



## An expeditious, bidirectional synthesis of furofuranones: a new application of Morita–Baylis–Hillman adducts

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### ABSTRACT

A concise, flexible approach of general utility to the furo[3,2-*b*]furanones from readily available Morita–Baylis–Hillman adducts is delineated. In an expeditious variant of this approach, a four-step cascade process is executed in a one-pot operation to generate the furofuranone framework containing two quaternary centers.

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Natural products based on the furo[3,2-*b*]furanone framework such as goniofufurone **1**<sup>1</sup> and plakortones A and B **2**<sup>2</sup> have periodically surfaced in the literature. However, the furofuranone motif has been widely encountered as a dominant sub-structure in a diverse range of complex natural products of mixed biosynthesis including pallavicinin **3**,<sup>3</sup> norrisolide **4**,<sup>4</sup> dendrillolide A **5**,<sup>5</sup> and more recently, micrandilactone A **6**<sup>6</sup> and its siblings, Figure 1. Interestingly, not only goniofufurone **1** and plakortones A and B **2**, based exclusively on the furo[3,2-*b*]furanone platform, but even others such as **3–6**, containing this moiety as part of their structure, exhibit a wide range of biological activities. For example, plant-derived **1** is known to be cytotoxic to several human cancer cell lines<sup>1</sup> and marine-derived **2** displayed activation of cardiac SR-Ca<sup>2+</sup>-pumping ATPase at micromolar concentrations.<sup>2,7</sup> Compounds **3–6** have also been found to exhibit a range of biological activities.<sup>8</sup> Thus, the furo[3,2-*b*]furanone core appears to be a promising pharmacophoric group and this attribute, along with the complex natural product architecture into which it is embedded, has generated considerable interest in assembling this moiety. However, synthetic efforts in this area have mainly focused on a particular natural product target bearing the furo[3,2-*b*]furanone moiety,<sup>9,10</sup> and generally applicable solutions to this system are lacking, barring an approach based on the Pd-mediated carbonylation of 1,3-diols.<sup>11</sup> We report herein a simple, concise methodology for assembling diverse furo[3,2-*b*]furanones from readily available Morita–Baylis–Hillman (MBH) adducts.<sup>12,13</sup>

An outline of the methodology is delineated in Scheme 1 involving propargylation of the MBH adduct (**7**→**8**), elaboration to a  $\gamma$ -butenolide (**8**→**9**) and an oxy-Michael addition (**9**→**10**), to generate the requisite furo[3,2-*b*]furanone moiety.<sup>10</sup> Bi-directionality can be imparted to this overall process by exploiting either of the two oxygen functionalities of the MBH adduct **7** for the ini-

tial propargylation reaction and its manifestation provides access to either furo[3,2-*b*]furanone **10** or **12** with swapping of the R<sup>1</sup> and R<sup>2</sup> substituents. This protocol gives considerable latitude in terms of the placement of the substituents, particularly with quaternary centers on the furo[3,2-*b*]furanone framework.

To test the viability of the methodology depicted in Scheme 1, the readily available TBS-protected MBH adduct **13**,<sup>13</sup> from methyl vinyl ketone and formaldehyde, was smoothly propargylated to

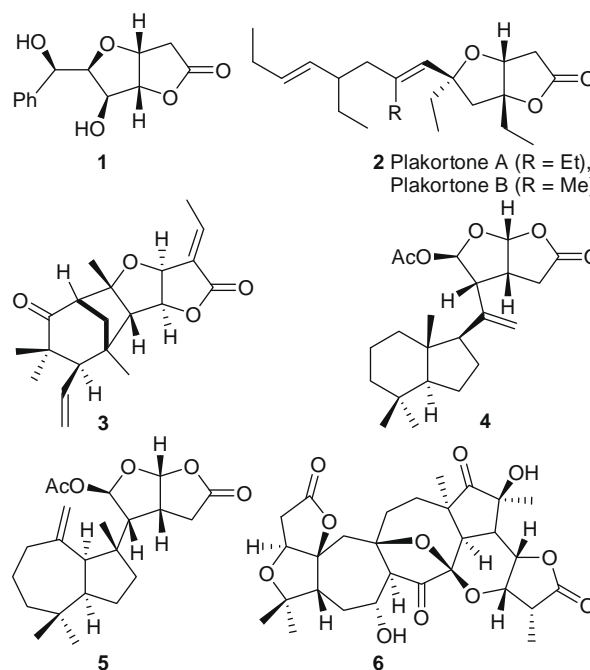
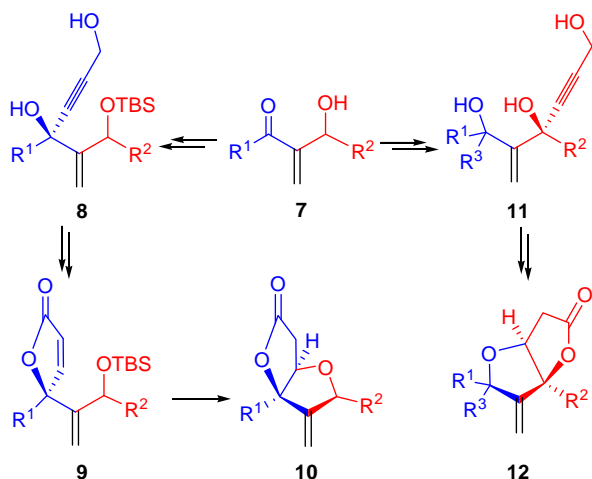


Figure 1. Structural diversity in furofuranone-containing natural products.

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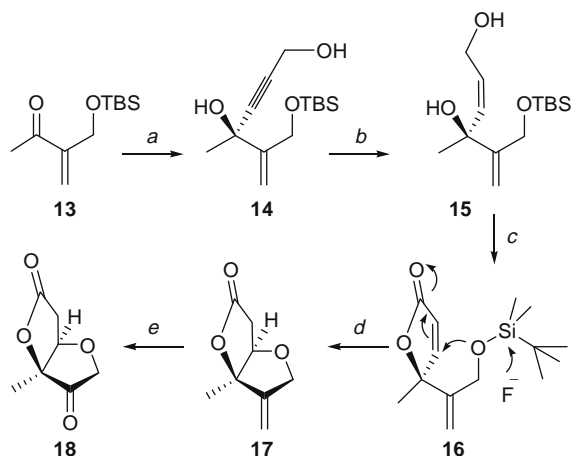
E-mail address: [gm@orgchem.iisc.ernet.in](mailto:gm@orgchem.iisc.ernet.in) (G. Mehta).



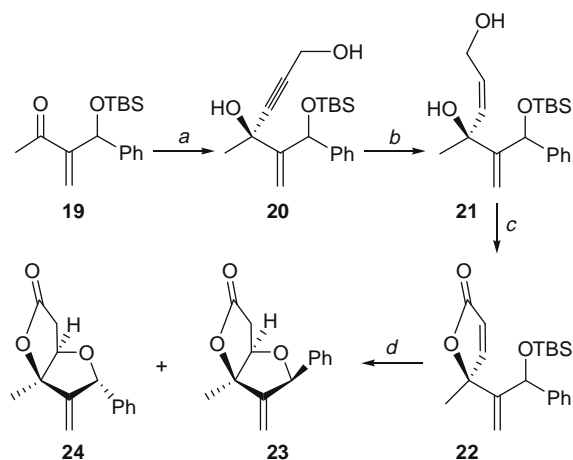
**Scheme 1.** A general bidirectional approach for the construction of furo[3,2-*b*]furanones.

give adduct **14**. Regio- and stereoselective hydrogenation of **14** furnished the *Z*-allylic alcohol **15** and  $\text{MnO}_2$  oxidation led to the butenolide **16**. Silyl deprotection in **16** led to concomitant oxy-Michael addition and generation of the furofuranone **17**<sup>14</sup> in four steps, **Scheme 2**. The placement of the terminal methylene on the furofuranone framework was quite useful as it could be oxidatively cleaved to deliver a versatile bicyclic ketone **18**.<sup>14</sup> The preceding sequence emanating from **13** could also be implemented on the TBS-protected MBH adduct **19**,<sup>13</sup> derived from methyl vinyl ketone and benzaldehyde, via propargylation (**19**→**20**), regio- and stereoselective alkyne reduction (**20**→**21**),  $\text{MnO}_2$  oxidation (**21**→**22**) and silyl deprotection to furnish the readily separable furofuranoid diastereomers **23** and **24** (55:45),<sup>14</sup> **Scheme 3**. The stereochemistry of **23** and **24** was confirmed by X-ray crystal structure analysis of furofuranone **24**.<sup>15</sup>

The generality of this version of the furofuranone synthesis was further demonstrated through the preparation of adducts **25** and **26**, readily obtainable in two steps from the TBS-protected acrolein-formaldehyde MBH adduct **27**,<sup>13</sup> **Scheme 4**. Implementation of the above described four-step protocol on **25** (**25**→**28**→**29**→**30**→**31**) and **26** (**26**→**32**→**33**→**34**→**35**) led to the furofuranones **31** and **35**,<sup>14</sup> respectively.

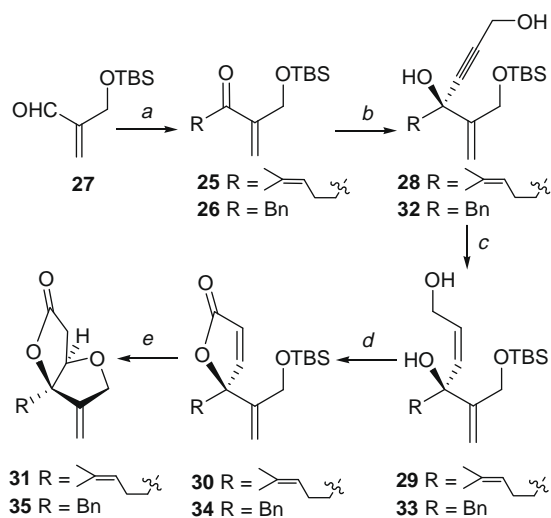


**Scheme 2.** Reagents and conditions: (a) propargyl alcohol, *n*-BuLi, THF, 0 °C, 4 h, 66%; (b) Lindlar catalyst,  $\text{H}_2$ , MeOH, rt, 2 h, 94%; (c)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 20 h, 92%; (d) TBAF, THF, rt, 20 min, 98%; (e) (i)  $\text{OsO}_4/\text{NMMO}$ , acetone/ $\text{H}_2\text{O}$  (4:1), 55 °C, 20 h, 90%; (ii)  $\text{NaIO}_4$ , THF/ $\text{H}_2\text{O}$  (3:1), 30 min, 60%.

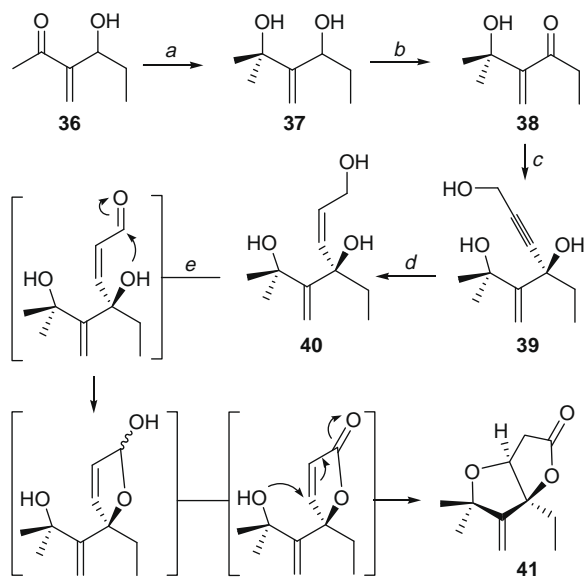


**Scheme 3.** Reagents and conditions: (a) propargyl alcohol, *n*-BuLi, THF, 0 °C, 6 h, 62%; (b) Lindlar catalyst,  $\text{H}_2$ , MeOH, rt, 2 h, 85%; (c)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 20 h, 92%; (d) TBAF, THF, rt, 20 min, 94% (**23**:**24**, 55:45).

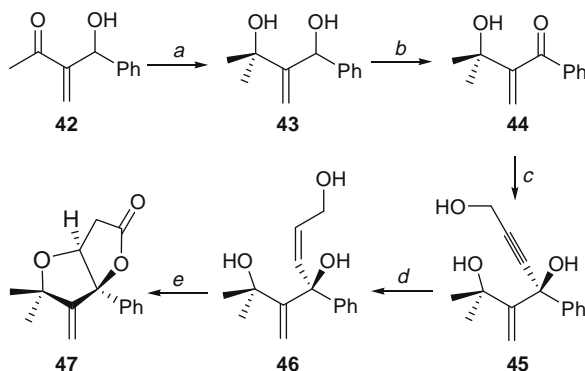
In a bidirectional variant of our furofuranone approach, the MBH adduct **36**<sup>13</sup> of methyl vinyl ketone and propionaldehyde was transformed into hydroxyketone **38** through Grignard addition to give **37** and further chemoselective oxidation, **Scheme 5**. Propargylation of **38** to **39** and selective alkyne reduction led to the key precursor triol **40**.<sup>14</sup>  $\text{MnO}_2$  oxidation of **40** triggered a four-step cascade process in a one-pot operation to deliver furo[3,2-*b*]furanone derivative **41**<sup>14</sup> in near quantitative yield, **Scheme 5**. Interestingly, access to furofuranone **41** is free of any protecting group manoeuvre and its framework has two quaternary centers in place, a structural feature reminiscent of plakortones **2** and micrandilactone **6**. The efficacy of this cascade process to furofuranone systems was further demonstrated employing the MBH adduct **42**<sup>13</sup> of methyl vinyl ketone and benzaldehyde. Elaboration of **42** to hydroxyketone **44** via **43** was followed by propargylation to **45** and stereocontrolled partial reduction furnished the triol **46** to set the stage for the four-step cascade cyclization. Indeed, exposure of **46** to  $\text{MnO}_2$  resulted in furofuranone **47** in quantitative yield,<sup>14</sup>



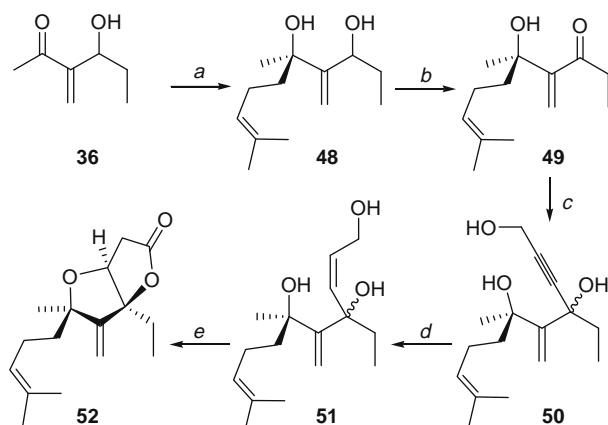
**Scheme 4.** Reagents and conditions: (a) (i) homoprenyl bromide, Mg, THF, 0 °C, 30 min; benzyl chloride, Mg, THF, 0 °C, 1 h; (ii) Dess–Martin periodinane,  $\text{CH}_2\text{Cl}_2$ , rt, 2 h, 83% (**25**) and 52% (**26**) [over two steps]; (b) propargyl alcohol, *n*-BuLi, THF, 0 °C, 6 h, 60% (**28**) and 62% (**32**); (c) Lindlar catalyst,  $\text{H}_2$ , MeOH, rt, 2 h, 92% (**29**) and 88% (**33**); (d)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 20 h, 90% (**30**) and 92% (**34**); (e) TBAF, THF, rt, 20 min, 94% (**31**) and 92% (**35**).



**Scheme 5.** Reagents and conditions: (a)  $\text{CH}_3\text{I}$ , Mg,  $\text{Et}_2\text{O}$ , rt, 1 h, 75%; (b) Dess–Martin periodinane,  $\text{CH}_2\text{Cl}_2$ , rt, 2 h, 93%; (c) propargyl alcohol, *n*-BuLi, THF, 0 °C, 6 h, 62 %; (d) Lindlar catalyst,  $\text{H}_2$ , EtOAc, rt, 30 min, 92%; (e)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 6 h, 96%.



**Scheme 6.** Reagents and conditions: (a)  $\text{CH}_3\text{I}$ , Mg,  $\text{Et}_2\text{O}$ , rt, 1 h, 80%; (b) Dess–Martin periodinane,  $\text{CH}_2\text{Cl}_2$ , rt, 2 h, 90%; (c) propargyl alcohol, *n*-BuLi, THF, 0 °C, 6 h, 80%; (d) Lindlar catalyst,  $\text{H}_2$ , EtOAc, rt, 30 min, 98%; (e)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 8 h, 99%.



**Scheme 7.** Reagents and conditions: (a) homoprenyl bromide, Mg, THF, 0 °C, 1 h, 80%; (b) Dess–Martin periodinane,  $\text{CH}_2\text{Cl}_2$ , rt, 2 h, 93%; (c) propargyl alcohol, *n*-BuLi, THF, 0 °C, 6 h, 60%; (d) Lindlar catalyst,  $\text{H}_2$ , EtOAc, rt, 30 min, 90%; (e)  $\text{MnO}_2$ ,  $\text{CH}_2\text{Cl}_2$ , rt, 6 h, 96%.

**Scheme 6.** Further amplification of this theme with the intent to probe stereochemical preferences during the installation of the quaternary center led us to ketone **49** via **48**, obtainable in turn from the MBH adduct **36**.<sup>13</sup> Propargylation of **49** led to a separable mixture of diastereomers **50** (7:3) and further selective alkyne reduction of the major diastereomer led to **51**. An  $\text{MnO}_2$ -mediated oxidative cascade cyclization of **51** furnished **52** (stereostructure delineated through NOESY)<sup>14</sup> in which the ethyl and the homoprenyl arms on the furofuranone are *trans*-disposed, **Scheme 7**.

In conclusion, a general approach to structurally embellished furo[3,2-*b*]furanones, a motif widely present among natural products, from readily available Morita–Baylis–Hillman adducts, involving cascade cyclizations has been outlined. Application of the methodology delineated here towards the synthesis of micrandilactone **6** as well as the development of its asymmetric variant is being actively pursued and will be reported shortly.

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## References and notes

- Fang, X.; Anderson, J. E.; Chang, C.; Fanwick, P. E.; McLaughlin, J. L. *J. Chem. Soc., Perkin Trans. 1* **1990**, 1655–1661.
- Patil, A. D.; Freyer, A. J.; Bean, M. F.; Carte, B. K.; Westley, J. W.; Johnson, R. K.; Lahouratate, P. *Tetrahedron* **1996**, *52*, 377–394.
- (a) Wu, C. L.; Liu, H. L.; Uang, H. L. *Phytochemistry* **1994**, *35*, 822–824; (b) Asakawa, Y. *Phytochemistry* **2001**, *56*, 297–312.
- Hochlowski, J.; Faulkner, D. J.; Matsumoto, G.; Clardy, J. *J. Org. Chem.* **1983**, *48*, 1141–1142.
- Sullivan, B. J.; Faulkner, D. J. *J. Org. Chem.* **1984**, *49*, 3204–3209.
- Li, R. T.; Zhao, Q. S.; Li, S. H.; Han, Q. B.; Sun, H. D.; Lu, Y.; Zhang, L. L.; Zheng, O. T. *Org. Lett.* **2003**, *5*, 1023–1026.
- Caffierei, F.; Fattorusso, E.; Tagliatalata-Scafati, O.; Di Rosa, M.; Ianaro, A. *Tetrahedron* **1999**, *55*, 13831–13840.
- (a) Takizawa, P. A.; Yucel, J. K.; Veit, B.; Faulkner, D. J.; Deerinck, T.; Soto, G.; Ellisman, M.; Malhotra, V. *Cell* **1993**, *73*, 1079–1090; (b) Toyota, M.; Saito, T.; Asakawa, Y. *Chem. Pharm. Bull.* **1998**, *46*, 178–180.
- Selected references: (a) Kim, C.; Hoang, R.; Theodorakis, E. A. *Org. Lett.* **1999**, *1*, 1295–1297; (b) Peng, X. S.; Wong, H. N. C. *Chem. Asian J.* **2006**, *1*–2, 111–120; (c) Semmelhack, M. F.; Hooley, R. J.; Kraml, C. M. *Org. Lett.* **2006**, *8*, 5203–5206. and references cited therein; (d) Prasad, K. R.; Gholap, S. L. *J. Org. Chem.* **2008**, *73*, 2–11 and references cited therein.
- (a) Mehta, G.; Bhat, B. A. *Tetrahedron Lett.* **2009**, *50*, 2472–2477; (b) Imagawa, H.; Saijo, H.; Kurisaki, T.; Yamamoto, H.; Kubo, M.; Fukuyama, Y.; Nishizawa, M. *Org. Lett.* **2009**, *11*, 1253–1255; (c) Chen, A. P.-J.; Muller, C. C.; Cooper, H. M.; Williams, C. M. *Org. Lett.* **2009**, *11*, 3758–3761.
- (a) Paddon-Jones, G. C.; McErlean, C. S. P.; Hayes, P.; Moore, C. J.; Konig, W. A.; Kitching, W. J. *Org. Chem.* **2001**, *66*, 7487–7495; (b) Kapitán, P.; Gracza, T. *ARKIVOC* **2008**, 8–11 and references cited therein.
- For a recent review, see: Basavaiah, D.; Rao, K. V.; Reddy, R. J. *Chem. Soc. Rev.* **2007**, *36*, 1581–1588.
- (a) Kawamura, M.; Kobayashi, S. *Tetrahedron Lett.* **1999**, *40*, 1539–1552; (b) Shi, M.; Liu, Y. H. *Org. Biomol. Chem.* **2006**, *4*, 1468–1470.
- All new compounds were fully characterized on the basis of IR,  $^1\text{H}$  NMR,  $^{13}\text{C}$  NMR and HRMS spectral data. Spectral data of selected compounds: **compound 17** IR (neat) 2924, 2853, 1778, 1233, 1097, 1055, 937  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  5.42 (m, 1H), 5.27 (m, 1H), 4.66–4.60 (m, 1H), 4.44–4.34 (m, 2H), 2.84 (dd,  $J = 18.3, 5.1$  Hz, 1H), 2.74 (d,  $J = 18.3$  Hz, 1H), 1.54 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ )  $\delta$  174.4, 147.4, 109.9, 89.8, 83.1, 71.2, 36.4, 20.2; HRMS (ES)  $m/z$  calcd for  $\text{C}_8\text{H}_{10}\text{O}_3\text{Na}$  ( $\text{M}+\text{Na}^+$ ): 177.0528; found: 177.0524; **compound 18**: IR (neat) 2926, 2855, 1777, 1061  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  4.58 (d,  $J = 4.2$  Hz, 1H), 4.39 (d,  $J = 18.0$  Hz, 1H), 4.06 (d,  $J = 18.0$  Hz, 1H), 2.91–2.89 (m, 2H), 1.47 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  206.3, 173.5, 83.3, 81.2, 70.2, 36.1, 14.1; HRMS (ES)  $m/z$  calcd for  $\text{C}_7\text{H}_8\text{O}_4\text{Na}$  ( $\text{M}+\text{Na}^+$ ): 179.1258; found: 179.1261; **compound 23**: IR (neat) 2956, 2925, 2855, 1784, 1463  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.38–7.26 (m, 5H), 5.49 (s, 1H), 5.36 (s, 1H), 4.96 (s, 1H), 4.42 (d,  $J = 4.4$  Hz, 1H), 2.94–2.82 (m, 2H), 1.62 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  174.9, 152.2, 139.7, 129.1 (3C), 128.3 (2C), 113.6, 91.0, 84.9, 82.4, 36.7, 21.7; HRMS (ES)  $m/z$  calcd for  $\text{C}_4\text{H}_{14}\text{O}_3\text{Na}$  ( $\text{M}+\text{Na}^+$ ): 253.0841; found: 253.0854; **compound 24**: IR (neat) 2956, 2925, 2855, 1784, 1463  $\text{cm}^{-1}$ ;  $^1\text{H}$

NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.40–7.28 (m, 5H), 5.61 (s, 1H), 5.51 (s, 1H), 5.00 (s, 1H), 4.60 (t,  $J$  = 5.4 Hz, 1H), 2.95–2.82 (m, 2H), 1.61 (s, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  174.7, 150.5, 139.6, 128.6 (2C), 128.3 (2C), 126.9, 113.1, 90.3, 83.0, 81.8, 36.6, 20.1; HRMS (ES)  $m/z$  calcd for C<sub>14</sub>H<sub>14</sub>O<sub>3</sub>Na (M+Na<sup>+</sup>): 253.0841; found: 253.0854; **compound 31**: IR (neat) 2923, 2855, 1781, 1059 cm<sup>-1</sup>; <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  5.38 (s, 1H), 5.29 (s, 1H), 5.07 (t,  $J$  = 5.4 Hz, 1H), 4.58 (d,  $J$  = 13.5 Hz, 1H), 4.51 (d,  $J$  = 5.7 Hz, 1H), 4.35 (d,  $J$  = 11.8 Hz, 1H), 2.82 (dd,  $J$  = 18.6, 6.0 Hz, 1H), 2.70 (d,  $J$  = 18.5 Hz, 1H), 2.06–1.84 (m, 4H), 1.69 (s, 3H), 1.60 (s, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>)  $\delta$  174.6, 147.0, 133.2, 122.4, 110.1, 92.3, 80.9, 71.2, 36.9, 34.8, 25.6, 22.6, 17.7; HRMS (ES)  $m/z$  calcd for C<sub>13</sub>H<sub>18</sub>O<sub>3</sub>Na (M+Na<sup>+</sup>): 245.1154; found: 245.1158; **compound 35**: IR (neat) 2927, 2853, 1779, 1054 cm<sup>-1</sup>; <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  7.36–7.23 (m, 5H), 5.50 (s, 1H), 5.35 (s, 1H), 4.61 (d,  $J$  = 12.3 Hz, 1H), 4.44–4.33 (m, 2H), 3.43 (d,  $J$  = 14.4 Hz, 1H), 2.93 (d,  $J$  = 14.1 Hz, 1H), 2.33 (d,  $J$  = 18.6 Hz, 1H), 1.59 (m, 1H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>)  $\delta$  173.3, 147.7, 134.2 (2C), 130.2, 128.8 (2C), 127.6, 110.2, 91.4, 81.4, 71.1, 40.9, 36.9; HRMS (ES)  $m/z$  calcd for C<sub>14</sub>H<sub>14</sub>O<sub>3</sub>Na (M+Na<sup>+</sup>): 253.0841; found: 253.0848; **compound 41**: IR (neat) 2966, 2926, 2854, 1778, 1462, 1198, 1054 cm<sup>-1</sup>; <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  5.30 (s, 1H), 5.17 (s, 1H), 4.46 (d,  $J$  = 5.1 Hz, 1H), 2.79 (dd,  $J$  = 18.3, 5.1 Hz, 1H), 2.68 (d,  $J$  = 18.3 Hz, 1H), 1.99–1.88 (m, 2H), 1.27 (s, 3H), 1.25 (s, 3H), 0.97 (t,  $J$  = 7.5 Hz, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>)  $\delta$  174.9, 154.9, 139.2, 109.9, 94.5, 83.6, 37.4, 28.8, 28.1, 27.8, 8.4; HRMS (ES)  $m/z$  calcd for C<sub>11</sub>H<sub>16</sub>O<sub>3</sub>Na (M+Na<sup>+</sup>): 219.0000; found: 219.0000; **compound 47**: IR (neat) 2927, 1780, 1187, 1059, 1027 cm<sup>-1</sup>; <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  7.43–7.35 (m, 5H), 5.24 (s, 1H), 4.99 (s, 1H), 4.62 (m, 1H), 2.73–2.59 (m, 2H), 1.51 (s, 3H), 1.49 (s, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>)  $\delta$  175.0, 158.0, 137.4, 128.6 (2C), 128.4, 125.7 (2C), 113.5, 95.5, 84.6, 82.2, 35.7, 29.3, 28.3; HRMS (ES)  $m/z$  calcd for C<sub>15</sub>H<sub>17</sub>O<sub>3</sub> (M+H<sup>+</sup>): 245.1177; found: 245.1182; **compound 52**: IR (neat) 2961, 2927, 2855, 1780, 1733 cm<sup>-1</sup>; <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  5.36 (s, 1H), 5.13 (s, 1H), 5.07 (t,  $J$  = 7.2 Hz, 1H), 4.47 (d,  $J$  = 4.8 Hz, 1H), 2.78 (dd,  $J$  = 18.3,

4.8 Hz, 1H), 2.68 (d,  $J$  = 18.3 Hz, 1H), 2.02–1.89 (m, 4H), 1.77–1.60 (m, 2H), 1.66 (s, 3H), 1.56 (s, 3H), 1.24 (s, 3H), 0.96 (t,  $J$  = 7.5 Hz, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>)  $\delta$  174.8, 153.5, 131.8, 123.9, 110.3, 94.4, 86.2, 77.1, 41.0, 37.2, 28.0, 27.1, 25.6, 22.4, 17.6, 8.5; HRMS (ES)  $m/z$  calcd for C<sub>16</sub>H<sub>24</sub>O<sub>3</sub>Na (M+Na<sup>+</sup>): 287.0000; found: 287.0032.

15. X-ray data were collected at 291 K on a SMART CCD-BRUKER diffractometer with graphite monochromated Mo K $\alpha$  radiation ( $\lambda$  = 0.7107 Å). The crystal structure was solved by direct methods (SIR92) and refined by full-matrix least-squares method on  $F^2$  using SHELXL-97. Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre, CCDC 727573. **Compound 24**: C<sub>14</sub>H<sub>14</sub>O<sub>3</sub>, MW = 230.25, crystal system: Orthorhombic, space group:  $P2_12_12_1$ , cell parameters:  $a$  = 5.4657(8) Å,  $b$  = 8.7936(12) Å,  $c$  = 25.119(3) Å,  $V$  = 1207.3(3) Å<sup>3</sup>,  $Z$  = 4,  $\rho_{\text{calc}}$  = 1.267 g cm<sup>-3</sup>,  $F(0\ 0\ 0)$  = 488,  $\mu$  = 0.089 mm<sup>-1</sup>, number of l.s. parameters = 155,  $R_1$  = 0.0529 for 1023 reflections with  $I > 2\sigma(I)$  and 0.0749 for 1341 data.  $wR_2$  = 0.1127, GOF = 1.099 for all data. An ORTEP diagram of **24** with 30% ellipsoidal probability is depicted below.

