 (Ar CH), 129.4 (Ar CH), 139.3 ($\text{RCH}=\text{CH}_2$), 142.1 (quat. Ar C), 142.9 (quat. Ar C), 151.5 (quat. Ar C), 170.3 ($\text{N}=\text{CO}$); IR (CH_2Cl_2) ν_{max} : 3054, 2986, 1638, 1613, 1569, 1456, 1421, 1263, 1152, 994, 926, 896; HRMS calcd for $[\text{M}+\text{H}]$ 264.1388, found 264.1382.

2b: (2-(1,3-diphenylpent-4-en-2-yl)benzoxazole): white solid: 98:2 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 3.21 (dd, 1H: $J = 10.9, 13.9$ Hz, CHHPh), 3.34 (dd, 1H: $J = 4.0, 13.9$ Hz, CHHPh), 3.72 (ddd, 1H: $J = 4.0, 9.6, 10.9$ Hz, $\text{R}_2\text{CHCH}_2\text{Ph}$), 3.92 (t, 1H: $J = 9.6$ Hz, R_2CHPh), 5.25 (app. d, 1H: $J = 10.0$ Hz, H_A), 5.29 (app. d, 1H: $J = 17.0$ Hz, H_B), 6.22 (ddd, 1H: $J = 1.3, 10.0, 17.0$ Hz, $\text{RCH}=\text{CH}_2$), 7.03-7.21 (m, 12H: overlapping Ar CH's), 7.31 (m, 1H: Het Ar CH), 7.55 (m, 1H: Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 38.3 (PhCH_2R), 48.3 ($\text{R}_2\text{CHCH}_2\text{Ph}$), 55.2 (R_2CHPh), 111.0 (Het Ar CH), 118.3 ($\text{RCH}=\text{CH}_2$), 120.5 (Het Ar CH), 124.8 (Het Ar CH), 125.2 (Het Ar CH), 127.3 (Ar CH), 127.7 (Ar CH), 128.6 (Ar CH), 129.4 (Ar CH), 129.5 (Ar CH), 129.7 (Ar CH), 140.0 ($\text{RCH}=\text{CH}_2$), 140.1 (quat. Ar C), 141.9 (quat. Ar C), 142.4 (quat. Ar C), 151.3 (quat. Ar C), 168.5 ($\text{OC}=\text{N}$); IR (CH_2Cl_2) ν_{max} : 3054, 2985, 1637, 1612, 1570, 1495, 1455, 1421, 1263, 1144, 992, 926, 896; HRMS calcd for $[\text{M}+\text{H}]$ 340.1701, found 340.1712.

2c: (2-(1,3-diphenylpent-4-en-2-yl)benzothiazole): yellow oil: 98:2 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 3.20 (dd, 1H: $J = 11.0, 14.0$ Hz, CHHPh), 3.45 (dd, 1H: $J = 3.8, 14.0$ Hz, CHHPh), 3.77 (ddd, 1H: $J = 3.8, 9.9, 11.0$ Hz, $\text{R}_2\text{CHCH}_2\text{Ph}$), 3.95 (t, 1H: $J = 9.9$ Hz, R_2CHPh), 5.25 (dd, 1H: $J = 1.3, 9.9$ Hz, H_A), 5.31 (app. d, 1H: $J = 17.0$ Hz, H_B), 6.23 (dt, 1H: $J = 9.9, 17.0$ Hz, RCH=CH_2), 7.03-7.21 (m, 10H: overlapping Ar CH's), 7.24 (ddd, 1H: $J = 1.0, 7.3, 8.0$ Hz, Het Ar CH), 7.38 (ddd, 1H: $J = 1.0, 7.3, 8.0$ Hz, Het Ar CH), 7.63 (d, 1H: $J = 8.0$ Hz, Het Ar CH), 7.92 (d, 1H: $J = 8.0$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 40.2 (PhCH_2R), 52.3 ($\text{R}_2\text{CHCH}_2\text{Ph}$), 56.6 (R_2CHPh), 117.5 (RCH=CH_2), 121.5 (Het Ar CH), 122.8 (Het Ar CH), 124.6 (Het Ar CH), 125.7 (Het Ar CH), 126.3 (Ar CH), 126.7 (Ar CH), 128.0 (Ar CH), 128.5 (Ar CH), 128.6 (Ar CH), 129.1 (Ar CH), 134.8 (quat. Ar C), 138.4 (quat. Ar C), 139.7 (RCH=CH_2), 142.1 (quat. Ar C), 147.0 (quat. Ar C), 173.4 (SC=N); IR (CH_2Cl_2) ν_{max} : 3053, 2986, 1637, 1601, 1550, 1496, 1454, 1436, 1422, 1264, 924, 896; HRMS calcd for $[\text{M}+\text{H}]$ 356.1473, found 356.1482.

2d: (2-(1-(1-phenylallyl)cyclohexyl)benzothiazole): pale yellow oil: 98:2 hex/EtOAc: ^1H NMR (400 MHz, CDCl_3) δ 1.15-1.40 (m, 2H: overlapping cyclohexyl CH 's), 1.44-1.56 (m, 2H: overlapping cyclohexyl CH 's), 1.63-1.79 (m, 4H: overlapping cyclohexyl CH 's), 2.34 (app. d, 1H: $J = 12.5$ Hz, cyclohexyl CH), 2.42 (app. d, 1H: $J = 13.2$ Hz, cyclohexyl CH), 3.52 (d, 1H: $J = 9.9$ Hz, R_2CHPh), 5.03 (app. dd, 1H: $J = 1.7, 16.7$ Hz, H_B), 5.09 (dd, 1H: $J = 1.7, 10.1$ Hz, H_A), 6.36 (dt, 1H: $J = 10.1, 16.7$ Hz, $\text{RCH}=\text{CH}_2$) 6.84 (dd, 2H: $J = 1.8, 7.7$ Hz, overlapping Ar CH 's), 7.13 (m, 3H: overlapping Ar CH 's), 7.35 (app. t, 1H: $J = 7.8$ Hz, Het Ar CH), 7.45 (app. t, 1H: $J = 7.8$ Hz, Het Ar CH) 7.84 (d, 1H: $J = 7.8$ Hz, Het Ar CH), 8.01 (d, 1H: $J = 7.8$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 22.9 (overlapping cyclohexyl CH_2 's), 25.9 (cyclohexyl CH_2), 24.9 (cyclohexyl CH_2), 35.9 (cyclohexyl CH_2), 49.3 (quat. cyclohexyl C), 63.1 (R_2CHPh), 117.5 ($\text{RCH}=\text{CH}_2$), 121.6 (Het Ar CH), 123.1 (Het Ar CH), 124.7 (Het Ar CH), 125.7 (Het Ar CH), 126.7 (Ar CH), 127.9 (Ar CH), 129.5 (Ar CH), 135.5 (Ar CH), 137.4 ($\text{RCH}=\text{CH}_2$), 140.6 (quat.

Ar C), 153.2 (quat. Ar C), 177.2 (SC=N); IR (CH₂Cl₂) ν_{max} : 3054, 2986, 2933, 2857, 1633, 1600, 1492, 1451, 1421, 1313, 1264, 1047, 1013, 919, 896; HRMS calcd for [M+H] 343.1630, found 343.1630.

2e: (1-methyl-2-(3-phenylpent-4-en-2-yl)-1H-benzimidazole): yellow solid: 95:5 to 90:10 hex/EtOAc: ¹H NMR (500 MHz, CDCl₃) δ 1.29 (d, 3H: J = 6.9 Hz, R₂CHCH₃), 3.44 (dq, 1H: J = 6.9, 9.5 Hz, R₂CHCH₃), 3.63 (s, 3H: NCH₃), 3.90 (t, 1H: J = 9.5 Hz, R₂CHPh), 4.84 (app. d, 1H: J = 17.0 Hz, H_B), 4.88 (d, 1H: J = 0.7, 10.4 Hz, H_A), 6.01 (ddd, 1H: J = 8.2, 10.4, 17.0 Hz, RCH=CH₂), 7.24 (dd, 2H: J = 7.8, 9.0 Hz, Ar H's), 7.28 (m, 4H: Ar CH), 7.33 (overlapping dd, 3H: J = 7.8, 15.3 Hz, Ar CH's); ¹³C NMR (125 MHz, CDCl₃) δ 19.1 (R₂CHCH₃), 29.9 (NCH₃), 37.2 (R₂CHCH₃), 56.0 (R₂CHPh), 109.4 (Ar CH), 116.8 (RCH=CH₂), 119.4 (Ar CH), 122.3 (Ar CH), 127.0 (Ar CH), 128.7 (2 Ar CH's), 128.9 (2 Ar CH's), 135.2 (quat Ar C), 139.2 (RCH=CH₂), 142.3 (quat. Ar C), 157.8 (NC=N); IR (CH₂Cl₂) ν_{max} : 3054, 2987, 1599, 1550, 1422, 1265, 1153, 896; HRMS calcd for [M+H] 277.1705, found 277.1698.

2f: (2-(1,3-diphenylpent-4-en-2-yl)-1-methyl-1H-benzimidazole): pale yellow oil: 95:5 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 2.90 (dd, 1H: $J = 3.8, 13.1$ Hz, PhCHH), 3.02 (s, 3H: NCH_3), 3.12 (dd, 1H: $J = 11.2, 13.1$ Hz, PhCHH), 3.48 (dt, 1H: $J = 4.1, 10.2$ Hz, R_2CHBn), 4.12 (t, 1H: $J = 8.5$ Hz, R_2CHPh), 4.86 (app. d, 1H: $J = 17.0$ Hz, H_B), 4.89 (app. d, 1H: $J = 10.3$ Hz, H_A), 5.98 (ddd, 1H: $J = 8.1, 10.3, 17.0$ Hz, $\text{RCH}=\text{CH}_2$), 6.79 (m, 2H: overlapping Ar CH's), 7.06 (m, 3H: overlapping Ar CH's), 7.15 (d, 1H: $J = 7.9$ Hz, Het Ar CH), 7.23 (dt, 1H: 1.1, 7.9 Hz, Het Ar CH), 7.26 (m, 1H: Het Ar CH), 7.30 (m, 3H: overlapping Ar CH's), 7.39 (m, 2H: overlapping Ar CH's), 7.85 (d, 1H: $J = 7.9$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 29.0 (NCH_3), 40.4 (CH_2Ph), 46.2 (R_2CHBn), 54.8 (R_2CHPh), 109.4 (Ar CH), 116.9 ($\text{RCH}=\text{CH}_2$), 119.4 (Ar CH), 122.0 (overlapping Ar CH's), 126.4 (Ar CH), 127.1 (Ar CH), 128.4 (Ar CH), 128.5 (Ar CH), 128.9 (Ar CH), 129.1 (Ar CH), 135.0 (quat. Ar C), 139.0 ($\text{RCH}=\text{CH}_2$), 140.2 (quat. Ar C), 142.5 (quat. Ar CH), 143.0 (quat. Ar C), 156.3 ($\text{NC}=\text{N}$); IR (CH_2Cl_2) ν_{max} : 3054, 2987, 1601, 1551, 1493, 1466, 1440, 1422, 1267, 1154, 896; HRMS calcd for $[\text{M}+\text{H}]$ 353.2018, found 353.2015.

2g: (2-(2-phenylpent-4-en-2-yl)pyridine): pale orange oil: 95:5 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 1.39 (d, 3H: $J = 7.0$ Hz, R_2CHCH_3), 3.24 (dq, 1H: $J = 7.0, 9.7$ Hz, R_2CHCH_3), 3.68 (t, 1H: $J = 9.7$ Hz, R_2CHPh), 5.10 (dd, 1H: $J = 1.4, 10.1$ Hz, H_A), 5.16 (app. d, 1H: $J = 17.0$ Hz, H_B), 6.10 (dt, 1H: $J = 9.7, 17.0$ Hz, RCH=CH_2), 6.82 (d, 1H: $J = 7.7$ Hz, R(C=N)CH), 6.96 (dd, 1H: $J = 4.4$ Hz, NCH=CH), 7.04 (m, 3H: Ar CH's), 7.12 (m, 2H: Ar CH's), 7.37 (t, 1H: $J = 7.5$ Hz, NCH=CHCH), 8.48 (d, 1H: $J = 4.4$ Hz, NCH); ^{13}C NMR (125 MHz, CDCl_3) δ 19.4 (R_2CHCH_3), 47.0 (R_2CHCH_3), 56.9 (R_2CHPh), 116.3 (RCH=CH_2), 121.2 (NCH=CH), 123.3 (N=CRCH), 126.1 (Ar CH), 128.1 (Ar CH), 128.7 (Ar CH), 136.2 (NCH=CHCH), 140.4 (RCH=CH_2), 143.7 (quat. Ar C), 149.1 (NCH), 164.6 (N=CR); IR (CH_2Cl_2) ν_{max} : 3054, 2987, 1637, 1591, 1569, 1550, 1474, 1422, 1263, 1150, 992, 896; HRMS calcd for $[\text{M}+\text{H}]$ 224.1439, found 224.1426.

2h: (2-(1,3-diphenylpent-4-en-2-yl)pyridine): yellow oil: 100% CH_2Cl_2 : ^1H NMR (500 MHz, CDCl_3) δ 3.12 (app. t, 1H: $J = 11.5$ Hz, PhCHHR), 3.32 (m, 2H: one of PhCHHR and BnCHR), 3.89 (t, 1H: $J = 9.6$ Hz, R_2CHPh), 5.22 (dd, 1H: $J = 1.4, 10.0$ Hz, H_A), 5.30 (d, 1H: $J = 17.1$ Hz, H_B), 6.22 (dt, 1H: $J = 10.0, 17.1$ Hz, $\text{RCH}=\text{CH}_2$), 6.38 (d, 1H: $J = 7.6$ Hz, Het Ar CH), 6.89 (d, 3H: $J = 7.3$ Hz, overlapping Het Ar CH and 2 Ar CH's), 6.98-7.12 (m, 9H: one Het Ar CH and 8 Ar CH's), 8.50 (dd, 1H: $J = 0.9, 4.8$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 39.9 (PhCH_2R), 44.2 (R_2CHBn), 56.2 (R_2CHPh), 116.7 ($\text{RCH}=\text{CH}_2$), 121.1 (Het Ar CH), 125.3 (Het Ar CH), 125.8 (Ar CH), 126.1 (Ar CH), 128.0 (Ar CH), 128.1 (Ar CH), 128.3 (Ar CH), 129.2 (Ar CH), 135.5 (Het Ar CH), 140.8 ($\text{RCH}=\text{CH}_2$), 140.9 (quat. Ar C), 143.4 (quat. Ar C), 149.1 (Het Ar CH), 161.8 ($\text{N}=\text{CR}$); IR (CH_2Cl_2) ν_{max} : 3054, 2987, 1637, 1600, 1570, 1551, 1490, 1470, 1435, 1422, 996, 920, 896; HRMS calcd for $[\text{M}+\text{H}]$ 300.1752, found 300.1765.

2i: (2-(1,3-diphenylpent-4-en-2-yl)-4,5-diphenyloxazole): yellow oil: 98:2 hex/EtOAc: ^1H NMR (400 MHz, CDCl_3) δ 3.20 (dd, 1H: $J = 10.8, 13.9$ Hz, RCHHPh), 3.31 (dd, 1H: $J = 4.2, 13.9$ Hz, RCHHPh), 3.61 (ddd, 1H: $J = 4.2, 10.8, 10.8$ Hz, $\text{R}_2\text{CHCH}_2\text{Ph}$), 3.87 (t, 1H: $J = 9.4$ Hz, R_2CHPh), 5.26 (dd, 1H: $J = 1.3, 9.8$ Hz, H_A), 5.29 (app. d, 1H: $J = 17.0$ Hz, H_B), 6.25 (dt, 1H: $J = 9.8, 17.0$ Hz, $\text{RCH}=\text{CH}_2$), 7.12-7.17 (m, 4H: Ar CH's), 7.19-7.25 (m, 8H: Ar CH's), 7.27-7.34 (m, 6H: Ar CH's), 7.46 (m, 2H: Ar CH's); ^{13}C NMR (125 MHz, CDCl_3) δ 38.4 (RCH_2Ph), 48.0 ($\text{R}_2\text{CHCH}_2\text{Ph}$), 55.4 (R_2CHPh), 118.1 ($\text{RCH}=\text{CH}_2$), 127.2 (Ar CH), 127.4 (Ar CH), 127.6 (Ar CH), 128.8 (Ar CH), 128.9 (Ar CH), 128.9 (Ar CH), 129.1 (Ar CH), 129.3 (Ar CH), 129.4 (Ar CH), 129.6 (overlapping Ar CH's), 129.9 (Ar CH), 130.1 (quat. Ar C), 133.8 (quat. Ar C), 135.9 (quat. Ar C), 140.3 ($\text{RCH}=\text{CH}_2$), 140.6 (quat. Ar C), 142.9 (quat. Ar C), 145.7 (quat. Ar C), 164.7

(N=CO); IR (CH₂Cl₂) ν_{max} : 3054, 2986, 1695, 1602, 1560, 1494, 1436, 1421, 1263, 1157, 1072, 1025, 992, 963, 896; HRMS calcd for [M+H] 442.2171, found 442.2175.

2j: (2-(3,3-dimethylpent-4-en-2-yl)benzoxazole): pale orange oil: 98:2 hex/EtOAc: ¹H NMR (500 MHz, CDCl₃) δ 1.12 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 1.13 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 1.38 (d, 3H: J = 7.2 Hz, R₂CHCH₃), 3.08 (q, 1H: J = 7.2 Hz, R₂CHCH₃), 5.01 (dd, 1H: J = 1.1, 17.5 Hz, H_B), 5.04 (dd, 1H: J = 1.1, 10.8 Hz, H_A), 5.94 (dd, 1H: J = 10.8, 17.5 Hz, RCH=CH₂), 7.31 (m, 2H: Het Ar CH), 7.51 (m, 1H: Het Ar CH), 7.71 (m, 1H: Het Ar CH); ¹³C NMR (125 MHz, CDCl₃) δ 14.5 (R₂CHCH₃), 24.0 (one of diastereotopic R₂C(CH₃)₂), 25.8 (one of diastereotopic R₂C(CH₃)₂), 40.3 (R₂C(CH₃)₂), 44.0 (R₂CHCH₃), 110.6 (Het Ar CH), 112.6 (RCH=CH₂), 119.9 (Het Ar CH), 124.4 (Het Ar CH), 124.6 (Het Ar CH), 141.4 (quat. Het Ar C), 145.9 (RCH=CH₂), 150.6 (quat. Het Ar C), 169.4 (N=CO); IR (CH₂Cl₂) ν_{max} : 3054, 2984, 1782, 1638, 1610, 1563, 1456, 1421, 1378, 1263, 1139, 1074, 1003, 922, 895; HRMS calcd for [M+H] 216.1388, found 216.1390.

2k: (2-(2-benzyl-3,3-dimethyl-1-phenylpent-4-en-2-yl)benzoxazole): pale yellow solid: 98:2 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 1.14 (s, 6H: $\text{R}_2\text{C}(\text{CH}_3)_2$), 3.45 (d, 2H: $J = 14.9$ Hz, $\text{R}_2\text{C}(\text{CHHPh})_2$), 3.60 (d, 2H: $J = 14.9$ Hz, $\text{R}_2\text{C}(\text{CHHPh})_2$), 4.97 (dd, 1H: $J = 1.0, 17.4$ Hz, H_B), 5.02 (dd, 1H: $J = 1.0, 10.2$ Hz, H_A), 6.11 (dd, 1H: $J = 10.2, 17.4$ Hz, $\text{RCH}=\text{CH}_2$), 7.02 (m, 4H: Ar CH's), 7.07 (m, 6H: Ar CH's), 7.36 (dp, 2H: $J = 1.5, 7.3$ Hz, Ar CH's), 7.50 (app. d, 1H: $J = 7.3$ Hz, Het Ar CH), 7.81 (app. d, 1H: $J = 7.3$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 24.6 ($\text{R}_2\text{C}(\text{CH}_2\text{Ph})_2$), 40.0 ($\text{R}_2\text{C}(\text{CH}_3)_2$), 45.4 ($\text{R}_2\text{C}(\text{CH}_3)_2$), 52.0 ($\text{R}_2\text{C}(\text{CH}_2\text{Ph})_2$), 111.4 (Het Ar CH), 113.7 ($\text{RCH}=\text{CH}_2$), 120.9 (Het Ar CH), 125.1 (Het Ar CH), 125.6 (Het Ar CH), 126.9 (Ar CH), 128.8 (Ar CH), 131.5 (Ar CH), 139.7 (quat. Ar C), 141.9 (quat. Ar C), 146.0 ($\text{RCH}=\text{CH}_2$), 151.0 (quat. Ar C), 170.9 ($\text{N}=\text{CO}$); IR (CH_2Cl_2) ν_{max} : 3054, 2987, 1603, 1550, 1496, 1456, 1421, 1261, 1154, 896; HRMS calcd for $[\text{M}+\text{H}]$ 382.2171, found 382.2172.

dr = 2.5 : 1
b:l = 12.5 : 1

2l: (2-(3-methyl-1-phenylpent-4-en-2-yl)benzoxazole): colorless oil: 99:1 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ major diastereomer: 1.02 (d, 3H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 2.73 (sext., 1H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 3.15-3.22 (m, 3H: overlapping PhCH_2 and $\text{PhCH}_2\text{CHR}_2$), 5.13 (dd, 1H: $J = 1.1, 10.2$ Hz, H_A), 5.15 (dd, 1H: $J = 1.1, 17.2$ Hz, H_B), 5.86 (ddd, 1H: $J = 8.3, 10.2, 17.2$ Hz, $\text{RCH}=\text{CH}_2$), 7.07 (m, 2H: overlapping Ar CH's), 7.20 (m, 3H: overlapping Ar CH's), 7.29 (m, 2H: overlapping Het Ar CH's), 7.46 (m, 1H: Het Ar CH), 7.67 (m, 1H: Het Ar CH); minor diastereomer: 1.16 (d, 3H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 2.73 (sext., 1H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 3.11 (m, 1H: PhCHHR), 3.25 (m, 1H: BnCHR_2), 3.36 (dt, 1H: $J = 5.6, 9.4$ Hz, PhCHHR), 5.06 (m, 2H: $\text{RCH}=\text{CH}_2$), 5.87 (ddd, 1H: 8.2, 10.4, 17.0 Hz, $\text{CH}_2=\text{CHR}$), 7.12 (m, 2H: overlapping Ar CH's), 7.20 (m, 3H: overlapping Ar CH's), 7.29 (m, 2H: overlapping Het Ar CH's), 7.46 (m, 1H: Het Ar CH), 7.67 (m, 1H: Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ major diastereomer: 18.3 (R_2CHCH_3), 37.9 (PhCH_2R), 42.3 ($\text{CH}_2=\text{CHCHCH}_3$), 48.1 ($\text{PhCH}_2\text{CHR}_2$), 110.6 (Het Ar CH), 115.8 ($\text{RCH}=\text{CH}_2$), 120.0 (Het Ar CH), 124.3 (Het Ar CH), 124.6 (Het Ar CH), 126.4 (Ar CH), 128.6 (Ar CH), 128.9 (Ar CH), 139.6 (quat. Ar C), 141.4 (quat. Ar C), 141.7 ($\text{RCH}=\text{CH}_2$), 150.8 (quat Ar C), 168.2 ($\text{N}=\text{CO}$);

minor diastereomer: 18.4 (R_2CHCH_3), 36.8 ($PhCH_2R$), 41.5 ($CH_2=CHCHCH_3$), 47.7 ($PhCH_2CHR_2$), 110.6 (Het Ar CH), 115.9 ($RCH=CH_2$), 120.0 (Het Ar CH), 124.2 (Het Ar CH), 124.6 (Het Ar CH), 126.5 (Ar CH), 128.6 (Ar CH), 129.0 (Ar CH), 129.1 (quat 139.7 (quat. Ar C), 140.5 ($RCH=CH_2$), 141.4 (quat. Ar C), 170.0 ($N=CO$); IR (CH_2Cl_2) ν_{max} : 3054, 2986, 1641, 1565, 1485, 1455, 1421, 1264, 1141, 1003, 923, 896; HRMS calcd for $[M+H]$ 278.1545, found 278.1544.

dr = 2.9 : 1
b:l = 15.9 : 1

2m: (2-(3-methylpent-4-en-2-yl)benzoxazole): yellow oil: 98:2 hex/EtOAc: 1H NMR (500 MHz, $CDCl_3$) δ major diastereomer: 1.03 (d, 3H: $J = 6.8$ Hz, $CH_2=CHCHCH_3$), 1.40 (d, 3H: $J = 7.1$ Hz, R_2CHCH_3), 2.70 (p, 1H: $J = 7.1$ Hz, R_2CHCH_3), 3.03 (app. p, 1H: $J = 7.1$ Hz, $CH_2=CHCHCH_3$), 5.06 (dd, 1H: $J = 1.7, 10.4$ Hz, H_A), 5.08 (dd, 1H: $J = 1.0, 17.2$ Hz, H_B), 5.76 (dd, 1H: $J = 10.4, 17.2$ Hz, $RCH=CH_2$), 7.31 (m, 2H: overlapping Het Ar CH's), 7.50 (m, 1H: Het Ar CH's), 7.70 (m, 1H: Het Ar CH); minor diastereomer: 1.09 (d, 3H: $J = 6.8$ Hz, $CH_2=CHCHCH_3$), 1.42 (d, 3H: $J = 7.1$ Hz, R_2CHCH_3), 2.74 (p, 1H: $J = 7.1$ Hz, R_2CHCH_3), 3.16 (app. p, 1H: $J = 7.1$ Hz, $CH_2=CHCHCH_3$), 4.99 (m, 2H: H_B and H_A), 5.80 (m, 1H: $RCH=CH_2$), 7.31 (m, 2H: overlapping Het Ar CH's), 7.50 (m, 1H: Het Ar CH's), 7.70 (m, 1H: Het Ar CH); ^{13}C NMR (125 MHz, $CDCl_3$) δ major diastereomer: 16.1 (R_2CHCH_3), 18.5 ($CH_2=CHCHCH_3$), 39.9 (R_2CHCH_3), 42.7 ($CH_2=CHCHCH_3$), 110.5 (Het Ar CH), 115.6 ($RCH=CH_2$), 119.9 (Het Ar CH), 124.3

(Het Ar CH), 124.6 (Het Ar CH), 141.1 (RCH=CH₂), 141.2 (quat. Ar C), 150.8 (quat Ar C), 170.0 (N=CO); minor diastereomer: 14.8 (R₂CHCH₃), 16.6 (CH₂=CHCHCH₃), 39.6 (R₂CHCH₃), 41.9 (CH₂=CHCHCH₃), 110.5 (Het Ar CH), 115.1 (RCH=CH₂), 119.9 (Het Ar CH), 124.2 (Het Ar CH), 124.6 (Het Ar CH), 141.1 (RCH=CH₂), 141.3 (quat. Ar C), 141.4 (quat. Ar C), 170.0 (N=CO); IR (CH₂Cl₂) ν_{max} : 3052, 2983, 1780, 1640, 1612, 1566, 1456, 1421, 1264, 1147, 1069, 1003, 922, 896; HRMS calcd for [M+H] 202.1232, found 202.1226.

2n: (2-(3,3-dimethyl-1-phenylpent-4-en-2-yl)benzothiazole): colorless oil: 98:2 hex/EtOAc: ¹H NMR (400 MHz, CDCl₃) δ 1.16 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 1.25 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 3.17 (m, 2H: R₂C(CH₂Ph)₂), 3.34 (dd, 1H: J = 3.4, 11.4 Hz, R₂CHBn), 5.12 (dd, 1H: J = 1.0, 17.3 Hz, H_B), 5.15 (dd, 1H: J = 1.0, 10.7 Hz, H_A), 6.10 (dd, 1H: J = 10.7, 17.3 Hz, RCH=CH₂), 7.01 (m, 2H: overlapping Ar CH's), 7.09 (m, 3H: overlapping Ar CH's), 7.33 (app. t, 1H: J = 8.1 Hz, Het Ar CH), 7.43 (app. t, 1H: J = 8.1 Hz, Het Ar CH), 7.78 (d, 1H: J = 8.1 Hz, Het Ar CH), 7.99 (d, 1H: J = 8.1 Hz, Het Ar CH); ¹³C NMR (125 MHz, CDCl₃) δ 23.6 (one of diastereotopic R₂C(CH₃)₂), 27.0 (one of diastereotopic R₂C(CH₃)₂), 37.7 (RCH₂Ph), 40.9 (R₂C(CH₃)₂), 57.1 (R₂CHBn), 113.1 (RCH=CH₂), 121.5 (Het Ar CH), 123.0 (Het Ar CH), 124.7 (Het Ar CH), 125.8 (Het Ar CH), 126.1 (Ar CH), 128.4 (Ar CH), 128.9 (Ar CH), 134.9 (quat. Ar C), 140.4 (quat. Ar C), 146.4 (RCH=CH₂), 153.2 (quat. Ar C),

172.6 (N=CS); IR (CH₂Cl₂) ν_{max} : 3054, 2986, 1603, 1550, 1501, 1437, 1421, 1265, 920, 896; HRMS calcd for [M+H] 308.1473, found 308.1477.

2o: (2-(3,3-dimethylpent-4-en-2-yl)benzothiazole): pale yellow oil: 98:2 hex/EtOAc: ¹H NMR (500 MHz, CDCl₃) δ 1.13 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 1.14 (s, 3H: one of diastereotopic R₂C(CH₃)₂), 1.40 (d, 3H: J = 7.1 Hz, R₂CHCH₃), 3.27 (q, 1H: J = 7.1 Hz, R₂CHCH₃), 5.03 (dd, 1H: J = 1.3, 17.4 Hz, H_B), 5.08 (dd, 1H: J = 1.3, 10.9 Hz, H_A), 5.99 (dd, 1H: J = 10.9, 17.4 Hz, RCH=CH₂), 7.36 (ddd, 1H: J = 1.2, 7.2, 8.1 Hz, Het Ar CH), 7.46 (ddd, 1H: J = 1.2, 7.2, 8.1 Hz, Het Ar CH), 7.85 (d, 1H: J = 8.1 Hz, Het Ar CH), 8.01 (d, 1H: J = 8.1 Hz, Het Ar CH); ¹³C NMR (125 MHz, CDCl₃) δ 17.0 (R₂CHCH₃), 24.2 (one of diastereotopic R₂C(CH₃)₂), 26.2 (one of diastereotopic R₂C(CH₃)₂), 40.2 (R₂C(CH₃)₂), 49.2 (R₂CHCH₃), 112.9 (RCH=CH₂), 121.5 (Het Ar CH), 122.9 (Het Ar CH), 124.8 (Het Ar CH), 125.9 (Het Ar CH), 135.1 (quat. Het Ar C), 145.9 (RCH=CH₂), 153.0 (quat. Het Ar C), 174.9 (N=CS); IR (CH₂Cl₂) ν_{max} : 3054, 2979, 1637, 1506, 1455, 1437, 1421, 1265, 1048, 1004, 918, 896; HRMS calcd for [M+H] 232.1160, found 232.1158.

2p: (2-(2-benzyl-3-methyl-1-phenylpent-4-en-2-yl)benzothiazole): pale yellow oil: 99.5:0.5 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ 1.06 (d, 3H: $J = 6.8$ Hz, R_2CHCH_3), 2.76 (dq, 1H: $J = 6.8, 8.7$ Hz, R_2CCHCH_3), 3.09 (d, 1H: $J = 15.4$ Hz, one of diastereotopic $\text{R}_2\text{C}(\text{CHHPh})_2$), 3.47 (app. q, 2H: $J = 14.4$ Hz, diastereotopic $\text{R}_2\text{C}(\text{CHHPh})_2$), 3.63 (d, 1H: $J = 15.4$ Hz, one of diastereotopic $\text{R}_2\text{C}(\text{CHHPh})_2$), 5.02 (dd, 1H: $J = 1.7, 17.1$ Hz, H_B), 5.07 (dd, 1H: $J = 1.7, 10.2$ Hz, H_A), 6.01 (ddd, 1H: $J = 8.8, 10.2, 17.1$ Hz, $\text{RCH}=\text{CH}_2$), 6.98 (m, 2H: overlapping Ar CH's), 7.01 (m, 2H: overlapping Ar CH's), 7.16 (m, 3H: overlapping Ar CH's), 7.20 (m, 3H: Ar CH's), 7.41 (ddd, 1H: $J = 0.9, 7.4, 8.1$ Hz, Het Ar CH), 7.52 (ddd, 1H: $J = 1.2, 7.4, 8.1$ Hz, Het Ar CH), 7.90 (d, 1H: $J = 8.1$ Hz, Het Ar CH), 8.09 (d, 1H: $J = 8.1$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ 16.8 (R_2CHCH_3), 41.2 (diastereotopic CH_2Ph), 43.2 (diastereotopic CH_2Ph), 45.7 (R_2CHCH_3), 52.1 ($\text{R}_2\text{C}(\text{CH}_2\text{Ph})_2$), 117.2 ($\text{RCH}=\text{CH}_2$), 122.3 (Het Ar CH), 124.1 (Het Ar CH), 125.7 (Het Ar CH), 126.7 (Het Ar CH), 127.1 (Ar CH), 127.4 (Ar CH), 128.9 (Ar CH), 129.0 (Ar CH), 131.3 (Ar CH), 131.7 (Ar CH), 136.1 (quat Ar. C), 138.6 (quat Ar. C), 139.3 (quat. Ar C), 141.3 ($\text{RCH}=\text{CH}_2$), 153.8 (quat. Ar C), 178.5 ($\text{N}=\text{CS}$); IR (CH_2Cl_2) ν_{max} : 3055, 2985, 1635, 1603, 1550, 1496, 1453, 1437, 1421, 1263, 1004, 951, 919, 896; HRMS calcd for $[\text{M}+\text{H}]$ 384.1786, found 384.1785.

dr = 10.7 : 1

b:l = 18.5 : 1

2q: (2-(3-methylpent-4-en-2-yl)benzothiazole): yellow oil: 98:2 hex/EtOAc: ^1H NMR (500 MHz, CDCl_3) δ major diastereomer: 1.04 (d, 3H: $J = 6.9$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 1.42 (d, 3H: $J = 7.0$ Hz, R_2CHCH_3), 2.65 (sext., 1H: $J = 6.9$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 3.17 (dq, 1H: $J = 6.9, 7.8$ Hz, R_2CHCH_3), 5.06 (dd, 1H: $J = 1.6, 10.3$ Hz, H_A), 5.09 (dd, 1H: $J = 1.6, 17.2$ Hz, H_B), 5.77 (ddd, 1H: $J = 8.3, 10.3, 17.2$ Hz, $\text{RCH}=\text{CH}_2$), 7.36 (ddd, 1H: $J = 1.3, 7.3, 8.2$ Hz, Het Ar CH), 7.46 (ddd, 1H: $J = 1.3, 7.3, 8.2$ Hz, Het Ar CH), 7.86 (app. d, 1H: $J = 8.2$ Hz, Het Ar CH), 8.00 (app. d, 1H: $J = 8.2$ Hz, Het Ar CH); minor diastereomer: 1.10 (d, 3H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 1.44 (d, 3H: $J = 7.1$ Hz, R_2CHCH_3), 2.73 (sext., 1H: $J = 7.1$ Hz, $\text{CH}_2=\text{CHCHCH}_3$), 3.32 (app. p, 1H: $J = 7.1$ Hz, R_2CHCH_3), 4.99 (dt, 1H: $J = 1.4, 10.2$ Hz, H_B), 5.03 (dt, 1H: 1.4, 17.3 Hz, H_B), 5.83 (ddd, 1H: $J = 7.3, 10.2, 17.3$ Hz, $\text{RCH}=\text{CH}_2$), 7.36 (ddd, 1H: $J = 1.3, 7.3, 8.2$ Hz, Het Ar CH), 7.46 (ddd, 1H: $J = 1.3, 7.3, 8.2$ Hz, Het Ar CH), 7.86 (app. d, 1H: $J = 8.2$ Hz, Het Ar CH), 8.00 (app. d, 1H: $J = 8.2$ Hz, Het Ar CH); ^{13}C NMR (125 MHz, CDCl_3) δ major diastereomer: 18.7 (R_2CHCH_3), 18.8 ($\text{CH}_2=\text{CHCHCH}_3$), 44.5 (R_2CHCH_3), 44.7 ($\text{CH}_2=\text{CHCHCH}_3$), 115.4 ($\text{RCH}=\text{CH}_2$), 121.5 (Het Ar CH), 122.7 (Het Ar CH), 124.6 (Het Ar CH), 125.8 (Het Ar CH), 134.7 (quat. Het Ar C), 141.1 ($\text{RCH}=\text{CH}_2$), 153.0 (quat. Het Ar C), 176.6 ($\text{N}=\text{CS}$); IR (CH_2Cl_2) ν_{max} : 3053, 2983, 2930, 1695, 1641, 1514, 1455, 1438, 1421, 1268, 1042, 999, 920, 896; HRMS calcd for $[\text{M}+\text{H}]$ 218.1003, found 218.0993.

Crystal Structure for **4g**