

Samarium(II)-mediated reactions of γ,δ -unsaturated ketones.

Cyclisation and fragmentation processes.

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Supporting Information

General Considerations

All experiments were performed under an atmosphere of Ar or N₂, using anhydrous solvents, unless stated otherwise. THF was distilled from sodium/benzophenone, CH₂Cl₂ was distilled from CaH₂. MeOH was distilled from the corresponding magnesium alkoxide and stored under argon. HMPA was distilled from CaH₂ and stored under N₂. Samarium(II) Iodide was prepared by the method of Imamoto and Ono,¹ with the modification that the samarium/iodine/THF solution was heated at 60°C rather than at reflux.

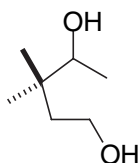
Melting points were measured on a Kofler hot stage apparatus and are uncorrected. Microanalyses were carried out at the University of Glasgow using an EAI CE-440 Elemental Analyzer.

¹H NMR and ¹³C NMR were recorded on a Bruker DPX 400 spectrometer, with chemical shift values being reported in ppm relative to residual chloroform ($\delta_{\text{H}} = 7.27$ or $\delta_{\text{C}} = 77.2$) as internal standards unless otherwise stated. All coupling constants (*J*) are reported in Hertz (Hz). Mass spectra were obtained using a JEOL JMS-700 spectrometer, and infra-red spectra were recorded using a JASCO FT/IR 410 spectrometer.

Column chromatography was carried out using Fischer Matrex silica gel 60, or Fluka type 507 C neutral alumina where stated. Macherey-Nagel aluminium backed plates, pre-coated with silica gel 60 (UV₂₅₄) or Fluka aluminium backed plates, pre-coated with alumina (UV₂₅₄) were used for thin layer chromatography as appropriate, and were visualized by UV or staining with alkali KMnO₄.

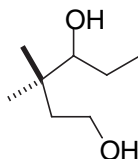
General procedure A for the formation of diols 3a – 3e

¹ Imamoto, T.; Ono, M. *Chem. Lett.* **1987**, 501.



3, 3-Dimethyl-pentane-1, 4-diol 3a²

MeLi.LiBr (1.26 M in Et₂O, 27.3 ml, 34.4 mmol, 4 eq.) was added dropwise to a stirred solution of 3,3-dimethyl-tetrahydro-furan-2-ol (1.00 g, 8.61 mmol, 1 eq.) in THF (2 ml) at -78°C. The solution was then allowed to warm to r. and stirred for 16 h. The solution was cooled to 0°C before the dropwise addition of aqueous saturated NH₄Cl (20 ml). The aqueous layer was separated and extracted with EtOAc (4 x 50 ml). The combined organic extracts were dried (MgSO₄), and concentrated *in vacuo* to give the crude product. Purification by column chromatography (eluting with EtOAc) gave diol **3a** (832 mg, 6.34 mmol, 74%) as a clear, colourless oil: ν_{max} (neat)/cm⁻¹ 3266s (OH), 2967s, 1473m, 1372m, 1296w, 1084m, 1044m, 1013m, 981m and 914m; δ_{H} (400 MHz, CDCl₃) 0.81 [3H, s, C(CH₃)₂], 0.85 [3H, s, C(CH₃)₂], 1.07 [3H, d, *J* 6.4, CH(OH)CH₃], 1.34 [1H, apparent ddd, *J* 14.8, 6.1, 4.3, AB system, 1H from C(CH₃)₂CH₂], 1.66 [1H, apparent ddd, *J* 14.8, 8.1, 4.8, AB system, 1H from C(CH₃)₂CH₂], 3.47 [1H, q, *J* 6.4, CH(OH)], 3.57 – 3.66 [2H, m, CH₂OH] and 3.84 [2H, s, 2 x OH]; δ_{C} (100 MHz, CDCl₃) 18.0 [CH(OH)CH₃], 23.9 [C(CH₃)₂], 25.6 [C(CH₃)₂], 37.8 [C(CH₃)₂], 42.2 [C(CH₃)₂CH₂], 59.1 [CH₂OH] and 74.3 [CH(OH)]; *m/z* (CI mode, NH₃) 150 [(M + NH₄)⁺ 100%], 133 (50) and 115 (12).

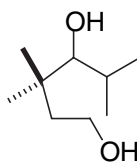


3, 3-Dimethyl-hexane-1, 4-diol 3b

As for general procedure A. EtMgBr (1 M in THF, 4.30 ml, 8.60 mmol, 4 eq.), upon reaction with 3,3-dimethyl-tetrahydro-furan-2-ol (250 mg, 2.15 mmol, 1 eq.), and after purification by column chromatography [eluting with 60% EtOAc in petroleum

² (a) Zaidlewicz, M.; Sarnowski, R. *Heterocycles* **1982**, *18*, 281. (b) Ding, Y.; Jiang, X.-R. *Chem. Commun.* **1995**, *16*, 1693.

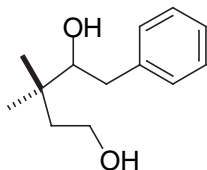
ether (40-60°C)], gave diol **3b** as a clear, colourless oil (140 mg, 0.96 mmol, 45%): $\nu_{\max}$ (neat)/cm⁻¹ 3427s (OH), 2875m, 1467m, 1099m, 1051m, 1019m, 972m; δ_{H} (400 MHz, CDCl₃) 0.82 [3H, s, C(CH₃)₂], 0.88 [3H, s, C(CH₃)₂], 0.94 [3H, t, *J* 7.4, CH₂CH₃], 1.26 – 1.36 [1H, m, AB system, 1H from C(CH₃)₂CH₂], 1.47 – 1.55 (2H, m, CH₂CH₃), 1.67 – 1.74 [1H, m, AB system, 1H from C(CH₃)₂CH₂], 2.49 [2H, bs, 2 x OH], 3.13 [1H, dd, *J* 10.5, 1.9, CH(OH)] and 3.60 – 3.72 [2H, m, CH₂OH]; δ_{C} (100 MHz, CDCl₃) 12.0 [CH₂CH₃], 24.4 [CH₂CH₃], 24.8 [C(CH₃)₂], 25.1 [C(CH₃)₂], 37.8 [C(CH₃)₂], 42.4 [CH₂CH₂OH], 59.6 [CH₂OH] and 80.7 [CH(OH)]; *m/z* (CI mode, NH₃) 164 [(M + NH₄)⁺ 100%], 147 (85), 129 (40), 111 (8) and 99 (10). [Found: (M + H)⁺, 147.1387. C₈H₁₉O₂ requires *M*, 147.1385].



3, 3, 5-Trimethyl-hexane-1, 4-diol 3c³

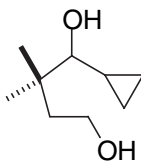
As for general procedure A. ⁱPrMgCl (2 M in THF, 4.30 ml, 8.60 mmol, 4 eq.), upon reaction with 3,3-dimethyl-tetrahydro-furan-2-ol (250 mg, 2.15 mmol, 1 eq.), and after purification by column chromatography [eluting with 60% EtOAc in petroleum ether (40-60°C)], gave the pure diol **3c** (261 mg, 1.64 mmol, 76%) as a clear, colourless oil: $\nu_{\max}$ (neat)/cm⁻¹ 3360s (OH), 2960s, 2875s, 1471m, 1388m, 1366m, 1119m, 1073m and 979s; δ_{H} (400 MHz, CDCl₃) 0.87 [3H, d, *J* 6.9, CH(CH₃)₂], 0.88 [3H, s, C(CH₃)₂], 0.89 [3H, s, C(CH₃)₂], 0.93 [3H, d, *J* 6.9 CH(CH₃)₂], 1.35 [1H, apparent ddd, *J* 14.8, 6.1, 5.0, AB system, 1H from C(CH₃)₂CH₂], 1.69 [1H, apparent ddd, *J* 14.8, 7.4, 5.4, AB system, 1H from C(CH₃)₂CH₂], 1.88 [1H, d septet, *J* 6.9, 2.5, CH(CH₃)₂], 3.12 [1H, d, *J* 2.5, CH(OH)], 3.20 [2H, bs, 2 x OH] and 3.59 – 3.68 [2H, m, CH₂OH]; δ_{C} (100 MHz, CDCl₃) 17.6 [CH(CH₃)₂], 24.1 [CH(CH₃)₂], 24.5 [C(CH₃)₂], 26.2 [C(CH₃)₂], 29.2 [CH(CH₃)₂], 38.6 [C(CH₃)₂], 43.9 [C(CH₃)₂CH₂], 59.4 [CH₂OH] and 82.3 [CH(OH)]; *m/z* (CI mode, isobutane) 161 [(M + H)⁺ 5%], 143 (20), 117 (17), 99 (80) and 87 (22) [Found: (M + H)⁺, 161.1539. C₉H₂₁O₂ requires *M*, 161.1542].

³ Mudryk, B.; Cohen, T. J. *Org. Chem.* **1991**, 56, 5760.



3,3-Dimethyl-5-phenyl-pentane-1,4-diol 3d

As for general procedure A. BnMgCl (2 M in THF, 8.61 ml, 17.2 mmol, 4 eq.), upon reaction with 3,3-dimethyl-tetrahydro-furan-2-ol (500 mg, 4.30 mmol, 1 eq.), and after purification by recrystallisation from 50% EtOAc in petroleum ether (40-60°C), gave the pure diol **3d** as a white crystalline solid (454 mg, 2.20 mmol, 51%), mp 88-89°C: ν_{max} (CDCl_3 solⁿ)/ cm^{-1} 3347s (OH), 3289s (OH), 2956s, 2893m, 2871m, 1494m, 1416w, 1360m, 1077m, 1053w, 1024m and 972w; δ_{H} (400 MHz, CDCl_3) 1.05 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.07 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.51 [1H, apparent ddd, J 14.6, 5.8, 4.4, AB system, 1H from $\text{CH}_2\text{CH}_2\text{OH}$], 1.89 [1H, apparent ddd, J 14.6, 8.4, 5.0, AB system, 1H from $\text{CH}_2\text{CH}_2\text{OH}$], 2.19 [1H, bs, OH], 2.63 [1H, dd, J 13.6, 10.8, AB system, 1H from CH_2Ph], 2.92 [1H, bs, OH], 2.94 [1H, dd, J 13.6, 1.9, AB system, 1H from CH_2Ph], 3.50 [1H, dd, J 10.8, 1.9, CHOH], 3.70-3.81 [2H, m, CH_2OH], 7.24-7.28 [3H, m, 3 x Ar-H] and 7.32-7.36 [2H, m, 2 x Ar-H]; δ_{C} (100 MHz, CDCl_3) 25.0 [$\text{C}(\text{CH}_3)_2$], 25.4 [$\text{C}(\text{CH}_3)_2$], 37.6 [$\text{C}(\text{CH}_3)_2$], 38.4 [CH_2Ph], 42.6 [$\text{CH}_2\text{CH}_2\text{OH}$], 59.6 [CH_2OH], 79.8 [CHOH], 126.9 [Ar CH], 129.0 [2 x Ar CH], 129.8 [2 x Ar CH] and 140.0 [Ar C]; m/z (FAB+ mode) 283 (5%), 239 (5), 209 [(M + H)⁺ 45], 191 (15), 173 (20), 145 (15), 133 (50), 117 (20), 90 (100), 88 (50), 74 (35) and 60 (20); (Found: C, 75.13; H, 9.75; $\text{C}_{13}\text{H}_{20}\text{O}_2$ requires C, 74.96; H, 9.68).

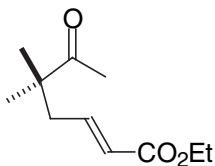


1-Cyclopropyl-2,2-dimethyl-butane-1,4-diol 3e

A single crystal of I_2 was added to a suspension of dry magnesium powder (620 mg, 25.8 mmol, 12 eq.) in THF (1 ml). Cyclopropyl bromide (2.60 ml, 32.5 mmol, 15 eq.) and THF (4 ml) were added dropwise to the magnesium suspension, and the mixture heated to 65°C and stirred for 1 hr. As for general procedure A, a portion of the resulting cyclopropyl magnesium bromide solution (5.00 ml, 12.9 mmol, 6 eq.), upon reaction with 3,3-dimethyl-tetrahydro-furan-2-ol, and after purification by column chromatography

[eluting with 80% EtOAc in petroleum ether (40-60°C)], yielded the pure diol **3e** (220 mg, 1.39 mmol, 65%) as a clear, colourless oil: $\nu_{\max}$ (CDCl₃ solⁿ)/cm⁻¹ 3365s (OH), 2959m, 1468s, 1430m, 1386m, 1364m, 1044s, 1019s and 973m; δ_{H} (400 MHz, CDCl₃) -0.02 - 0.04 [1H, m, 1H from CHCH₂^A], 0.09 - 0.14 [1H, m, 1H from CHCH₂^B], 0.23 - 0.30 [1H, m, 1H from CHCH₂^A], 0.39 - 0.46 [1H, m, 1H from CHCH₂^B], 0.78 [6H, s, C(CH₃)₂], 0.79 - 0.85 [1H, m, HC(OH)CH], 1.24 - 1.30 [1H, m, 1H from CH₂CH₂OH], 1.57 - 1.64 [1H, m, 1H from CH₂CH₂OH], 2.37 [1H, d, *J* 9.2, CH(OH)] and 3.45 - 3.52 [2H, m, CH₂CH₂OH]; δ_{C} (100 MHz, CDCl₃) 0.0 [CHCH₂^A], 3.8 [CHCH₂^B], 12.1 [CHCH₂], 22.2 [C(CH₃)₂], 23.7 [C(CH₃)₂], 36.3 [C(CH₃)₂], 41.2 [CH₂CH₂OH], 57.5 [CH₂OH] and 81.8 [CH(OH)]. *m/z* (EI+ mode) 158 [(M⁺) 1%], 140 (2), 125 (30), 112 (10), 95 (5), 83 (10), 70 (100), 55 (45) and 43 (40); [Found: (M⁺), 158.1304. C₉H₁₈O₂ requires *M*, 158.1307].

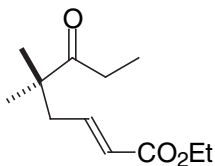
General Oxidation/Olefination Procedure B



Ethyl-(*E*)-5,5-dimethyl-6-oxo-hept-2-enoate **4a**

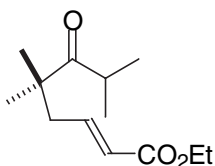
DMSO (650 μ l, 9.15 mmol, 4 eq.) was added to a stirred solution of (COCl)₂ (400 μ l, 4.57 mmol, 2 eq.) in CH₂Cl₂ (8 ml) at -78°C and the resulting solution was stirred for 10 min. Diol **3a** (300 mg, 2.29 mmol, 1 eq.) was then added as a solution in CH₂Cl₂ (7 ml) and the resultant solution stirred for a further 30 min. Triethylamine (3.28 ml, 22.9 mmol, 10 eq.) was then added. After 2 h (carbethoxymethylene)triphenylphosphorane (1.60 g, 4.57 mmol, 2 eq.) was added as a solution in CH₂Cl₂ (15 ml) and the reaction mixture allowed to warm to rt and stirred for 16 h. Aqueous saturated NaHCO₃ (10 ml) was then added, and the aqueous layer was separated and extracted with EtOAc (4 x 10 ml). The combined organic extracts were dried (MgSO₄), and concentrated *in vacuo* to give the crude product. Purification by column chromatography [eluting with 60% EtOAc in petroleum ether (40-60°C)], gave the ketone **4a** (398 mg, 2.01 mmol, 88%) as a yellow

oil: $\nu_{\max}$ (neat)/ cm^{-1} 2970s, 1723s (C=O), 1655s, 1472m, 1035m and 982m; δ_{H} (400 MHz, CDCl_3) 1.10 [6H, s, $\text{C}(\text{CH}_3)_2$], 1.21 [3H, t, J 7.1, CH_2CH_3], 2.08 [3H, s, $\text{C}(\text{O})\text{CH}_3$], 2.32 [2H, dd, J 7.7, 1.3, $\text{C}(\text{CH}_3)_2\text{CH}_2$], 4.10 [2H, q, J 7.1, CH_2CH_3], 5.77 [1H, dt, J 15.5, 1.3, CHCHCO_2Et] and 6.77 [1H, dt, J 15.5, 7.7, CHCHCO_2Et]; δ_{C} (100 MHz, CDCl_3) 14.6 [CH_2CH_3], 24.7 [2 x $\text{C}(\text{CH}_3)_2$], 25.6 [$\text{C}(\text{O})\text{CH}_3$], 42.0 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 48.1 [$\text{C}(\text{CH}_3)_2$], 60.7 [CH_2CH_3], 124.7 [CHCHCO_2Et], 144.9 [CHCHCO_2Et], 166.5 [$\text{C}(\text{O})\text{O}$] and 212.8 [$\text{C}(\text{O})\text{CH}_3$]; m/z (CI+ mode, isobutane) 199 [(M + H)⁺ 20%], 153 (100), 141 (10), 127 (10), 109 (30), 95 (10) and 81 (15) [Found: (M + H)⁺, 199.1336. $\text{C}_{11}\text{H}_{19}\text{O}_3$ requires M , 199.1334].



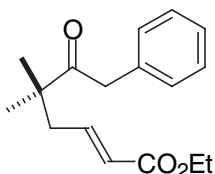
Ethyl-(*E*)-5,5-dimethyl-6-oxo-oct-2-enoate **4b**

As for general procedure B. Diol **3b** (140 mg, 0.96 mmol, 1 eq.), after oxidation and reaction with (carbethoxymethylene)triphenylphosphorane for 16 h and purification by column chromatography [eluting with 80% EtOAc in petroleum ether (40-60°C)], gave the ketone **4b** (125 mg, 0.59 mmol, 57%) as a yellow oil: $\nu_{\max}$ (neat)/ cm^{-1} 2975s, 2938s, 2879s, 1730s (C=O), 1651s, 1470m, 1369w, 1187w, 1151w, 1099m, 1041m and 973w; δ_{H} (400 MHz, CDCl_3) 1.04 [3H, t, J 7.2, $\text{C}(\text{O})\text{CH}_2\text{CH}_3$], 1.18 [6H, s, $\text{C}(\text{CH}_3)_2$], 1.30 [3H, t, J 7.1, OCH_2CH_3], 2.42 [2H, dd, J 1.3, 7.7, CH_2CH], 2.51 [2H, q, J 7.2, $\text{C}(\text{O})\text{CH}_2$], 4.19 [2H, q, J 7.1, OCH_2], 5.84 [1H dt, J 15.5, 1.3, CH_2CHCH] and 6.85 [1H dt, J 15.5, 7.7 CH_2CH]; δ_{C} (100 MHz, CDCl_3) 8.4 [$\text{C}(\text{O})\text{CH}_2\text{CH}_3$], 14.6 [OCH_2CH_3], 24.8 [2 x $\text{C}(\text{CH}_3)_2$], 30.6 [$\text{C}(\text{O})\text{CH}_2$], 42.3 [CH_2CHCH], 47.8 [$\text{C}(\text{CH}_3)_2$], 60.7 [OCH_2], 124.6 [CHCHCO_2Et], 145.1 [CHCHCO_2Et], 166.6 [$\text{C}(\text{O})\text{O}$] and 215.2 [$\text{C}(\text{O})$]; m/z (EI+ mode) 212 [(M⁺) 20%], 167 (32), 155 (100), 141 (28), 109 (80), 81 (42), 57 (65), 41 (23) and 39 (10); [Found: (M⁺), 212.1411. $\text{C}_{12}\text{H}_{20}\text{O}_3$ requires M , 212.1412].



Ethyl-(*E*)-5, 5, 7-trimethyl-6-oxo-oct-2-enoate **4c**

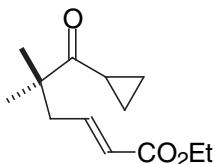
As for general procedure B. Diol **3c** (261 mg, 1.64 mmol, 1 eq.), after oxidation and reaction with (carbethoxymethylene)triphenylphosphorane for 16 h and purification by column chromatography [eluting with 80% EtOAc in petroleum ether (40-60°C)], gave ketone **4c** (163 mg, 0.718 mmol, 44%): $\nu_{\max}$ (neat)/cm⁻¹ 2974s, 2936s, 2875s, 1717s, (C=O), 1654s, 1469m, 1368m, 1268m, 1193m, 1038m and 1009m; δ_{H} (400 MHz, CDCl₃) 0.98 [6H, d, *J* 6.7 CH(CH₃)₂], 1.11 [6H, s, C(CH₃)₂], 1.21 [3H, t, *J* 7.1, CH₂CH₃], 2.33 [2H, dd, *J* 7.7, 1.4, C(CH₃)₂CH₂], 3.02 [1H, septet, *J* 6.7, CH(CH₃)₂], 4.11 [2H, q, *J* 7.1, CH₂CH₃], 5.76 [1H, dt, *J* 15.5, 1.4, CHCHCO₂Et] and 6.78 [1H, dt, *J* 15.5, 7.7, CHCHCO₂Et]; δ_{C} (100 MHz, CDCl₃) 14.6 [CH₂CH₃], 20.4 [2 x CH(CH₃)₂], 24.3 [2 x C(CH₃)₂], 34.6 [CH(CH₃)₂], 41.8 [C(CH₃)₂CH₂], 48.4 [C(CH₃)₂], 60.6 [C(O)OCH₂], 124.7 [CHCHCO₂Et], 145.3 [CHCHCO₂Et], 166.6 [C(O)O] and 212.8 [C(O)]. *m/z* (EI+ mode) 226 [(M⁺) 20%], 181 (30), 155 (100), 139 (15), 127 (25), 109 (55), 81 (30), 71 (70), 43 (65) and 41 (20); [Found: (M⁺), 226.1567. C₁₃H₂₂O₃ requires *M*, 226.1569].



Ethyl-(*E*)-5,5-dimethyl-6-oxo-7-phenyl-hept-2-enoate **4d**

As for general procedure B. Diol **3d** (454 mg, 2.19 mmol, 1 eq.), after oxidation and reaction with (carbethoxymethylene)triphenylphosphorane for 16 h and purification by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave the ketone **4d** (494 mg, 1.80 mmol, 82%) as a yellow oil: $\nu_{\max}$ (neat)/cm⁻¹ 2976s, 2935s, 1720s (C=O), 1654s, 1496m, 1468m, 1367m, 1191m, 1043m, 729s and 698s; δ_{H} (400 MHz, CDCl₃) 1.16 [6H, s, C(CH₃)₂], 1.21 [3H, t, *J* 7.1 OCH₂CH₃], 2.37 [2H, dd, *J* 7.7, 1.2, CH₂CHCH], 3.72 [2H, s, C(O)CH₂Ph], 4.12 [2H, q, *J* 7.1, OCH₂CH₃], 5.76 [1H apparent d, *J* 15.5, CHCHCO₂Et], 6.77 [1H, dt, *J* 15.5, 7.7, CHCHCO₂Et], 7.08 [2H, m, 2 x Ar *o*-CH], 7.19 [1H, m, Ar *p*-CH] and 7.24 [2H, m, 2 x Ar *m*-CH]; δ_{C} (100 MHz, CDCl₃) 14.6 [OCH₂CH₃], 24.8 [2 x C(CH₃)₂], 42.2 [CH₂CHCH], 44.2 [C(O)CH₂Ph], 48.4 [C(CH₃)₂], 60.7 [OCH₂CH₃], 124.9 [CHCHCO₂Et], 127.2 [Ar *p*-CH], 128.9 [2 x Ar *m*-CH], 129.9 [2 x Ar *o*-CH], 134.7 [Ar C], 144.8 [CHCHCO₂Et], 166.5 [C(O)O] and 211.6

[C(O)]; m/z (EI+ mode) 274 [(M^+) 15%], 229 (20), 183 (50), 155 (100), 127 (30), 109 (25), 91 (90), 81 (21), 55 (15), 41 (13); [Found: (M^+) , 274.1572. $C_{17}H_{22}O_3$ requires M , 274.1569].



Ethyl-(*E*)-6-cyclopropyl-5,5-dimethyl-6-oxo-hex-2-enoate 4e

As for general procedure B. Diol **3e** (200 mg, 1.26 mmol, 1 eq.), after oxidation and reaction with (carbethoxymethylene)triphenylphosphorane for 16 h and purification by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave ketone **4e** (150 mg, 0.67 mmol, 53%): $\nu_{\max}$ (neat)/ cm^{-1} 2976s, 2935s, 2875s, 1719s (C=O), 1655s, 1468s, 1448m, 1389m, 1270m, 1194m, 1046m, 1010m and 986m; δ_{H} (400 MHz, CDCl_3) 0.77 – 0.84 [2H, m, 1H from $\text{C(O)CHCH}_2^{\text{A}}$, 1H from $\text{C(O)CHCH}_2^{\text{B}}$], 0.87 – 0.94 [2H, m, 1H from $\text{C(O)CHCH}_2^{\text{A}}$, 1H from $\text{C(O)CHCH}_2^{\text{B}}$], 1.16 [6H, s, $\text{C}(\text{CH}_3)_2$], 1.21 [3H, t, J 7.1, OCH_2CH_3], 2.05 [1H, tt, J 7.7, 3.2, C(O)CH], 2.39 [2H, dd, J 7.7, 1.3, CH_2CHCH], 4.10 [2H, q, J 7.1 OCH_2CH_3], 5.76 [1H, dt, J 15.5, 1.3, CHCHCO_2Et] and 6.79 [1H, dt, J 15.5 7.7, CHCHCO_2Et]; δ_{C} (100 MHz, CDCl_3) 11.6 [$\text{C(O)CHCH}_2^{\text{A}}$], 11.7 [$\text{C(O)CHCH}_2^{\text{B}}$], 14.6 [OCH_2CH_3], 16.4 [C(O)CH], 24.6 [2 x $\text{C}(\text{CH}_3)_2$], 42.3 [CH_2CHCH], 48.0 [$\text{C}(\text{CH}_3)_2$], 60.6 [OCH_2CH_3], 124.6 [CHCHCO_2Et], 145.2 [CHCHCO_2Et], 166.6 [C(O)O], and 214.1 [C(O)]; m/z (EI+ mode) 224 [(M^+) 5%], 179 (10), 155 (30), 127 (5), 109 (20), 81 (10), 69 (100), 41 (22), 39 (5); [Found: (M^+) , 224.1410. $C_{13}H_{20}O_3$ requires M , 224.1410].

General Procedure C - Cyclisation of γ,δ -unsaturated ketones



***rac*-(1*S*, 2*S*)-Ethyl-2-hydroxy-2, 3, 3-trimethyl-cyclopentanoate 5a**

Ethyl-5, 5-dimethyl-6-oxo-heptanoate 6a

Dry MeOH (8 ml) was added to a stirred solution of SmI_2 (0.1 M in THF, 30.3 ml, 3.03 mmol, 4 eq.) at 0°C and the resulting solution was stirred for 10 min. Ketone **4a**

(150 mg, 0.76 mmol, 1 eq.) was added as a solution in THF (1.5 ml) and the resultant solution stirred at 0°C for 4 h. The reaction was quenched by opening to the air, followed by the addition of aqueous saturated NaCl (15 ml). The organic layers were extracted with 80% EtOAc in petroleum ether (40-60°C) (4 x 15 ml). The combined organic extracts were dried (MgSO₄) and concentrated *in vacuo* to give the crude product. Purification by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave cyclopentanol **5a** (68.2 mg, 0.34 mmol, 45%) as a clear, colourless oil, and ketone **6a** (67.5 mg, 0.34 mmol, 44%) as a clear, colourless oil:

***rac*-(1S, 2S)-Ethyl-2-hydroxy-2, 3, 3-trimethyl-cyclopentanoate 5a**

ν_{max} (neat)/cm⁻¹ 3509m (OH), 2964s, 2873m, 1710s (C=O), 1467m, 1374m, 1040m and 926m; δ_{H} (400 MHz, CDCl₃) 0.80 [3H, s, C(OH)CH₃], 0.94 [3H, s, C(CH₃)₂], 1.14 [3H, s, C(CH₃)₂], 1.22 [3H, t, *J* 7.1, OCH₂CH₃], 1.36 – 1.43 [1H, m, 1H from C(CH₃)₂CH₂], 1.81 – 1.86 [1H, m, 1H from C(CH₃)₂CH₂], 1.86 – 1.97 [2H, m, C(CH₃)₂CH₂CH₂], 2.81 [1H, apparent t, *J* 9.3, CHCO₂Et], 3.17 [1H, bs, OH] and 4.06 – 4.18 [2H, m, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 13.2 [OCH₂CH₃], 19.8 [C(CH₃)₂], 20.1 [C(CH₃)₂], 23.3 [C(CH₃)₂CH₂CH₂], 24.9 [C(OH)CH₃], 36.8 [C(CH₃)₂CH₂], 44.9 [C(CH₃)₂], 50.3 [CHCO₂Et], 59.6 [OCH₂CH₃], 81.3 [C(OH)CH₃] and 175.0 [C(O)O]; *m/z* (EI+ mode) 200 [(M⁺) 15%], 182 (15), 167 (20), 155 (25), 143 (100), 130 (60), 109 (80), 97 (70), 86 (80), 71 (75) and 43 (90); [Found: (M⁺), 200.1412. C₁₁H₂₀O₃ requires *M*, 200.1412].

Ethyl-5, 5-dimethyl-6-oxo-heptanoate 6a

ν_{max} (neat)/cm⁻¹ 2966s, 2874s, 1739s (ester C=O), 1703s (ketone C=O), 1472m, 1355w, 1053m and 1029m; δ_{H} (400 MHz, CDCl₃) 1.06 [6H, s, C(CH₃)₂], 1.19 [3H, t, *J* 7.1, OCH₂CH₃], 1.39 – 1.50 [4H, m, C(CH₃)₂CH₂ and C(CH₃)₂CH₂CH₂], 2.06 [3H, s, C(O)CH₃], 2.21 [2H, t, *J* 6.6, CH₂CO₂Et] and 4.05 [2H, q, *J* 7.1, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 14.6 [OCH₂CH₃], 20.6 [CH₂CH₂CO₂Et], 24.6 [2 x C(CH₃)₂], 25.4 [C(O)CH₃], 34.9 [CH₂CO₂Et], 39.6 [C(CH₃)₂CH₂], 48.0 [C(CH₃)₂], 60.7 [OCH₂CH₃], 173.7 [C(O)O] and 214.1 [C(O)CH₃]; *m/z* (EI+ mode) 200 [(M⁺) 15%], 157 (70), 155 (30), 137 (15), 111 (100), 83 (85), 69 (95), 43 (60) and 41 (30); [Found: (M⁺), 200.1414. C₁₁H₂₀O₃ requires *M*, 200.1412].



rac*-(1S, 2S)-Ethyl-2-ethyl-2-hydroxy-3,3-dimethyl-cyclopentanoate **5b*
Ethyl-5,5-dimethyl-6-oxo-octanoate **6b**

As for general procedure C. Ketone **4b** (50 mg, 0.24 mmol, 1 eq.), after a reaction time of 4 h and purification of the crude product mixture by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave cyclopentanol **5b** (16.6 mg, 0.08 mmol, 32%) as a clear, colourless oil, and ketone **6b** (33.3 mg, 0.16 mmol, 66%) as a clear, colourless oil:

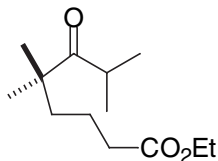
rac*-(1S, 2S)-Ethyl-2-ethyl-2-hydroxy-3,3-dimethyl-cyclopentanoate **5b*

$\nu_{\max}$ (CDCl₃ sol^B)/cm⁻¹ 3684w (OH), 3021s, 1738w (C=O), 1523w, 1424w, 1225s, 1240s, 929w; δ_{H} (400 MHz, CDCl₃) 0.80 [3H, s, C(CH₃)₂], 0.83 [3H, t, *J* 7.5, C(OH)CH₂CH₃], 0.96 [3H, s, C(CH₃)₂], 1.21 [3H, t, *J* 7.2, OCH₂CH₃], 1.35 – 1.38 [1H, m, 1H from C(CH₃)₂CH₂], 1.44 – 1.58 [2H, m, C(OH)CH₂CH₃], 1.72 – 1.79 [1H, m, 1H from C(CH₃)₂CH₂CH₂], 1.90 – 1.97 [2H, m, 1H from C(CH₃)₂CH₂, 1H from C(CH₃)₂CH₂CH₂], 2.75 [1H, apparent t, *J* 8.5, CHCO₂Et] and 4.09 [2H, AB system, apparent dq, *J* 1.9, 7.2, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 8.8 [C(OH)CH₂CH₃], 14.5 [OCH₂CH₃], 22.1 [C(CH₃)₂], 25.7 [C(CH₃)₂], 26.5 [C(CH₃)₂CH₂CH₂], 28.3 [C(OH)CH₂CH₃], 39.2 [C(CH₃)₂CH₂], 47.3 [C(CH₃)₂], 49.6 [CHCO₂Et], 61.1 [OCH₂CH₃], 84.5 [C(OH)CH₂CH₃] and 178.2 [C(O)O]; *m/z* (EI+ mode) 214 [(M⁺) 10%], 185 (30), 157 (80), 144 (82), 139 (50), 123 (45), 84 (100), 57 (40), 55 (38) and 41 (30); [Found: (M⁺), 214.1568. C₁₂H₂₂O₃ requires *M*, 214.1569].

Ethyl-5,5-dimethyl-6-oxo-octanoate **6b**

$\nu_{\max}$ (neat)/cm⁻¹ 2972s, 2877s, 1736s (ester C=O), 1702s (ketone C=O), 1473m, 1374w, 1099w, 1034m and 971m; δ_{H} (400 MHz, CDCl₃) 0.96 [3H, t, *J* 7.2, C(O)CH₂CH₃], 1.05 [6H, s, C(CH₃)₂], 1.18 [3H, t, *J* 7.1, OCH₂CH₃], 1.36 – 1.49 [4H, m, C(CH₃)₂CH₂ and C(CH₃)₂CH₂CH₂], 2.20 [2H, t, *J* 7.0, CH₂CO₂Et], 2.41 [2H, q, *J* 7.2, C(O)CH₂CH₃] and 4.05 [2H, q, *J* 7.1, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 8.4 [C(O)OCH₂CH₃], 14.6 [OCH₂CH₃], 20.7 [CH₂CH₂CO₂Et], 24.8 [C(CH₃)₂], 30.3 [C(O)CH₂], 35.0 [CH₂CO₂Et], 39.8 [C(CH₃)₂CH₂], 47.7 [C(CH₃)₂], 60.7 [OCH₂CH₃], 173.7 [C(O)O] and 216.5

[C(O)CH₂CH₃]; *m/z* (EI+ mode) 214 [(M⁺) 10%], 157 (85), 156 (10), 123 (35), 111 (100), 100 (35), 69 (65), 57 (30), 41 (20) and 39 (5); [Found: (M⁺), 214.1568. C₁₂H₂₂O₃ requires *M*, 214.1569].

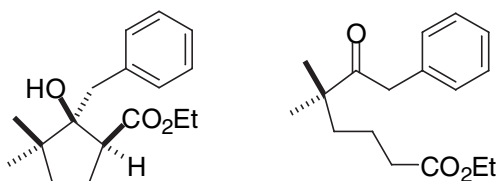


Ethyl-5,5,7-trimethyl-6-oxo-octanoate 6c

As for general procedure C. Ketone **4c** (20 mg, 0.09 mmol, 1 eq.), after a reaction time of 4 h and purification of the crude product mixture by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave a trace of cyclopentanol **5c** (not characterised) and ketone **6c** (16.7 mg, 0.07 mmol, 83%) as a clear, colourless oil:

Ethyl-5,5,7-trimethyl-6-oxo-octanoate 6c

ν_{max} (neat)/cm⁻¹ 2970s, 1736s (ester C=O), 1702s (ketone C=O), 1473m, 1381m, 1268w, 1187m, 1134m, 1020m; δ_{H} (400 MHz, CDCl₃) 0.96 [6H, d, *J* 6.7, CH(CH₃)₂], 1.07 [6H, s, C(CH₃)₂], 1.18 [3H, t, *J* 7.1, OCH₂CH₃], 1.41 – 1.45 [4H, m, C(CH₃)₂CH₂ and C(CH₃)₂CH₂CH₂], 2.21 [2H, t, *J* 6.5, CH₂CO₂Et], 3.03 [1H, septet, *J* 6.7, CH(CH₃)₂] and 4.05 [2H, q, *J* 7.1, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 14.6 [OCH₂CH₃], 20.5 [CH(CH₃)₂], 20.7 [CH₂CH₂CO₂Et], 24.3 [C(CH₃)₂], 34.4 [CH(CH₃)₂], 35.1 [CH₂CO₂Et], 39.0 [C(CH₃)₂CH₂], 48.4 [C(CH₃)₂], 60.7 [OCH₂CH₃], 173.7 [C(O)O] and 213.2 [C(O)]; *m/z* (EI+ mode) 228 [(M⁺) 5%], 183 (15), 157 (100), 111 (95), 95 (10), 69 (60), 43 (40), 41 (25); [Found: (M⁺), 228.1723. C₁₃H₂₄O₃ requires *M*, 228.1725].



***rac*-(1S, 2S)-Ethyl-2-benzyl-2-hydroxy-3,3-dimethyl-cyclopentanoate 5d**

Ethyl-5,5-dimethyl-6-oxo-7-phenyl-heptanoate 6d

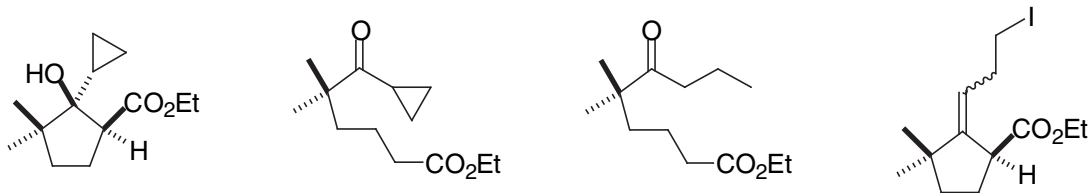
As for general procedure C. Ketone **4d** (40 mg, 0.15 mmol, 1 eq.), after a reaction time of 4 h and purification of the crude product mixture by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave cyclopentanol **5d** (6.8 mg, 0.03 mmol, 17%) as a clear, colourless oil, and ketone **6d** (14.5 mg, 0.05 mmol, 36%) as a clear, colourless oil:

***rac*-(1S, 2S)-Ethyl-2-benzyl-2-hydroxy-3,3-dimethyl-cyclopentanoate 5d**

ν_{max} (CDCl₃ solⁿ)/cm⁻¹ 3685w (OH), 3017s, 1709w (C=O), 1530w, 1477w, 1425w, 1215s, 1015w; δ_{H} (400 MHz, CDCl₃) 0.93 [3H, s, C(CH₃)₂], 1.00 [3H, s, C(CH₃)₂], 1.01 [3H, t, *J* 7.2, OCH₂CH₃], 1.32 – 1.41 [1H, m, 1H from C(CH₃)₂CH₂], 1.50 [1H, bs, OH], 1.60 – 1.70 [1H, m, 1H from C(CH₃)₂CH₂CH₂], 1.91 – 2.02 [2H, m, 1H from C(CH₃)₂CH₂, 1H from C(CH₃)₂CH₂CH₂], 2.60 [1H apparent d, *J* 13.3, AB system, 1H from CH₂Ph], 2.78 [1H apparent d, *J* 13.3, AB system, 1H from CH₂Ph], 2.87 [1H dd, *J* 10.1, 8.8, CHCO₂Et], 3.43 – 3.51 [1H, m, 1H from OCH₂CH₃], 3.62 – 3.70 [1H, m, 1H from OCH₂CH₃] and 7.10 – 7.20 [5H, m, Ar CH]; δ_{C} (100 MHz, CDCl₃) 14.2 [OCH₂CH₃], 21.8 [C(CH₃)₂], 25.9 [C(CH₃)₂], 26.8 [C(CH₃)₂CH₂CH₂], 38.8 [C(CH₃)₂CH₂], 41.3 [CH₂Ph], 47.5 [C(CH₃)₂], 48.5 [CHCO₂Et], 60.8 [OCH₂CH₃], 84.2 [C(OH)CH₂Ph], 126.7 [Ar CH], 128.2 [2 x Ar CH], 131.0 [2 x Ar CH], 138.0 [Ar C] and 177.5 [C(O)O]. *m/z* (FAB+ mode) 277 [(M+ H)⁺ 55%], 259 (60), 213 (15), 185 (70), 154 (50), 137 (40), 136 (40), 91 (100), 89 (15) and 56 (15); [Found: (M+ H)⁺ 277.1802. C₁₇H₂₅O₃ requires *M*, 277.1804].

Ethyl-5,5-dimethyl-6-oxo-7-phenyl-heptanoate 6d

ν_{max} (CDCl₃ solⁿ)/cm⁻¹ 2960m, 2933m, 2901m, 1729s (ester C=O), 1708s (ketone C=O), 1556w, 1467s, 1383s, 1214m and 1104m; δ_{H} (400 MHz, CDCl₃) 1.12 [6H, s, C(CH₃)₂], 1.18 [3H, t, *J* 7.1, OCH₂CH₃], 1.39 – 1.47 [2H, m, C(CH₃)₂CH₂CH₂], 1.47 – 1.56 [2H, m, C(CH₃)₂CH₂], 2.19 [2H, t, *J* 7.2, CH₂CO₂Et], 3.71 [2H, s, CH₂Ph], 4.05 [2H, q, *J* 7.1, OCH₂CH₃], 7.10 – 7.26 [5H, m, Ar-CH]; δ_{C} (100 MHz, CDCl₃) 14.7 [OCH₂CH₃], 20.7 [CH₂CH₂CO₂Et], 24.7 [2 x C(CH₃)₂], 35.0 [CH₂CO₂Et], 39.6 [C(CH₃)₂CH₂], 43.9 [CH₂Ph], 48.4 [C(CH₃)₂], 60.7 [OCH₂CH₃], 127.0 [Ar CH], 128.8 [2 x Ar CH], 130.0 [2 x Ar CH], 135.1 [Ar C], 173.7 [C(O)O] and 212.7 [C(O)CH₂Ph]. *m/z* (EI+ mode) 276 [(M⁺) 25%], 231 (30), 185 (100), 157 (100), 139 (15), 111 (100), 91 (100), 83 (100), 69 (100) and 41 (40); [Found: (M⁺), 276.1724. C₁₇H₂₄O₃ requires *M*, 276.1725].



rac*-(1*S*, 2*S*)-Ethyl-2-cyclopropyl-2-hydroxy-3,3-dimethyl-cyclopentanoate **5e*

Ethyl-6-cyclopropyl-5,5-dimethyl-6-oxo-hexanoate **6e**

Ethyl-5,5-dimethyl-6-oxo-nonanoate **10**

Ethyl-2-(3'-iodo-propylidene)-3,3-dimethyl-cyclopentanoate **9**

As for general procedure C. Ketone **4e** (50 mg, 0.22 mmol, 1 eq.), after a reaction time of 4 h and purification of the crude product mixture by column chromatography [eluting with 10% EtOAc in petroleum ether (40-60°C)], gave cyclopentanol **5e** (7.5 mg, 0.03 mmol, 15%) as a clear, colourless oil, ketone **6e** (21.4 mg, 0.10 mmol, 42%) as a clear, colourless oil, ring-opened ketone **10** (5.2 mg, 0.02 mmol, 10%) as a clear, colourless oil, and iodide **9** (4.0 mg, 0.01 mmol, 5%) as a yellow oil:

rac*-(1*S*, 2*S*)-Ethyl-2-cyclopropyl-2-hydroxy-3,3-dimethyl-cyclopentanoate **5e*

$\nu_{\max}$ (CDCl₃ sol^B)/cm⁻¹ 3469s (OH), 3054s, 2980s, 2870m, 1703s (C=O), 1467m, 1441m, 1346m, 1288s, 1183s, 1041m and 1010m; δ_{H} (400 MHz, CDCl₃) -0.04 – 0.02 [2H, m, CHCH₂^A], 0.07 – 0.13 [1H, m, 1H from CHCH₂^B], 0.25 – 0.30 [1H, m, 1H from CHCH₂^B], 0.54 – 0.60 [1H, m, C(OH)CH], 0.79 [3H, s, C(CH₃)₂], 0.82 [3H, s, C(CH₃)₂], 1.08 [3H, t, *J* 7.2, OCH₂CH₃], 1.23 – 1.28 [1H, m, 1H from C(CH₃)₂CH₂], 1.65 – 1.68 [1H, m, 1H from C(CH₃)₂CH₂], 1.68 – 1.80 [2H, m, C(CH₃)₂CH₂CH₂], 2.78 [1H, apparent t, *J* 9.3, CHCO₂Et], 3.45 [1H, s, OH], and 3.90 – 4.03 [2H, m, OCH₂CH₃]; δ_{C} (100 MHz, CDCl₃) 0.0 [CHCH₂^A], 0.9 [CHCH₂^B], 15.3 [C(OH)CH], 16.07 [OCH₂CH₃], 24.0 [C(CH₃)₂], 27.5 [C(CH₃)₂CH₂CH₂], 27.7 [C(CH₃)₂], 40.4 [C(CH₃)₂CH₂], 49.33 [C(CH₃)₂], 52.6 [CHCO₂Et], 62.7 [OCH₂CH₃], 83.4 [C(OH)CH] and 179.4 [C(O)O]; *m/z* (EI+ mode) 226 [(M⁺) 15%], 198 (5), 183 (10), 169 (100), 137 (7), 123 (16), 111 (14), 83 (20), 69 (50), 55 (22) and 41 (20); [Found: (M⁺), 226.1566. C₁₃H₂₂O₃ requires *M*, 226.1569].

Ethyl-6-cyclopropyl-5,5-dimethyl-6-oxo-hexanoate **6e**

$\nu_{\max}$ (neat)/cm⁻¹ 2871s, 1736s (C=O), 1685s, 1474m, 1006m and 870m; δ_{H} (400 MHz, CDCl₃) 0.83 – 0.87 [2H, m, CHCH₂], 0.96 – 0.99 [2H, m, CHCH₂], 1.19 [6H, s, C(CH₃)₂], 1.27 [3H, t, *J* 7.1, OCH₂CH₃], 1.50 – 1.59 [2H, m, C(CH₃)₂CH₂CH₂], 1.61 – 1.67 [2H, m, C(CH₃)₂CH₂], 2.12 – 2.18 [1H, m, C(O)CH], 2.31 [2H, t, *J* 7.2, CH₂CO₂Et]

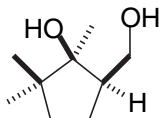
and 4.14 [2H, q, J 7.1, OCH_2CH_3]; δ_{C} (100 MHz, CDCl_3) 11.3 [2 x CHCH_2], 14.6 [OCH_2CH_3], 16.2 [$\text{C}(\text{O})\text{CH}$], 20.8 [$\text{CH}_2\text{CH}_2\text{CO}_2\text{Et}$], 24.7 [2 x $\text{C}(\text{CH}_3)_2$], 35.1 [$\text{CH}_2\text{CO}_2\text{Et}$], 39.7 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 47.9 [$\text{C}(\text{CH}_3)_2$], 60.6 [OCH_2CH_3], 173.8 [$\text{C}(\text{O})\text{O}$] and 215.3 [$\text{C}(\text{O})$]; m/z (EI+ mode) 226 [(M^+) 5%], 181 (7), 157 (60), 111 (80), 83 (50), 69 (100), 56 (15), 41 (43) and 39 (10); [Found: (M^+) , 226.1569. $\text{C}_{13}\text{H}_{22}\text{O}_3$ requires M , 226.1569].

Ethyl-5,5-dimethyl-6-oxo-nonanoate 10

ν_{max} (CDCl_3 solⁿ)/ cm^{-1} 3017, 1729m (ester $\text{C}=\text{O}$), 1703m (ketone $\text{C}=\text{O}$), 1519m, 1477w, 1214s and 1014w; δ_{H} (400 MHz, CDCl_3) 0.83 [3H, t, J 7.4 $\text{C}(\text{O})\text{CH}_2\text{CH}_2\text{CH}_3$], 1.05 [6H, s, $\text{C}(\text{CH}_3)_2$], 1.18 [3H, t, J 7.1, OCH_2CH_3], 1.37 – 1.45 [4H, m, $\text{C}(\text{CH}_3)_2\text{CH}_2$ and $\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2$], 1.47 – 1.56 [2H, m, $\text{C}(\text{O})\text{CH}_2\text{CH}_2$], 2.20 [2H, t, J 6.7, $\text{CH}_2\text{CO}_2\text{Et}$], 2.36 [2H, t, J 7.1, $\text{C}(\text{O})\text{CH}_2$] and 4.05 [2H, q, J 7.1, OCH_2CH_3]; δ_{C} (100 MHz, CDCl_3) 14.2 [$\text{C}(\text{O})\text{CH}_2\text{CH}_2\text{CH}_3$], 14.6 [OCH_2CH_3], 17.6 [$\text{C}(\text{O})\text{CH}_2\text{CH}_2$], 20.6 [$\text{CH}_2\text{CH}_2\text{CO}_2\text{Et}$], 24.7 [$\text{C}(\text{CH}_3)_2$], 35.0 [$\text{CH}_2\text{CO}_2\text{Et}$], 39.1 [$\text{C}(\text{O})\text{CH}_2$], 39.6 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 47.7 [$\text{C}(\text{CH}_3)_2$], 60.7 [OCH_2CH_3], 173.7 [$\text{C}(\text{O})\text{O}$] and 215.8 [$\text{C}(\text{O})$]; m/z (EI+ mode) 228 [(M^+) 7%], 212 (5), 183 (12), 157 (80), 137 (35), 111 (100), 101 (10), 69 (80), 56 (19), 43 (42) and 41 (40); [Found: (M^+) , 228.1725. $\text{C}_{13}\text{H}_{24}\text{O}_3$ requires M , 228.1725].

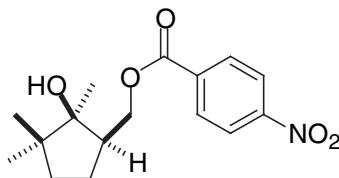
Ethyl-2-(3'-iodo-propylidene)-3,3-dimethyl-cyclopentanoate 9

ν_{max} (CDCl_3 solⁿ)/ cm^{-1} 3077s, 2439m, 2397s, 1724m ($\text{C}=\text{O}$), 1519m, 1424m, 1267s, 1204s, 1020m and 925m; δ_{H} (400 MHz, CDCl_3) 0.97 [3H, s, $\text{C}(\text{CH}_3)_2$], 0.99 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.20 [3H, t, J 7.1, OCH_2CH_3], 1.43 [1H, dt, J 12.3, 7.0, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 1.69 [1H, dt, J 12.3, 7.0, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 1.92 [2H, apparent q, J 7.0, $\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2$], 2.48 – 2.55 [2H, m, $\text{C}=\text{CHCH}_2$], 2.99 – 3.11 [2H, m, $\text{CHCH}_2\text{CH}_2\text{I}$], 3.44 [1H, apparent t, J 6.1, CHCO_2Et], 4.06 [2H, AB system, apparent dq, J 2.7, 7.1, OCH_2CH_3] and 5.15 [1H, dt, J 2.2, 7.4, $\text{CH}=\text{CH}_2\text{CH}_2\text{I}$]; δ_{C} (100 MHz, CDCl_3) 5.7 [CH_2I], 14.6 [OCH_2CH_3], 28.2 [$\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2$], 29.0 [$\text{C}(\text{CH}_3)_2$], 29.6 [$\text{C}(\text{CH}_3)_2$], 33.9 [$\text{CH}_2\text{CH}_2\text{I}$], 41.1 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 43.3 [$\text{C}(\text{CH}_3)_2$], 47.9 [CHCO_2Et], 61.0 [OCH_2CH_3], 122.0 [$\text{C}=\text{CH}$], 152.2 [$\text{C}=\text{CH}$] and 175.1 [$\text{C}(\text{O})\text{O}$]; m/z (CI mode, NH_3) 354 [$(\text{M} + \text{NH}_4)^+$ 100%], 337 [$(\text{M} + \text{H})^+$ 25], 209 (7), 96 (5) and 79 (2); For fragment following loss of I, m/z (EI+ mode) 209 [(M^+) 50%], 167 (17), 163 (20), 135 (100), 107 (40), 93 (50), 83 (30), 77 (20), 55 (12) and 41 (10); [Found: (M^+) , 209.1541. $\text{C}_{13}\text{H}_{21}\text{O}_3$ requires M , 209.1542].



5-Hydroxymethyl-1,2,2-trimethyl-cyclopentanol **7**

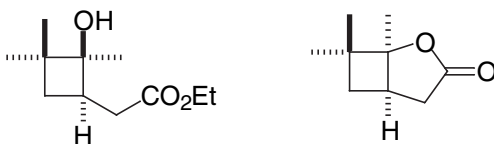
LiAlH₄ (10.6 mg, 0.28 mmol, 3 eq.) was added to a stirred solution of cyclopentanol **5a** (17.5 mg, 0.094 mmol, 1 eq.) in THF (0.5 ml) at – 10°C and the resultant solution was stirred for 2 h. The reaction was quenched by pouring the reaction mixture into H₂O (dist.) (20 ml), followed by extraction with EtOAc (3 x 30 ml). The combined organic layers were then dried (MgSO₄) and concentrated *in vacuo* to yield the crude diol. Purification by column chromatography [eluting with 50% EtOAc in petroleum ether (40-60°C)], yielded the pure diol **7** (12.7 mg, 0.08 mmol, 80 %) as a clear, colourless oil: $\nu_{\max}$ (neat)/cm⁻¹ 3488s (OH), 2867s, 1650m, 1469s, 1386s, 1111m, 1082m, 1024m, 955m and 908m; δ_{H} (400 MHz, CDCl₃) 0.81 [3H, s, C(OH)CH₃], 0.89 [3H, s, C(CH₃)₂], 1.13 [3H, s, C(CH₃)₂], 1.32 - 1.39 [1H, m, 1H from C(CH₃)₂CH₂], 1.53 [1H, s, C(OH)CH₃], 1.63 - 1.77 [3H, m, 1H from C(CH₃)₂CH₂, 2H from C(CH₃)₂CH₂CH₂], 1.95 - 1.99 [1H, m, CHCH₂OH], 2.65 [1H, dd, *J* 2.8, 7.8 CH₂OH], 3.65 [1H, ddd, *J* 11.3, 7.8, 5.0, 1H from CH₂OH] and 3.90 [1H apparent dt, *J* 11.3, 2.8, 1H from CH₂OH]; δ_{C} (100 MHz, CDCl₃) 21.5 [C(CH₃)₂], 21.7 [C(CH₃)₂], 22.7 [C(CH₃)₂CH₂CH₂], 26.2 [C(OH)CH₃], 38.1 [C(CH₃)CH₂], 46.6 [C(CH₃)₂], 47.6 [CHCH₂OH], 62.9 [CH₂OH] and 85.3 [C(OH)CH₃]; *m/z* (EI+ mode) 158 [(M⁺) 10%], 140 (25), 125 (30), 109 (15), 97 (35), 86 (100), 85 (45), 55 (50), and 43 (45); [Found: (M⁺), 158.1310. C₉H₁₈O₂ requires *M*, 158.1307].



2-Hydroxy-2,3,3-trimethyl-cyclopentylmethyl-*p*-nitro benzoate **8**

p-Nitrobenzoyl chloride (53 mg, 0.28 mmol, 1.5 eq.) was added to a stirred solution of diol **7** (30 mg, 0.19 mmol, 1 eq.) in pyridine (1 ml) at room temperature, and the resultant solution was stirred for 16 h. The reaction was quenched by the addition of H₂O (dist.) (1 ml). The organic layers were extracted with EtOAc (3 x 15 ml), and the combined organic extracts were then dried (Na₂SO₄) and concentrated *in vacuo* to give

the crude ester. Purification by column chromatography [eluting with 30% EtOAc in petroleum ether (40-60°C)], yielded pure **8** (45.1 mg, 0.147 mmol, 77 %) as a white, crystalline solid, m.p. 116-117°C [petroleum ether (40-60°C)]: $\nu_{\max}$ (neat)/cm⁻¹ 3521s (OH), 2954s, 2859m, 1714s (C=O), 1608m, 1532s, 1467w, 1354m, 1286s, 1122m, 1105m, 1015w and 943w; δ_{H} (400 MHz, CDCl₃) 0.86 [3H, s, C(OH)CH₃], 0.93 [3H, s, C(CH₃)₂], 1.16 [3H, s, C(CH₃)₂], 1.36 - 1.48 [2H, m, 1H from C(CH₃)₂CH₂CH₂, 1H from C(CH₃)₂CH₂], 1.52 [1H, s, OH], 1.69 - 1.77 [1H, m, 1H from C(CH₃)₂CH₂CH₂], 1.82 - 1.92 [1H, m, 1H from C(CH₃)₂CH₂], 2.42 [1H, apparent quintet, *J* 7.4, CHCH₂OH], 4.34 [1H, dd, *J* 11.0, 6.8, AB system, 1H from CH₂OH], 4.56 [1H, dd, *J* 11.0, 7.4, AB system, 1H from CH₂OH], 8.14 [2H, apparent dt, *J* 8.9, 1.9, 2 x Ar CH] and 8.22 [2H, apparent dt, *J* 8.9, 1.9, 2 x Ar CH]; δ_{C} (100 MHz, CDCl₃) 21.5 [C(CH₃)₂], 21.6 [C(CH₃)₂], 24.8 [C(CH₃)₂CH₂], 26.4 [C(OH)CH₃], 37.5 [C(CH₃)₂CH₂CH₂], 46.1 [CHCH₂OH], 46.8 [C(CH₃)₂], 67.3 [CH₂OH], 82.6 [C(OH)CH₃], 124.0 [2 x Ar CH], 131.1 [2 x Ar CH], 136.2 [Ar C], 150.9 [Ar CNO₂] and 165.3 [C(O)]; *m/z* (FAB+ mode) 308 [(M + H)⁺ 15%], 290 (20), 154 (25), 137 (22), 123 (100), 89 (7), 77 (7), 72 (5) and 56 (5); [Found: (M + H)⁺, 308.1505. C₁₆H₂₂O₅N requires *M*, 308.1498]; (Found: C, 62.46; H, 6.95; N, 4.53; C₁₆H₂₂O₅N requires C, 62.53; H, 6.89; N, 4.56).



Ethyl (2-hydroxy-2,3,3-trimethyl-cyclobutyl) ethanoate 11
1,7,7-Trimethyl-2-oxa-bicyclo[3.2.0]heptan-3-one 12

HMPA (263 μ l, 1.51 mmol, 6 eq.) was added to a stirred solution of SmI₂ (0.1 M in THF, 7.56 ml, 0.756 mmol, 3 eq.) at 0°C and the resultant solution stirred for 10 minutes. Ketone **4a** (50 mg, 0.252 mmol, 1 eq.) was taken up in THF (0.75 ml) and ^tBuOH (73 μ l, 0.756 mmol, 3 eq.) and added to the SmI₂/HMPA solution *via* cannula. The resulting solution was stirred at 0°C for 15 min. The reaction was quenched by opening to the air, followed by the addition of aqueous saturated NaCl (4 ml) and aqueous saturated NaHCO₃ (2 ml). The organic layers were extracted with 80% EtOAc in petroleum ether (40-60°C) (3 x 30 ml). The combined organic extracts were washed with H₂O (dist.) (3 x 30 ml), dried (MgSO₄) and concentrated *in vacuo* to give the crude

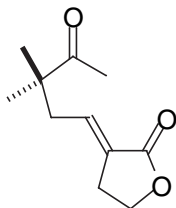
product. Purification by column chromatography (neutral Al_2O_3) [eluting with 20% EtOAc in petroleum ether (40-60°C)], gave lactone **12** (3.9 mg, 0.025 mmol, 8%) as a clear, colourless oil, and cyclobutanol **11** (11.3 mg, 0.056 mmol, 22%) as a clear, colourless oil:

Ethyl (2-hydroxy-2,3,3-trimethyl-cyclobutyl) ethanoate **11**

ν_{max} (neat)/ cm^{-1} 3469s (OH), 2967s, 2868s, 1735s (C=O), 1455m, 1372m, 1309m, 1187m, 1130m and 1029m; δ_{H} (400 MHz, CDCl_3) 0.88 [3H, s, $\text{C}(\text{CH}_3)_2$], 0.94 [1H apparent t, J 10.6, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 1.06 [3H, s, $\text{C}(\text{OH})\text{CH}_3$], 1.10 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.17 [3H, t, J 7.1, OCH_2CH_3], 1.60 [1H, apparent t, J 10.6, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 2.25 [1H, dd, J 6.9, 16.4, AB system, 1H from $\text{CH}_2\text{CO}_2\text{Et}$], 2.34 [1H, dd, J 8.7, 16.4, AB system, 1H from $\text{CH}_2\text{CO}_2\text{Et}$], 2.48 – 2.57 [1H, m, $\text{C}(\text{OH})\text{CH}$], 4.05 [2H, q, J 7.1, OCH_2]; δ_{C} (100 MHz, CDCl_3) 14.6 [OCH_2CH_3], 19.3 [$\text{C}(\text{OH})\text{CH}_3$], 23.4 [$\text{C}(\text{CH}_3)_2$], 23.8 [$\text{C}(\text{CH}_3)_2$], 34.4 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 34.8 [$\text{CH}_2\text{CO}_2\text{Et}$], 40.7 [$\text{C}(\text{CH}_3)_2$], 41.0 [$\text{CHC}(\text{OH})\text{CH}_3$], 60.9 [OCH_2], 76.0 [$\text{C}(\text{OH})\text{CH}_3$], 174.0 [$\text{C}(\text{O})$]; m/z (EI+ mode) 200 [(M^+) 2%], 183 (3), 179 (2), 155 (10), 144 (40), 127 (5), 115 (5), 86 (100), 71 (70), 55 (5) and 43 (30); [Found: (M^+) , 200.1416. $\text{C}_{11}\text{H}_{20}\text{O}_3$ requires M , 200.1412].

1,7,7-trimethyl-2-oxa-bicyclo[3.2.0]heptan-3-one **12**

ν_{max} (neat)/ cm^{-1} 3017s, 1761m (C=O), 1525m, 1420m, 1215s; δ_{H} (400 MHz, CDCl_3) 0.97 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.07 [3H, s, $\text{C}(\text{CH}_3)_2$], 1.23 [3H, s, $\text{C}(\text{CH}_3)\text{O}$], 1.43 – 1.49 [1H, m, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 1.88 – 1.93 [1H, m, 1H from $\text{C}(\text{CH}_3)_2\text{CH}_2$], 2.30 – 2.36 [1H, m, 1H from $\text{CH}_2\text{C}(\text{O})$], 2.58 – 2.69 [2H, m, 1H from $\text{CH}_2\text{C}(\text{O})$ and 1H from CH]; δ_{C} (100 MHz, CDCl_3) 17.5 [$\text{C}(\text{CH}_3)\text{O}$], 21.2 [$\text{C}(\text{CH}_3)_2$], 24.6 [$\text{C}(\text{CH}_3)_2$], 33.6 [CH], 34.6 [$\text{CH}_2\text{C}(\text{O})$], 37.1 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 40.1 [$\text{C}(\text{CH}_3)_2$], 91.8 [$\text{C}(\text{CH}_3)\text{O}$], 176.8 [$\text{C}(\text{O})$]; m/z (CI+ mode, isobutane) 309 (5%), 271 (1), 241 (2), 223 (2), 199 (5), 183 (5), 155 [$(\text{M} + \text{H})^+$ 100], 137 (5), 109 (3), 98 (5); [Found: $(\text{M} + \text{H})^+$, 155.1076. $\text{C}_9\text{H}_{15}\text{O}_2$ requires M , 155.1072].



3-(3,3-Dimethyl-4-oxo-pentylidene)-dihydro-furan-2-one **13**

As for general procedure B. Diol **3a** (94 mg, 0.72 mmol, 1 eq.), after oxidation and reaction with (1-butyrolactonylidene)triphenylphosphorane (495 mg, 1.43 mmol, 2 eq.) for 16 h and purification of the crude product mixture by column chromatography [eluting with 50% EtOAc in petroleum ether (40-60°C)], gave ketone **13** (81.4 mg, 0.42 mmol, 58%) as yellow oil: $\nu_{\max}$ (neat)/ cm^{-1} 2970s, 1755s (ester C=O), 1704 (ketone C=O), 1589w, 1471m, 1386m, 1303m, 1209m, 1017m and 963m; δ_{H} (400 MHz, CDCl_3) 1.23 [6H, s, $\text{C}(\text{CH}_3)_2$], 2.17 [3H, s, $\text{C}(\text{O})\text{CH}_3$], 2.40 [2H, dt, J 7.7, 1.6, $\text{C}(\text{CH}_3)_2\text{CH}_2$], 2.92 [2H, apparent tt, J , 7.4, 1.6, $\text{CH}_2\text{CH}=\text{C}$], 4.40 [2H, t, J 7.4, OCH_2CH_2] and 6.70 [1H, tt, J 7.7, 2.9, $\text{CH}=\text{C}$]; δ_{C} (100 MHz, CDCl_3) 24.9 [2 x $\text{C}(\text{CH}_3)_2$], 25.7 [$\text{C}(\text{O})\text{CH}_3$], 39.7 [$\text{C}(\text{CH}_3)_2\text{CH}_2$], 48.3 [$\text{C}(\text{CH}_3)_2$], 65.8 [$\text{CH}_2\text{CH}_2\text{O}$], 128.0 [$\text{CH}=\text{C}$], 136.8 [$\text{CH}=\text{C}$], 171.3 [$\text{C}(\text{O})\text{O}$] and 212.8 [$\text{C}(\text{O})\text{CH}_3$]; m/z (EI+ mode) 196 [(M^+) 15%], 181 (5), 167 (5), 154 (100), 153 (100), 139 (100), 99 (40), 91 (25), 81 (30), 67 (70) and 43 (85); [Found: (M^+) , 196.1100. $\text{C}_{11}\text{H}_{16}\text{O}_3$ requires M , 196.1099].

Crystal data for 2-Hydroxy-2,3,3-trimethyl-cyclopentylmethyl- *p*-nitro benzoate **8**

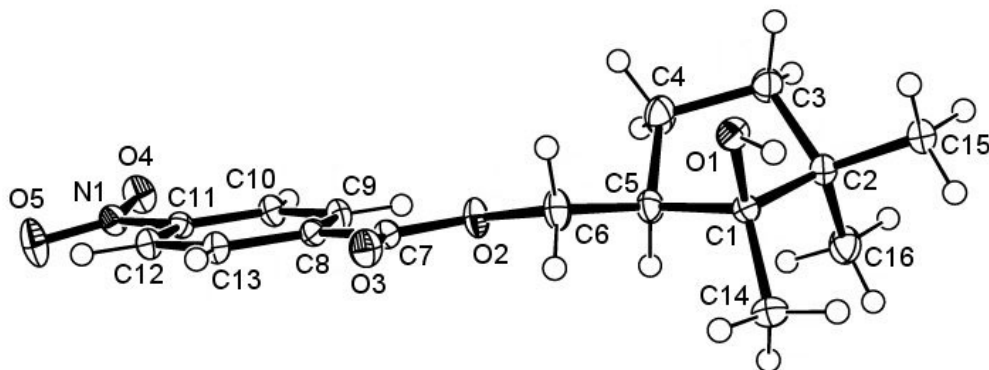


Table 1. Crystal data and structure refinement for km2901.

Identification code	km2901		
Empirical formula	C ₁₆ H ₂₁ N O ₅		
Formula weight	307.34		
Temperature	100(2) K		
Wavelength	0.71073 Å		
Crystal system	Monoclinic		
Space group	P 2 ₁ /c		
Unit cell dimensions	a = 10.4932(3) Å	α= 90°.	
	b = 13.0916(4) Å	β= 111.4100(13)°.	
	c = 12.2594(4) Å	γ= 90°.	
Volume	1567.89(8) Å ³		
Z	4		
Density (calculated)	1.302 Mg/m ³		
Absorption coefficient	0.097 mm ⁻¹		
F(000)	656		
Crystal size	0.45 x 0.2 x 0.2 mm ³		
Theta range for data collection	3.11 to 34.92°.		
Index ranges	-16<=h<=16, -19<=k<=21, -19<=l<=19		
Reflections collected	21423		
Independent reflections	6788 [R(int) = 0.044]		
Completeness to theta = 34.92°	99.0 %		
Absorption correction	None		

Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	6788 / 0 / 250
Goodness-of-fit on F^2	0.978
R indices [4438 with $I > 2\sigma(I)$]	$R1 = 0.0501$, $wR2 = 0.1179$
R indices (all data)	$R1 = 0.0933$, $wR2 = 0.1363$
Largest diff. peak and hole	0.41 and -0.24 $e.\text{\AA}^{-3}$

Notes:

- (a) Methyl hydrogens were refined as rigid groups. Other H-atoms were refined freely.
- (b) All positive peaks above 0.25 $e\text{\AA}^{-3}$ are located in the centres of covalent bonds.
- (c) PLATON gives absolute configuration of reference molecule as 1*R*, 5*S*.

Table 2. Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for km2901. $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U_{ij} tensor.

	x	y	z	U(eq)
O(1)	-1840(1)	-84(1)	8218(1)	18(1)
O(2)	2135(1)	-523(1)	8425(1)	21(1)
O(3)	3200(1)	-797(1)	10365(1)	21(1)
O(4)	7582(1)	-2546(1)	7351(1)	25(1)
O(5)	8773(1)	-2575(1)	9208(1)	31(1)
N(1)	7721(1)	-2392(1)	8375(1)	18(1)
C(1)	-1369(1)	680(1)	7599(1)	16(1)
C(2)	-2399(1)	739(1)	6313(1)	18(1)
C(3)	-2160(1)	-304(1)	5822(1)	22(1)
C(4)	-628(1)	-555(1)	6458(1)	26(1)
C(5)	-77(1)	224(1)	7471(1)	18(1)
C(6)	891(1)	-217(1)	8615(1)	22(1)
C(7)	3187(1)	-814(1)	9372(1)	16(1)
C(8)	4368(1)	-1191(1)	9074(1)	15(1)
C(9)	4314(1)	-1235(1)	7921(1)	18(1)
C(10)	5412(1)	-1631(1)	7682(1)	17(1)
C(11)	6552(1)	-1963(1)	8616(1)	14(1)
C(12)	6636(1)	-1919(1)	9767(1)	16(1)
C(13)	5525(1)	-1531(1)	9996(1)	16(1)
C(14)	-1116(1)	1683(1)	8269(1)	24(1)
C(15)	-3876(1)	876(1)	6239(1)	22(1)
C(16)	-2033(1)	1603(1)	5634(1)	25(1)

Table 3. Bond lengths [$\text{\AA}$] and angles [$^\circ$] for km2901.

O(1)-C(1)	1.4471(13)	C(14)-H(14B)	0.9600
O(1)-H(1)	0.894(18)	C(14)-H(14C)	0.9600
O(2)-C(7)	1.3327(12)	C(15)-H(15A)	0.9600
O(2)-C(6)	1.4631(13)	C(15)-H(15B)	0.9600
O(3)-C(7)	1.2129(13)	C(15)-H(15C)	0.9600
O(4)-N(1)	1.2275(12)	C(16)-H(16A)	0.9600
O(5)-N(1)	1.2231(11)	C(16)-H(16B)	0.9600
N(1)-C(11)	1.4735(13)	C(16)-H(16C)	0.9600
C(1)-C(14)	1.5195(15)		
C(1)-C(5)	1.5414(14)		
C(1)-C(2)	1.5547(14)		
C(2)-C(15)	1.5303(14)		
C(2)-C(16)	1.5337(16)		
C(2)-C(3)	1.5482(16)		
C(3)-C(4)	1.5438(16)		
C(3)-H(3A)	1.026(16)		
C(3)-H(3B)	1.013(16)		
C(4)-C(5)	1.5469(16)		
C(4)-H(4A)	0.973(17)		
C(4)-H(4B)	1.012(17)		
C(5)-C(6)	1.5148(15)		
C(5)-H(5)	1.016(14)		
C(6)-H(6A)	0.981(15)		
C(6)-H(6B)	0.981(15)		
C(7)-C(8)	1.4977(14)		
C(8)-C(9)	1.3948(14)		
C(8)-C(13)	1.3954(13)		
C(9)-C(10)	1.3893(14)		
C(9)-H(9)	0.944(14)		
C(10)-C(11)	1.3895(13)		
C(10)-H(10)	0.966(15)		
C(11)-C(12)	1.3817(14)		
C(12)-C(13)	1.3917(14)		
C(12)-H(12)	0.962(14)		
C(13)-H(13)	0.985(14)		
C(14)-H(14A)	0.9600		

C(1)-O(1)-H(1)	107.1(12)	O(2)-C(6)-H(6A)	107.7(8)
C(7)-O(2)-C(6)	116.23(8)	C(5)-C(6)-H(6A)	112.7(8)
O(5)-N(1)-O(4)	123.79(9)	O(2)-C(6)-H(6B)	106.8(8)
O(5)-N(1)-C(11)	118.10(9)	C(5)-C(6)-H(6B)	112.4(8)
O(4)-N(1)-C(11)	118.12(8)	H(6A)-C(6)-H(6B)	109.8(12)
O(1)-C(1)-C(14)	109.89(9)	O(3)-C(7)-O(2)	124.90(9)
O(1)-C(1)-C(5)	105.52(8)	O(3)-C(7)-C(8)	122.90(9)
C(14)-C(1)-C(5)	113.78(8)	O(2)-C(7)-C(8)	112.19(9)
O(1)-C(1)-C(2)	108.76(8)	C(9)-C(8)-C(13)	120.59(9)
C(14)-C(1)-C(2)	115.17(9)	C(9)-C(8)-C(7)	121.95(9)
C(5)-C(1)-C(2)	103.09(8)	C(13)-C(8)-C(7)	117.44(9)
C(15)-C(2)-C(16)	109.29(9)	C(10)-C(9)-C(8)	119.96(9)
C(15)-C(2)-C(3)	112.61(9)	C(10)-C(9)-H(9)	119.4(9)
C(16)-C(2)-C(3)	109.37(10)	C(8)-C(9)-H(9)	120.6(9)
C(15)-C(2)-C(1)	112.32(9)	C(9)-C(10)-C(11)	118.27(9)
C(16)-C(2)-C(1)	111.54(9)	C(9)-C(10)-H(10)	121.8(8)
C(3)-C(2)-C(1)	101.52(8)	C(11)-C(10)-H(10)	119.9(8)
C(4)-C(3)-C(2)	106.14(9)	C(12)-C(11)-C(10)	122.90(9)
C(4)-C(3)-H(3A)	108.9(8)	C(12)-C(11)-N(1)	118.20(8)
C(2)-C(3)-H(3A)	111.0(9)	C(10)-C(11)-N(1)	118.90(9)
C(4)-C(3)-H(3B)	111.7(9)	C(11)-C(12)-C(13)	118.38(9)
C(2)-C(3)-H(3B)	111.5(9)	C(11)-C(12)-H(12)	120.8(9)
H(3A)-C(3)-H(3B)	107.6(12)	C(13)-C(12)-H(12)	120.8(9)
C(3)-C(4)-C(5)	106.26(9)	C(12)-C(13)-C(8)	119.89(9)
C(3)-C(4)-H(4A)	111.5(10)	C(12)-C(13)-H(13)	121.1(8)
C(5)-C(4)-H(4A)	111.9(10)	C(8)-C(13)-H(13)	119.0(8)
C(3)-C(4)-H(4B)	109.8(9)	C(1)-C(14)-H(14A)	109.5
C(5)-C(4)-H(4B)	110.5(9)	C(1)-C(14)-H(14B)	109.5
H(4A)-C(4)-H(4B)	106.9(13)	H(14A)-C(14)-H(14B)	109.5
C(6)-C(5)-C(1)	111.75(9)	C(1)-C(14)-H(14C)	109.5
C(6)-C(5)-C(4)	114.80(10)	H(14A)-C(14)-H(14C)	109.5
C(1)-C(5)-C(4)	104.62(8)	H(14B)-C(14)-H(14C)	109.5
C(6)-C(5)-H(5)	108.0(8)	C(2)-C(15)-H(15A)	109.5
C(1)-C(5)-H(5)	108.0(8)	C(2)-C(15)-H(15B)	109.5
C(4)-C(5)-H(5)	109.4(8)	H(15A)-C(15)-H(15B)	109.5
O(2)-C(6)-C(5)	106.97(9)	C(2)-C(15)-H(15C)	109.5

H(15A)-C(15)-H(15C)	109.5
H(15B)-C(15)-H(15C)	109.5
C(2)-C(16)-H(16A)	109.5
C(2)-C(16)-H(16B)	109.5
H(16A)-C(16)-H(16B)	109.5
C(2)-C(16)-H(16C)	109.5
H(16A)-C(16)-H(16C)	109.5
H(16B)-C(16)-H(16C)	109.5

Table 4. Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for km2901. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	19(1)	18(1)	22(1)	1(1)	12(1)	1(1)
O(2)	13(1)	30(1)	21(1)	4(1)	7(1)	6(1)
O(3)	19(1)	25(1)	20(1)	0(1)	9(1)	3(1)
O(4)	24(1)	36(1)	17(1)	-6(1)	9(1)	3(1)
O(5)	17(1)	53(1)	20(1)	-2(1)	3(1)	12(1)
N(1)	15(1)	22(1)	17(1)	-2(1)	7(1)	1(1)
C(1)	14(1)	15(1)	19(1)	-1(1)	6(1)	0(1)
C(2)	15(1)	18(1)	20(1)	1(1)	5(1)	2(1)
C(3)	22(1)	22(1)	21(1)	-4(1)	4(1)	3(1)
C(4)	22(1)	28(1)	26(1)	-6(1)	8(1)	7(1)
C(5)	14(1)	21(1)	21(1)	3(1)	7(1)	2(1)
C(6)	14(1)	30(1)	23(1)	5(1)	8(1)	6(1)
C(7)	13(1)	16(1)	19(1)	0(1)	5(1)	0(1)
C(8)	13(1)	15(1)	16(1)	1(1)	6(1)	0(1)
C(9)	14(1)	22(1)	15(1)	2(1)	3(1)	1(1)
C(10)	16(1)	23(1)	13(1)	1(1)	5(1)	1(1)
C(11)	12(1)	16(1)	16(1)	-1(1)	6(1)	0(1)
C(12)	14(1)	20(1)	14(1)	1(1)	5(1)	1(1)
C(13)	15(1)	19(1)	14(1)	1(1)	6(1)	2(1)
C(14)	24(1)	18(1)	29(1)	-5(1)	8(1)	-2(1)
C(15)	15(1)	22(1)	28(1)	1(1)	5(1)	2(1)
C(16)	22(1)	26(1)	27(1)	9(1)	8(1)	3(1)

Table 5. Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for km2901.

	x	y	z	U(eq)
H(14A)	-1973	1962	8242	36
H(14B)	-680	2157	7918	36
H(14C)	-535	1565	9069	36
H(15A)	-3961	1515	6590	34
H(15B)	-4115	327	6648	34
H(15C)	-4480	871	5432	34
H(16A)	-2670	1605	4839	38
H(16B)	-1123	1498	5644	38
H(16C)	-2075	2246	5996	38
H(1)	-2301(18)	244(14)	8598(15)	43(5)
H(3A)	-2735(15)	-866(12)	6003(14)	33(4)
H(3B)	-2419(16)	-279(12)	4942(14)	32(4)
H(4A)	-130(16)	-522(13)	5927(15)	37(4)
H(4B)	-524(15)	-1276(13)	6776(14)	36(4)
H(5)	420(13)	796(10)	7228(12)	19(3)
H(6A)	1153(14)	280(11)	9257(13)	22(3)
H(6B)	524(14)	-834(11)	8847(13)	24(4)
H(9)	3530(14)	-1007(11)	7297(12)	21(3)
H(10)	5405(14)	-1670(11)	6893(13)	29(4)
H(12)	7443(15)	-2152(12)	10393(13)	28(4)
H(13)	5525(14)	-1512(11)	10799(12)	23(3)

Table 6. Torsion angles [°] for km2901.

O(1)-C(1)-C(2)-C(15)	51.71(11)	O(4)-N(1)-C(11)-C(12)	171.29(10)
C(14)-C(1)-C(2)-C(15)	-72.10(12)	O(5)-N(1)-C(11)-C(10)	172.04(10)
C(5)-C(1)-C(2)-C(15)	163.38(9)	O(4)-N(1)-C(11)-C(10)	-8.07(15)
O(1)-C(1)-C(2)-C(16)	174.80(9)	C(10)-C(11)-C(12)-C(13)	0.45(16)
C(14)-C(1)-C(2)-C(16)	50.99(12)	N(1)-C(11)-C(12)-C(13)	-178.88(9)
C(5)-C(1)-C(2)-C(16)	-73.53(11)	C(11)-C(12)-C(13)-C(8)	-0.48(16)
O(1)-C(1)-C(2)-C(3)	-68.81(10)	C(9)-C(8)-C(13)-C(12)	-0.12(16)
C(14)-C(1)-C(2)-C(3)	167.37(9)	C(7)-C(8)-C(13)-C(12)	178.03(9)
C(5)-C(1)-C(2)-C(3)	42.85(10)		
C(15)-C(2)-C(3)-C(4)	-153.48(10)		
C(16)-C(2)-C(3)-C(4)	84.80(11)		
C(1)-C(2)-C(3)-C(4)	-33.16(12)		
C(2)-C(3)-C(4)-C(5)	11.11(13)		
O(1)-C(1)-C(5)-C(6)	-47.34(11)		
C(14)-C(1)-C(5)-C(6)	73.21(12)		
C(2)-C(1)-C(5)-C(6)	-161.37(9)		
O(1)-C(1)-C(5)-C(4)	77.47(10)		
C(14)-C(1)-C(5)-C(4)	-161.99(10)		
C(2)-C(1)-C(5)-C(4)	-36.57(11)		
C(3)-C(4)-C(5)-C(6)	138.62(10)		
C(3)-C(4)-C(5)-C(1)	15.78(13)		
C(7)-O(2)-C(6)-C(5)	171.90(9)		
C(1)-C(5)-C(6)-O(2)	-173.90(9)		
C(4)-C(5)-C(6)-O(2)	67.18(12)		
C(6)-O(2)-C(7)-O(3)	-3.57(16)		
C(6)-O(2)-C(7)-C(8)	175.35(9)		
O(3)-C(7)-C(8)-C(9)	177.86(10)		
O(2)-C(7)-C(8)-C(9)	-1.08(14)		
O(3)-C(7)-C(8)-C(13)	-0.26(16)		
O(2)-C(7)-C(8)-C(13)	-179.21(9)		
C(13)-C(8)-C(9)-C(10)	0.78(16)		
C(7)-C(8)-C(9)-C(10)	-177.29(10)		
C(8)-C(9)-C(10)-C(11)	-0.81(16)		
C(9)-C(10)-C(11)-C(12)	0.20(16)		
C(9)-C(10)-C(11)-N(1)	179.52(10)		
O(5)-N(1)-C(11)-C(12)	-8.60(15)		

Table 7. Hydrogen bonds for km2901 [$\text{\AA}$ and $^\circ$].

D-H...A	d(D-H)	d(H...A)	d(D...A)	$\angle(\text{DHA})$
O(1)-H(1)...O(3)#1	0.894(18)	1.976(19)	2.8620(11)	170.7(16)

Symmetry transformations used to generate equivalent atoms:

#1 -x,-y,-z+2