Highly Accelerating Effect of Lewis Acids on Ruthenium(II)-Catalyzed Radical Addition Reactions

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The intramolecular ruthenium(II)-catalyzed radical addition of the trichloroacetyl pendant group to the 2-oxazolone skeleton is greatly enhanced in the presence of catalytic Lewis acids including rare earth metal triflates, thus providing a convenient route to a highly potential chiral synthon for *vic*-amino alcohols.

Key words 2-oxazolone; radical addition; ruthenium(II) complex; Lewis acid; accelerating effect

Vicinal amino alcohol functions are structural units which are contained in a substantial number of bioactive compounds as well as in chiral sources which are widely used for asymmetric synthesis.[1] We have previously demonstrated versatile synthetic routes for chiral *vic*-amino alcohols, which involve, as a key step, the highly efficient chiral functionalization of a simple 2-oxazolone heterocycle.[2] Among these, the intramolecular $RuCl_2$-catalyzed radical addition of α-chloroacyl pendant groups including trichloroacetyl and 2,2-dichloropropionyl groups as in compounds **1a**—**d** to the 2-oxazolone skeleton proceeds with perfect regio- and diastereo-selectivity to give the 12-membered macrolides **2a**—**d**, respectively, which, in turn, represent good precursors for the versatile synthesis of chiral 2-amino alcohols.[3—5] This methodology was successfully applied to chiral synthesis of 2,2-dichlorodifluoro (**3**) and 2,2-difluorostatine derivatives (**4**),[3] and the unusual amino hydroxy acids **5**[4] and **6**[5] with three contiguous chiral centers, which are key components of cyclosporins and bleomycins, respectively (Chart 1). There is still an ongoing need, however, to improve this radical addition which proceeds quite sluggishly and requires a reaction period in excess of 72 h to obtain reasonable yields. We have now found that the addition of Lewis acidic compounds such as lanthanoid triflates as additives results in a considerable reduction in reaction time. This paper describes the promising effects of Lewis acid additives on the remarkable acceleration of this type of Ru(II)-catalyzed radical cyclization reaction.

In a typical experiment, a solution of the 3-(1-apocamphanecarbonyl)-2-oxazolone (**1a**) bearing a trichloroacetyl pendant group, which is readily obtainable from DPPOx[6] (**7**) and the carboxylic acid (**8**), in benzene was refluxed in the presence of $RuCl_2(PPh_3)_3$ (0.1 eq) with $La(OTf)_3$ (0.1 eq) to give excellent yields of the sole cycloaddition product (**2a**) with excellent diastereoselectivity (above 99% de) within half an hour, as seen in Fig. 1. In the absence of $La(OTf)_3$, only an 11% yield of the macrolide was obtained, which was configurationally identical with **2a** and which could be unequivocally determined by conversion to the authentic 4-methoxy compound (**11**) (Chart 2). This suggests that similar confor-

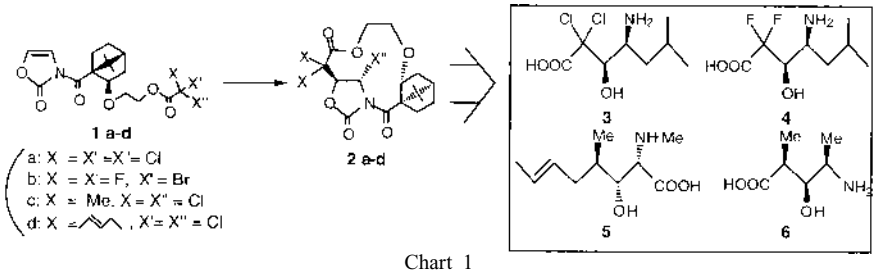

Chart 1

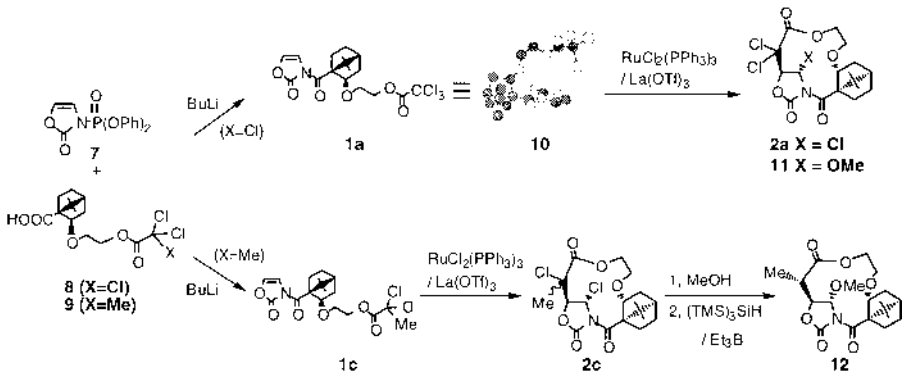

Chart 2

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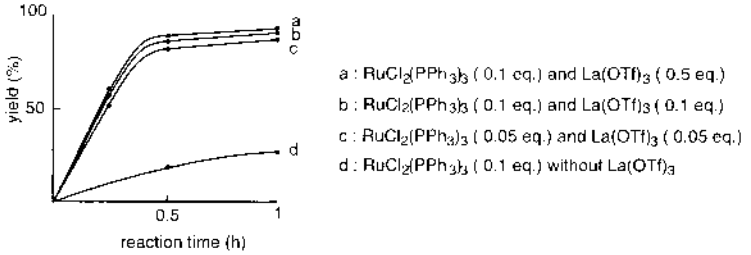


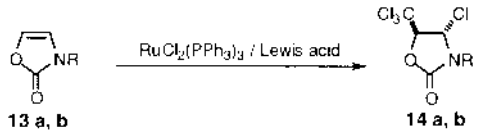
Fig. 1. Time Course for the Ru(II)-Catalyzed Intramolecular Cyclization of Compound (**1a**) to Macrolide (**2a**) (in Refluxing Benzene)

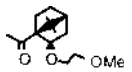
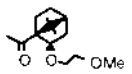
Table 1. The Effect of Lewis Acids on the Ru(II)-Catalyzed Intramolecular Cyclization of Compound **1a** to Macrolide **2a**[a)]

Lewis acid (eq)	Time (h)	Yield (%)[b)]
None	3 (0.5)	24 (11)[c)]
$La(OTf)_3$	3 (0.5)	96 (86)[c)]
$Ce(OTf)_4$	3	88
$Pr(OTf)_3$	3	80
$Nd(OTf)_3$	3	78
$Sm(OTf)_3$	3	84
$Eu(OTf)_3$	3	92
$Gd(OTf)_3$	3	82
$Tb(OTf)_3$	3	90
$Dy(OTf)_3$	3	83
$Ho(OTf)_3$	3	80
$Er(OTf)_3$	3	90
$Tm(OTf)_3$	3	82
$Yb(OTf)_3$	3	70
$Lu(OTf)_3$	3	73
$BF_3 \cdot OEt_2$	1	88
$Zn(OTf)_2$	1	94
$ZnCl_2$	1	91
$EtAlCl_2$	1	91

a) The reaction was performed with $RuCl_2(PPh_3)_3$ (0.1 eq) in the presence of Lewis acid (0.5 eq) in benzene at 80 °C. *b*) Isolated yield. *c*) Performed for 0.5 h.

Table 2. The Ru(II)-Catalyzed Addition of Carbon Tetrachloride[a)]



Compound	R	Lewis acid	Time (h)	Adduct	Yield (%)
13a	Ac	None	1	**14a**	28
13a	Ac	$Y(OTf)_3$	1	**14a**	44
13a	Ac	$Tb(OTf)_3$	1	**14a**	49
13a	Ac	$Er(OTf)_3$	1	**14a**	40
13b		None	12	**14b**	56[b)]
13b		$Tb(OTf)_3$	12	**14b**	77[b)]

a) This reaction was performed in the presence of $RuCl_2(PPh_3)_3$ (10 mol%) with or without Lewis acid (1 mol%) in boiling CCl_4. *b*) Isolated as a diastereomeric 1 : 1 mixture.

mations such as **10** with the anti-coplanar carbonyls due to dipole repulsion are operative at the transition states for both cyclizations, *i.e.*, with or without Lewis acids.

As seen in Table 1, the Lewis acidic additives examined in this study involve the rare earth metal triflates as well as conventional Lewis acids such as BF_3 and $ZnCl_2$. All of the lanthanoid triflates examined as additives were highly effective, apparently independent of the Lewis acidity of the lanthanoid complexes.[7)] The other reagents, $BF_3 \cdot OEt_2$, $Zn(OTf)_2$, $ZnCl_2$ and $EtAlCl_2$ were equally useful. A minimal amount of $La(OTf)_3$ up to 0.05 equimolar amounts was sufficiently effective to result in a moderate acceleration (Fig. 1).

The exclusive cyclization to the 5-position of 2-oxazolone heterocycle may be rationalized by assuming the favored conformation[8)] (**10**) with the anti-coplanar amido carbonyls based on an intramolecular steric and electrostatic interaction, which leads to the less strained 12-membered ring structure. It seems likely that coordination of the Lewis acids to carbonyl groups and chlorine atoms would be responsible for the enormous acceleration observed, but the details of this are not presently clear.

When the 2-oxazolone derivative (**1c**) with a 2,2-dichloropropionyl pendant group in place of the trichloroacetyl group was applied to this Lewis acid mediated intramolecular cyclization, the cycloaddition proceeded in a similar manner to give the diastereomeric mixture of cyclic adduct (**2c**), as has been previously reported for the reaction performed in the absence of a Lewis acid.[5)] No apparent acceleration, however, was observed in this reaction which gave only a 34% yield even for a prolonged reaction time of over 70 h. The structure of **2c** was confirmed by stereoselective conversion to the reductively dechlorinated **12**[5)] on treatment with tris(trimethylsilyl)silane in the presence of triethylborane at −78 °C.

The Ru(II)-catalyzed radical addition, as aided by lanthanoid triflates was explored for the intermolecular addition of carbon tetrachloride to 3-acyl-2-oxazolones (**13a**, **b**). The reaction resulted in the exclusive formation of *trans*-4-chloro-5-trichloromethyl-2-oxazolidinone derivatives (**14a**, **b**), but the acceleration effect of the triflates was only moderate (Table 2).

In conclusion, the intramolecular Ru(II)-catalyzed radical addition of the trichloroacetyl pendant group to the 2-oxazolone ring, which is dramatically accelerated by the presence of catalytic amounts of Lewis acids including the rare earth metal triflates, represents a promising tool for the chiral synthesis of 2-amino alcohols with *vicinal* stereogenic centers, by virtue of perfect diastereocontrol and high efficiency.

Experimental

General Methods Melting points were determined with a Yanaco micro melting point apparatus and are uncorrected. Optical rotations were measured with a JASCO DIP 370 polarimeter. ^{1}H-NMR spectra were recorded in $CDCl_3$ with tetramethylsilane as the internal standard on JEOL ALPHA-500

(500 MHz) and JEOL JNM-GX400 (400 MHz) spectrometers. MS and high resolution (HR)-MS were obtained with a JEOL JMS-DX303HF mass spectrometer.

***tert*-Butyl (1*S*,2*R*,4*R*)-2-(2-Hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]-heptane-1-carboxylate** To a solution of *tert*-butyl 2(*R*)-hydroxy-7,7-dimethylbicyclo[2.2.1]heptane-1(*S*)-carboxylate[9] (16.4 g, 69 mmol) in tetrahydrofuran (THF, 96 ml) was added allyl bromide (25 g, 207 mmol) in the presence of NaH (3.9 g, 163 mmol) and the mixture was then stirred at room temperature for 25 h. The reaction was quenched by passing the solution through a silica gel-pad using AcOEt (400 ml) as an eluent. The usual work-up followed by chromatography on silica gel (CH_2Cl_2 : AcOEt=9 : 1) yielded *tert*-butyl (1*S*,2*R*,4*R*)-2-allyloxy-7,7-dimethylbicyclo[2.2.1]heptane-1-carboxylate (19.0 g, 99%) as a colorless oil, $[\alpha]_D^{27}$ −45.5° (*c*=1.02, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.04 (3H, s), 1.00—1.06 (1H, m), 1.29 (3H, s), 1.37—1.42 (1H, m), 1.45 (9H, s), 1.61—1.72 (3H, m), 1.83—1.95 (2H, m), 3.67 (1H, dd, *J*=3.3, 7.7 Hz), 3.91 (1H, ddt, *J*=1.8, 5.1, 13.2 Hz), 3.94 (1H, ddt, *J*=1.8, 5.1, 13.2 Hz), 5.09 (1H, ddd, *J*=1.8, 3.7, 17.2 Hz), 5.24 (1H, ddd, *J*=5.1, 10.3, 17.2 Hz), 5.80—5.90 (1H, m). MS (electron impact (EI)) *m*/*z* 279 $(MH)^+$.

The 2-*exo*-allyloxy derivative thus obtained (2.47 g, 8.8 mmol) was ozonolyzed in MeOH (52 ml) at −78 °C for 4 h. The reaction was quenched by treatment with $NaBH_4$ (3.6 g, 88 mmol) at room temperature for 1 h. The usual work-up followed by chromatography on silica gel (CH_2Cl_2 : AcOEt= 8 : 2) yielded *tert*-butyl (1*S*,2*R*,4*R*)-2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]heptane-1-carboxylate (2.49 g, 99%) as a colorless oil, $[\alpha]_D^{29}$ −18.9° (*c*=1.06, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.05 (3H, s), 1.04—1.09 (1H, m), 1.25 (3H, s), 1.38—1.46 (1H, m), 1.47 (9H, s), 1.62—1.76 (3H, m), 1.84—1.97 (2H, m), 2.35 (1H, br), 3.38—3.43 (1H, m), 3.59—3.70 (3H, m), 3.74 (1H, dd, *J*=3.3, 7.3 Hz). MS (EI) *m*/*z* 284 $(MH)^+$.

(1*S*,2*R*,4*R*)-2-(2-Trichloroacetoxyethoxy)-7,7-dimethylbicyclo[2.2.1]-heptane-1-carboxylic Acid (8) To a solution of *tert*-butyl (1*S*,2*R*,4*R*)-2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]heptane-1-carboxylate (3.6 g, 7.0 mmol) in THF (56 ml) was added trichloroacetyl chloride in the presence of NaH (54 mg, 22.4 mmol), and the mixture was then stirred at room temperature for 3 h. The mixture was passed through a silica gel-pad with EtOAc (200 ml) as an eluent. The usual work-up followed by chromatography on silica gel (hexane : CH_2Cl_2=4 : 6) yielded *tert*-butyl (1*S*,2*R*,4*R*)-2-(2-trichloroacetoxy)ethoxy-7,7-dimethylbicyclo[2.2.1]heptane-1-carboxylate (4.48 g, 93%) as a colorless oil, $[\alpha]_D^{29}$ −47.2° (*c*=1.00, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.03 (3H, s), 1.01—1.07 (1H, m), 1.23 (3H, s), 1.36—1.43 (1H, m), 1.46 (9H, s), 1.64—1.73 (3H, m), 1.85—1.94 (2H, m), 3.69—3.74 (3H, m), 4.38—4.44 (2H, m). MS (EI) *m*/*z* 429 $(MH)^+$.

The 2-*exo*-trichloroacetoxyethoxy derivative (0.43 g, 1.0 mmol) thus obtained was treated with CF_3COOH (1.2 g, 10 mmol) in CH_2Cl_2 (5.8 ml) at room temperature for 10 min. Removal of the solvent, followed by chromatography on silica gel (CH_2Cl_2 : AcOEt=9 : 1) yielded the carboxylic acid (**8**) (0.37 g, 99%) as a colorless oil, $[\alpha]_D^{30}$ −32.8° (*c*=1.00, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.07 (3H, s), 1.10—1.16 (1H, m), 1.23 (3H, s), 1.39—1.45 (1H, m), 1.78—1.85 (3H, m), 1.98—2.02 (1H, m), 2.12—2.28 (1H, m), 3.78—3.87 (3H, m), 4.46—4.55 (2H, m). MS (EI) *m*/*z* 372 $(M)^+$.

(1*S*,2*R*,4*R*)-2-[2-(2,2-Dichloropropionyloxy)ethoxy]-7,7-dimethylbicyclo[2.2.1]heptane-1-carboxylic Acid (9) In a manner similar to the above, this was obtained as a colorless oil by propionylation of *tert*-butyl (1*S*,2*R*,4*R*)-2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2.2.1]heptane-1-carboxylate with 2,2-dichloropropionyl chloride (99% yield), followed by treatment with CF_3COOH (96% yield), $[\alpha]_D^{28}$ −40.2° (*c*=1.00, $CHCl_3$). ^{1}H-NMR (500 MHz) δ: 10.4 (3H, s), 1.20 (3H, s), 1.24—1.35 (2H, m), 1.78—1.85 (4H, m), 1.99—2.04 (2H, m), 2.30 (3H, s), 3.73—3.78 (1H, m), 3.82—3.88 (2H, m), 4.39—4.48 (2H, m). HR-MS (FAB) Calcd for $C_{15}H_{22}O_5Cl_2Na$ (MNa^+): *m*/*z* 375.07344. Found: *m*/*z* 375.07420.

3-[(1*S*,2*R*,4*R*)-2-(2-Trichloroacetoxyethoxy)-7,7-dimethylbicyclo[2.2.1]heptane-1-carbonyl]-2-oxazolone (1a) To a solution of the lithium salts prepared from **8** (1.39 g. 3.7 mmol) and BuLi (2.7 ml, 1.53 M in hexane, 4.1 mmol) in THF (40 ml) was added DPPOx (**7**) (1.18 g, 3.7 mmol) at −78 °C and the mixture was then stirred at 0 °C for 5 h. The solution was passed through a silica gel-pad with AcOEt as an eluent. The usual work-up, followed by chromatography on silica gel (hexane–CH_2Cl_2=1 : 1 to CH_2Cl_2) gave 3-acyl-2-oxazolone (**1a**) (1.44 g, 88%) as colorless crystals, mp 56—57 °C (hexane), $[\alpha]_D^{31}$ −49.2° (*c*=1.00, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.13 (3H, s), 1.15—1.29 (1H, m), 1.31 (3H, s), 1.71—1.97 (5H, m), 2.32—2.39 (1H, m), 3.56 (1H, ddd, *J*=3.3, 5.1, 11.4 Hz), 3.70 (1H, ddd, *J*=3.3, 6.6, 11.4 Hz), 4.34 (1H, t, *J*=3.3 Hz), 4.37 (1H, t, *J*=3.3 Hz), 4.81 (1H, dd, *J*=3.3, 7.7 Hz), 6.78 (1H, d, *J*=2.2 Hz), 7.28 (1H, d, *J*=2.2 Hz). *Anal.* Calcd for $C_{17}H_{20}NO_6Cl_3$: C, 46.33; H, 4.57; N, 3.18. Found: C, 46.39; H, 4.55; N, 3.03.

3-[(1*R*,2*S*,4*S*)-2-[2-(2,2-Dichloropropionyloxy)ethoxy]-7,7-dimethylbicyclo[2,2,1]heptane-1-carbonyl]-2-oxazolone (1c) Analogous to the preparation of **1a**, this was obtained in 74% yield as a colorless oil, $[\alpha]_D^{26}$ +51.4° (*c*=1.00, $CHCl_3$). ^{1}H-NMR (300 MHz) δ: 0.90—2.65 (8H, m), 1.15 (3H, s), 1.32 (3H, s), 2.29 (3H, s), 3.64 (2H, t, *J*=3.6 Hz), 4.28 (2H, t, *J*=4.4 Hz), 6.89 (1H, d, *J*=1.6 Hz), 7.30 (1H, d, *J*=1.6 Hz). MS (FAB) *m*/*z*: 442 (MNa^+), 335, 169 $(CH_2CH_2OCOCCl_2Me^+)$, 149. HR-MS (FAB) Calcd for $C_{18}H_{23}NO_6Cl_2Na$ (MNa^+): *m*/*z* 442.0800. Found: *m*/*z* 442.0791.

2,2-Dichloro-{3-[2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]heptane-1-carbonyl]-4-chloro-2-oxo-oxazolidin-5-yl}acetic Acid, Lactone (2a) A mixture of **1a** (100 mg, 0.22 mmol), $La(OTf)_3$ (14 mg, 0.02 mmol) and $RuCl_2(PPh_3)_3$ (21 mg, 0.02 mmol) in benzene (3 ml) was refluxed for 3 h. The mixture was passed through a silica gel-pad with EtOAc as an eluent. Usual work-up, followed by chromatography on silica gel (hexane : CH_2Cl_2=1 : 1) afforded the 12-membered macrolide (**2a**) (96 mg, 96%) as colorless crystals, mp 192—193 °C (hexane), $[\alpha]_D^{27}$ +34.9° (*c*=0.98, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.15—1.20 (1H, m), 1.20 (6H, s), 1.64—1.70 (2H, m), 1.84—1.95 (3H, m), 2.24—2.30 (1H, m), 3.33 (1H, dt, *J*=2.2, 11.4 Hz), 3.80 (1H, dd, *J*=1.5, 11.4 Hz), 4.07 (1H, dt, *J*=1.5, 11.4 Hz), 4.32 (1H, dd, *J*=3.7, 8.1 Hz), 4.90 (1H, dt, *J*=2.2, 11.4 Hz), 5.12 (1H, d, *J*=1.5 Hz), 6.33 (1H, d, *J*=1.5 Hz). *Anal.* Calcd for $C_{17}H_{20}NO_6Cl_3$: C, 46.33; H, 4.57; N, 3.18. Found: C, 46.03; H, 4.47; N, 3.04.

2,2-Dichloro-{3-[2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]heptane-1-carbonyl]-4-methoxy-2-oxo-oxazolidin-5-yl}acetic Acid, Lactone (11) The macrolide **2a** (0.43 g, 0.97 mmol) was quantitatively converted to the 4-methoxy-2-oxazolidinone derivative by treatment with refluxing MeOH (20 ml) for 30 h. Chromatographic purification gave the 4-methoxy compound (**11**) (0.42 g, 98%) as colorless crystals, mp 199—200 °C (hexane), $[\alpha]_D^{28}$ +30.8° (*c*=1.01, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.14—1.67 (1H, m), 1.19 (3H, s), 1.21 (3H, s) 1.59—1.69 (2H, m), 1.82—1.95 (3H, m), 2.32—2.39 (1H, m), 3.34 (1H, dt, *J*=1.8, 11.0 Hz), 3.61 (3H, s), 3.80 (1H, d, *J*=11.0 Hz), 4.08 (1H, d, *J*=11.7 Hz), 4.36 (1H, dd, *J*=3.7, 7.7 Hz), 4.75 (1H, d, *J*=1.5 Hz), 4.84 (1H, dt, *J*=1.8, 11.7 Hz), 5.52 (1H, d, *J*=1.5 Hz). *Anal.* Calcd for $C_{18}H_{23}NO_7Cl_2$: C, 49.55; H, 5.31; N, 3.21. Found: C, 49.30; H,5.27; N, 3.21. This was identical with the authentic compound which was verified by X-ray crystal analysis.[3]

2-Chloro-{3-[2-(2-hydroxyethoxy)-7,7-dimethylbicyclo[2,2,1]heptane-1-carbonyl]-4-chloro-2-oxo-oxazolidin-5-yl}propionic Acid, Lactone (2c) A mixture of **1c** (100 mg, 0.23 mmol), $La(OTf)_3$ (14 mg, 0.02 mmol) and $RuCl_2(PPh_3)_3$ (23 mg, 0.02 mmol) in benzene (3 ml) was refluxed under an argon atmosphere for 70 h. The mixture was passed through a silica gel-pad with AcOEt as eluent. The usual work-up followed by chromatography on silica gel (hexane : CH_2Cl_2=1 : 1) afforded the 12-membered macrolide (**2c**) (34 mg, 34%) as a distereomeric mixture. ^{1}H-NMR (500 MHz/$CDCl_3$) δ: 1.16—1.26 (1H, m), 1.20 (0.44×6H, s), 1.21 (0.56×6H, s), 1.63—1.69 (2H, m), 1.84—1.94 (3H, m), 1.88 (0.44×3H, s), 1.96 (0.56×3H, s), 2.26—2.34 (1H, m), 3.26 (0.56H, t, *J*=11.0 Hz), 3.32 (0.44H, t, *J*=11.0 Hz), 3.75—3.78 (1H, m), 3.92 (1H, t, *J*=11.6 Hz), 4.29 (0.56H, dd, *J*=3.7, 4.3 Hz), 4.34 (0.44H, dd, *J*=3.7, 4.3 Hz), 4.76 (0.56H, d, *J*=1.2 Hz), 4.78 (0.44H, d, *J*=1.2 Hz), 4.88 (1H, t, *J*=11.6 Hz), 6.13 (0.44H, d, *J*=1.2 Hz), 6.44 (0.56H, d, *J*=1.2 Hz).

2-[3-(2-Hydroxyethoxy-7,7-dimethylbicyclo[2,2,1]heptane-1-carbonyl)-4-methoxy-2-oxo-oxazolidin-5-yl]propionic Acid, Lactone (12) Treatment of the diastereomeric mixture **2c** (1.8 g, 4.2 mmol) with refluxing MeOH (85 ml) for 12 h gave a quantitative yield of 4-methoxy-2-oxazolidinone derivative, which was treated with $(Me_3Si)_3SiH$ (1.25 g, 5.0 mmol) and BEt_3 (0.13 g, 1.3 mmol) in toluene (85 ml) under an argon atmosphere at −78 °C for 6 h. The mixture was passed through a silica gel pad with AcOEt as an eluent. The usual work-up followed by chromatography on silica gel (hexane : CH_2Cl_2=2 : 8) afforded **12** (1.49 g, 93%) as colorless crystals, mp 160—161 °C (hexane–CH_2Cl_2), $[\alpha]_D^{27}$ +24.0° (*c*=1.02, $CHCl_3$). ^{1}H-NMR (500 MHz) δ: 1.14—1.18 (1H, m), 1.19 (3H, s), 1.22 (3H, s), 1.25 (3H, d, *J*=7.3 Hz), 1.60—1.65 (2H, m), 1.82—1.93 (3H, m), 2.36—2.41 (1H, m), 2.97—3.02 (1H, m), 3.23—3.27 (1H, m), 3.50 (3H, s), 3.66—3.71 (1H, m), 4.29 (1H, d, *J*=3.7 Hz), 4.35 (1H, dd, *J*=3.7, 4.3 Hz), 4.96 (1H, dt, *J*=1.8, 9.8 Hz), 5.47 (1H, s). *Anal.* Calcd for $C_{19}H_{27}NO_7$: C, 59.83; H, 7.13; N, 3.67. Found: C, 59.56; H, 6.91; N, 3.79. This was identical with the authentic species reported previously.[5]

3-[(1*S*,2*R*,4*R*)-2-(2-Methoxyethoxy)-7,7-dimethylbicyclo[2.2.1]heptane-1-carbonyl]-2-oxazolone (13b) Analogous to the preparation of 2-oxazolone derivatives **1a** and **c**, this was obtained in 74% yield as colorless crystals, mp 61—62 °C (hexane), $[\alpha]_D^{28}$ −51.1° (*c*=1.0, $CHCl_3$). ^{1}H-NMR (400 MHz) δ: 1.15 (3H, s), 1.17—1.26 (1H, m), 1.33 (3H, s), 1.69—1.92

(5H, m), 2.41—2.46 (1H, m), 3.26 (3H, s), 3.34—3.42 (3H, m), 3.54—3.59 (1H, m), 4.70 (1H, dd, J=3.7, 7.7 Hz), 6.79 (1H, d, J=2.2 Hz), 7.29 (1H, d, J=2.2 Hz). *Anal.* Calcd for $C_{16}H_{23}NO_5$: C, 62.12; H, 7.49; N, 4.53. Found: C, 62.03; H, 7.40; N, 4.52.

***trans*-3-Acetyl-4-chloro-5-trichloromethyl-2-oxazolidinone (14a)** A solution of 3-acetyl-2-oxazolone[12] (**12a**) (100 mg, 0.79 mmol) in CCl_4 (5 ml) was refluxed in the presence of $RuCl_2(PPh_3)_3$ (76 mg, 0.08 mmol) and $Tb(OTf)_3$ (5 mg, 0.008 mmol) for 1 h. The mixture was passed through a silica gel-pad with EtOAc as eluent. Evaporation of the eluate followed by chromatography on silica gel (hexane : CH_2Cl_2=1 : 1) afforded 3-acetyl-4-chloro-5-trichloromethyl-2-oxazolidinone (**13a**) (107 mg, 49%) as colorless crystals, mp 56 °C. ^{1}H-NMR (500 MHz) δ: 2.58 (3H, s), 5.14 (1H, d, J=1.2 Hz), 6.36 (1H, d, J=1.2 Hz). This was identical with the reported compound.[10]

***trans*-3-[(1*S*,2*R*,4*R*)-2-(2-Methoxyethoxy)-7,7-dimethylbicyclo[2.2.1]-heptane-1-yl]-4-chloro-5-trichloromethyl-2-oxazolidinone (14b)** In a manner similar to the above, this was obtained as a diastereomeric mixture (1 : 1) in 75% yield as colorless crystals. Diastereomer **a**: $[\alpha]_D^{27}$ +15.0° (c=1.02, $CHCl_3$). ^{1}H-NMR (500 MHz) δ: 1.12 (3H, s), 1.12—1.19 (1H, m), 1.34 (3H, m), 1.67—1.79 (4H, m), 1.93—1.97 (1H, m), 2.17—2.22 (1H, m), 3.34 (3H, s), 3.39—3.49 (1H, m), 3.58—3.62 (1H, m), 4.62 (1H, dd, J=3.7, 4.3 Hz), 5.11 (1H, d, J=1.2 Hz), 6.44 (1H, d, J=1.2 Hz). HR-MS (FAB) Calcd for $C_{17}H_{23}NO_5Cl_4Na$ (MNa^+): m/z 484.0272. Found: m/z 484.0228. Diastereomer **b**: $[\alpha]_D^{27}$ −25.2° (c=1.00, $CHCl_3$). ^{1}H-NMR (500 MHz) δ: 1.14 (3H, s), 1.15—1.28 (1H, m), 1.35 (3H, s), 1.68—1.93 (5H, m), 2.21—2.28 (1H, m), 3.26 (3H, s), 3.28—3.37 (3H, m), 3.41—3.46 (1H, m), 4.58 (1H, dd, J=3.7, 4.3 Hz), 5.11 (1H, d, J=1.2 Hz), 6.51 (1H, d, J=1.2 Hz). HR-MS (FAB) Calcd for $C_{17}H_{23}NO_5Cl_4Na$ (MNa^+): m/z 484.0213. Found: m/z 484.0228.

References and Notes

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