molecular free-radical cyclization reactions provides direct access to a fundamental free radical comparable in synthetic utility to its ionic counterparts—the acylium ion,[12] the acyl anion,[13,14] and its synthetic equivalents.[14] The continued exploration of the scope of the participation of acyl radicals in free-radical reactions and their application are in progress and will be described in due course.

Acknowledgment. We gratefully acknowledge the financial support of the National Institutes of Health (CA 42056) and the Alfred P. Sloan Foundation.

Supplementary Material Available: Full details of the preparation and characterization of phenyl selenoesters **1a,d-o** and comparative or full spectroscopic and physical characterization of the free-radical cyclization products **2d-p** (9 pages). Ordering information is given on any current masthead page.

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Vibrational Circular Dichroism and Absolute Configuration of 1-Substituted Indans[1]

Summary: Vibrational circular dichroism (VCD) spectra of (*R*)- and (*S*)-1-aminoindan, (*S*)-1-methylindan, and (*R*)-1-methylindan-*1-d* were measured in the 800–1600 cm^{-1} region. The VCD feature associated with the C*–H bending mode at about 1350 cm^{-1} is found to correlate with their absolute configurations. This correlation is in agreement with one found for (*S*)-methyloxirane and (*R*)-methylthiirane and reflects the potential importance of VCD measurements in stereochemical analysis of chiral rings systems.

Sir: Vibrational circular dichroism[2,3] (VCD) is a new spectroscopic technique developed in the last decade. As part of this activity, we have found that the C*–H bending vibration gives, for a series of related compounds, a VCD sign correlating with their absolute configurations.[4-7] To expand the general validity of such correlations, we have now measured[8] the VCD spectra for the first time in the 800–1600 cm^{-1} region of chiral 1-substituted indans.

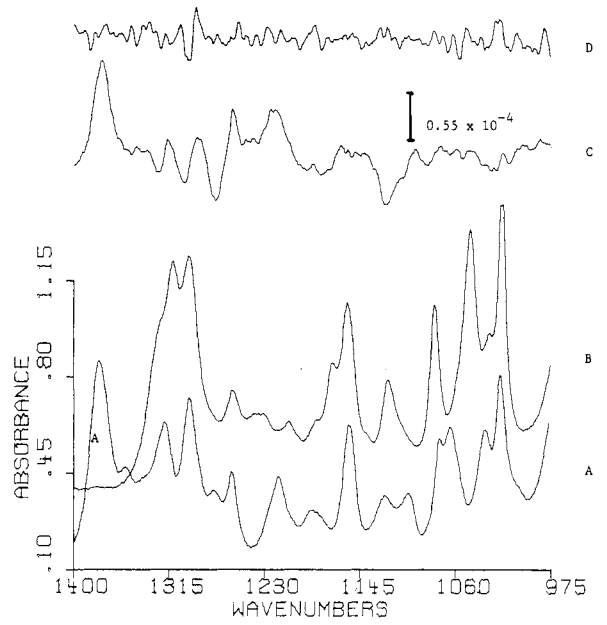
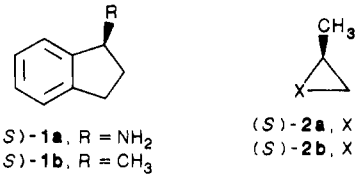


Figure 1. Fourier transform infrared absorption spectra of (*R*)-1-aminoindan [(*R*)-**1a**] (trace A) and (±)-1-aminoindan-*1-d* [(±)-**1a**-*1-d*] (trace B) and vibrational circular dichroism (VCD) spectrum of (*R*)-**1a** (trace C) for the neat liquids with a path lengths of ~60 μm. The absorption spectrum of (±)-**1a**-*1-d* (trace B) is moved upward in the figure for clarity. Trace D is the difference between two individual VCD observations for (*R*)-**1a** and provides an estimate of spectral reproducibility. The scale shown on the VCD spectrum is for $\Delta A = A_l - A_r$, the differential dichroic absorption for left versus right circularly polarized light.

(*R*)- and (*S*)-1-aminoindan[10,11] [(*R*)- and (*S*)-**1a**] were prepared by resolution of (±)-**1a** with *N*-acetyl-D- and -L-leucine,[13] while (±)-1-aminoindan-*1-d*[14] [(±)-**1a**-*1-d*] was obtained by reduction of 1-indanoxime with lithium aluminum deuteride. (±)- and (*S*)-1-Methylindane[15,16] (±)-



(*S*)-**1a**, R = NH_2
(*S*)-**1b**, R = CH_3

(*S*)-**2a**, X = O
(*S*)-**2b**, X = S

and (*S*)-**1b**] were synthesized by Friedal–Crafts cyclization of (±)- and (*S*)-3-phenylbutanoic acid to (±)- and (*S*)-3-methyl-1-indanone and subsequent Clemmensen reduction of these latter two ketones.[15] (±)- and (*R*)-1-methyl-

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(14) Greater than 95% deuterium incorporation as inferred by ^1H NMR measurement.

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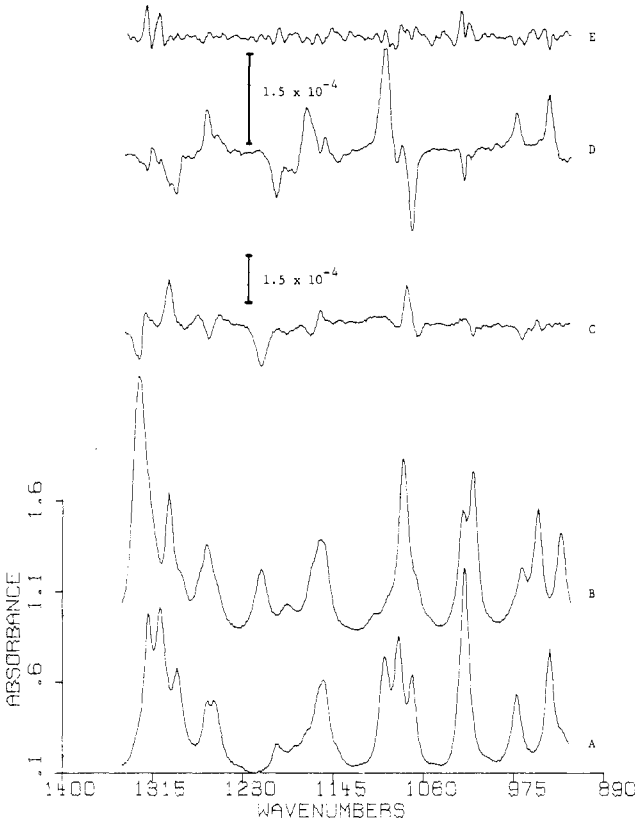

Figure 2. Fourier transform infrared absorption spectra of (*R*)-1-methylindan-*1-d* [(*R*)-**1b**-*1-d*] (trace A) and (*S*)-1-methylindan [(*S*)-**1b**] (trace B) and vibrational circular dichroism (VCD) spectra of (*S*)-**1b** (trace C) and (*R*)-**1b**-*1-d* (trace D) as the neat liquids with a path length of ~120 μm. The absorption spectrum of (*S*)-**1b** (trace B) is moved upward in the figure for clarity. Trace E is the difference between two individual VCD observations for (*R*)-**1b**-*1-d* and provides an estimate of spectral reproducibility. For the 1327 cm^{-1} band of (*S*)-**1b**, the infrared absorption and VCD measurements were also repeated at a shorter pathlength than that shown. The scale shown on the VCD spectra is for $\Delta A = A_l = A_r$, the differential dichoric absorption for left versus right circularly polarized light.

indan-*1-d*[14,16,17] [(±)- and (*R*)-**1b**-*1-d*] were prepared by a similar synthetic sequence except that (±)- and (*R*)-3-phenylbutanoic-*3-d* acid[18] were used for the initial cyclization step.

The VCD spectrum of (*R*)-**1a** (Figure 1) exhibits positive features associated with absorption bands at 1377, 1259, and 1219 cm^{-1} and negative VCD features at 1275, 1124, and 1024 cm^{-1}. The latter feature at 1024 cm^{-1} is weak but reproducible. For these same absorption bands, mirror image VCD features are shown by (*S*)-**1a**. The VCD sign associated with the 1297 and 1319 cm^{-1} bands are uncertain due to excessive noise. For (*S*)-**1b** (Figure 2), negative VCD features are associated with absorption bands at 1327, 1264, and 1213 cm^{-1} and positive features at 1300 and 1076 cm^{-1}. For (*R*)-**1b**-*1-d*, the absorption bands at 1292, 1197, and 1072 cm^{-1} have negative VCD while those at ~1260, 1170, 1097, 972, and 942 cm^{-1} have positive VCD.

Table I. Vibrational Circular Dichroism for Methine Hydrogen (or Deuterium) Bending Mode[a]

compd	VCD band position, cm^{-1}	VCD band $g^b \times 10^4$
(*R*)-**1a**	1377	+1.3
(*S*)-**1a**	1377	−1.0
(*S*)-**1b**	1327	−0.9
(*R*)-**1b**-*1-d*	1097	+2.5
(*S*)-**2a**[c]	1369	−1.0
(*R*)-**2b**[d]	1346	+4.3

[a] Neat liquids. [b] Dissymmetry factor that equals $\Delta A/A$, where A is the isotropic absorption and $\Delta A = A_l - A_r$. A_l and A_r are the absorbances of left and right circularly polarized light, respectively. These factors here are approximate estimates from the peak heights. [c] Data from ref 6. [d] Data from ref 7.

On the basis of a comparison of the absorption spectra of (±)-**1a** and (±)-**1a**-*1-d*, the absorption band at 1377 cm^{-1} is assigned to a C*–H bending motion in **1a** since this particular absorption band is not present in the spectrum of (±)-**1a**-*1-d*. A similar comparison using (±)-**1b** and (±)-**1b**-*1-d* indicates that the absorption bands at 1327 and 1213 cm^{-1} of **1b** contain contributions from the C*–H group. Because of the close proximity of the 1327 cm^{-1} absorption band for **1b** to the 1377 cm^{-1} absorption band for **1a**, we believe that the 1327 cm^{-1} band for **1b** corresponds to the 1377 cm^{-1} band of **1a**. The corresponding C*–D bending motion of (±)-**1b**-*1-d* is assigned to the 1097 cm^{-1} absorption band since at this position (±)-**1b** does not have an absorption band. The 1070 cm^{-1} band of (*R*)-**1b**-*1-d* appears to correspond to the 1080 cm^{-1} band of (*S*)-**1b** since the VCD signs associated with these bands are reversed, correlating with the reversal in their absolute configurations. With the C*–H and C*–D bending motion bands thus identified, the VCD associated with these bands are summarized in Table I. Also the VCD associated with the C*–H bending vibration in the spectra of (*S*)-methyloxirane[6] [(*S*)-**2a**] and (*R*)-methylthiirane[7] [(*R*)-**2b**] is included in Table I for comparison. It is seen then that there is a clear correlation between the absolute configurations and the sign of the VCD associated with the C*–H and C*–D bending vibrations: positive for the *R* configuration, negative for *S*. Thus VCD spectral studies appear to be well suited to determine the absolute configurations of related molecules.

The observed correlation (Table I) appears to have a different origin for (*S*)-**1a** and (*S*)-**1b** as compared to that for (*S*)-**2a** and (*S*)-**2b**. From the Raman spectra of (±)-**1b** and (±)-**1b**-*1-d* measured in our laboratories and that of (±)-**1b**-*2,2,3,3-d*$_4$ reported by Hug and co-workers,[19] the C*–H bending mode does not appear to have major contributions from the bending motions of C–H groups at the 2 and 3 positions. For 1-substituted phenylethanes, the C*–H bending mode is found[20] to be coupled to the aromatic C–H bending motion at the ortho position. If the same phenomenon is assumed for the indans considered here, a semiclassical theory[21] for the bending motions of the H–C*···C(Ar)–H segment can explain the observed VCD signs for (*S*)-**1a** and (*S*)-**1b**. However, for (*S*)-**2a** and (*S*)-**2b**, the C*–H bending mode was found[6,7] to be coupled to the bending motions of the methyl group. Despite these different origins for the VCD associated with the C*–H bending motion, the noted correlation is encouraging and reveals the usefulness of VCD in stereochemistry.

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Versatile Chiral Synthons for *vic*-Amino Alcohols. Facile Synthesis of (2*S*,3*R*)-3-Hydroxyglutamic Acid and (+)-Statine

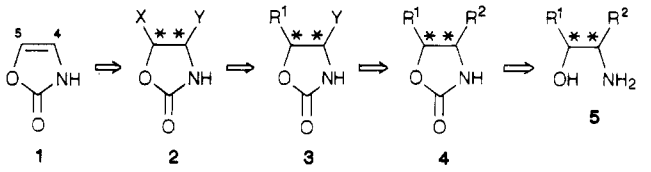
Summary: Functionalization of the 3-ketopinyl-2-oxazolone ring with a new reagent system, $Br_2/CH_3C(OCH_3)_3$/TMSOTf, results in highly diastereoselective formation of 5-bromo-4-methoxy-2-oxazolidinone derivatives **2**, which serve well as versatile chiral synthons for biologically significant *vic*-amino hydroxy compounds.

Sir: Our continuing work on the synthetic utility of the 2-oxazolone heterocycle has revealed its synthetic potential as an excellent leaving group in carboxy[1] and phosphoryl[2] activating processes. Such a leaving ability has led to the development of excellent condensing reagents for the formation of peptides,[1] β-lactams,[3] thio esters[4] and mixed phosphates.[2]

This paper describes another synthetic application of the simple heterocycle **1** as a building block for *vic*-amino alcohol structures, which are structural units found in a number of bioactive compounds such as amino sugar antibiotics, enzyme peptidic inhibitors and sympathomimetic amines.[5] The synthetic strategy shown in Scheme I offers versatile routes to a wide variety of *vic*-amino alcohols, in which the key step is functionalization of the olefinic moiety of the 2-oxazolone ring by regio- and stereodefined introductions of easily replaceable groups (X and Y), followed by stereospecific and stepwise substitutions with appropriate groups (R^1 and R^2). This methodology would be expected to result in predominant formation of threo derivatives, which could be readily converted to erythro configuration by inversion of the hydroxy group via oxazoline intermediates.[6a] This may be the most reliable and convenient route which can avoid serious side reactions such as β-elimination and epimerization, as evidenced by the mutual transformation of threonine and *allo*-threonine.[6b]

Bromo and methoxy groups were chosen as suitable functionalities for X and Y in compounds **2**, which have acetal-like structures sensitive to both nucleophilic and

Scheme I



Scheme II

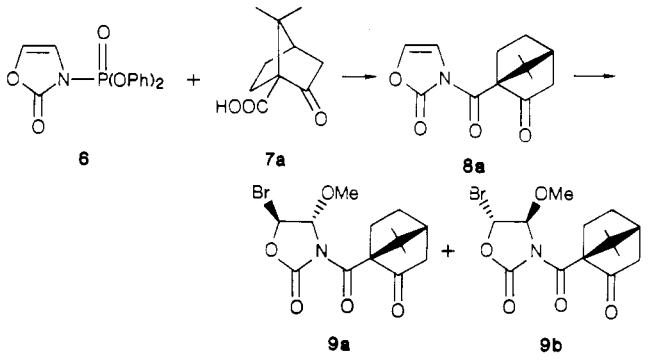


Table I. Diastereoselective Functionalization of (−)-3-Ketopinyl-2-oxazolone (8a)[a]

entry	conditions	yield,[b] %	ratio[c] 9a:9b
1	NBS, MeOH–dioxane, 20 °C	68 (0)	63:37
2	NBS, MeOH, −70 °C	54 (6)	57:43
3	Br_2, MeOH, 0 °C	47 (5)	68:32
4	Br_2, MeOH, −70 °C	75 (13)	81:19
5	Br_2, $MeC(OMe)_3$, −70 °C	58 (8)	90:10
6	Br_2, $MeC(OMe)_3$, TMSOTf, −70 °C	76 (10)	92:8
7	Br_2, $MeC(OMe)_3$, $ZnBr_2$, −70 °C	76 (11)	90:10
8	Br_2, $HC(OMe)_3$, TMSOTf, −70 °C	63 (6)	85:15
9	Br_2, $MeSi(OMe)_3$, TMSOTf, −70 °C	70 (14)	82:18
10	Br_2, $MeC(OMe)_3$, TMSOTf, −100 °C	78 (5)	95:5

[a] All reactions were run under the conditions given for 30 min (see text). [b] In isolated pure compounds. The numbers in parentheses refer to the yield of the 4,5-dibromo adducts. [c] Determined by ^1H NMR (400 MHz) analysis.[11]

radical species. The chiral synthons **2** are obtained in a diastereoselective manner from optically active 3-acyl-2-oxazolones, which are readily available on treatment of diphenyl (2-oxo-3-oxazolinyl)phosphonate (DPPOx)[1] (**6**) with a wide variety of chiral carboxylic acids. Among the chiral auxiliaries examined, including α-amino acid derivatives, (+)- and (−)-ketopinic acids (2-oxo-7,7-dimethylbicyclo[2.2.1]heptane-1-carboxylic acids)[7] (**7a** and **7b**) (Scheme II) were found to be the best choice owing to the availability of both enantiomers, the high diastereoselectivity attained, and the ease of separation of the diastereoisomers.

Thus, treatment of (−)-3-ketopinyl-2-oxazolone (**8a**) (mp 129 °C, $[\alpha]^{20}_D$ −49.2° ($CHCl_3$)) derived from (+)-ketopinic acid (**7a**) with *N*-bromosuccinimide (NBS) or bromine in methanol resulted in highly regioselective formation of *trans*-5-bromo-4-methoxy-2-oxazolidinone adducts (**9a** and **9b**) in rather low diastereoselectivity (up to 62% de).[8] On

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(6) (a) Fry, E. M. *J. Org. Chem.* **1949**, *14*, 887. (b) Treatment of *N*-benzoyl-L-threonine methyl ester with thionyl chloride in ether followed by acidic hydrolysis gave L-*allo*-threonine in 67% yield without any detectable threo configurations. Similarly *N*-benzoyl-L-*allo*-threonine gave back optically pure L-threonine in 83% yield.
(7) The acids **7a,b** were readily prepared in 40% yields by permanganate oxidation of commercially available (1*S*)- and (1*R*)-10-camphorsulfonic acids, according to the literature method: Bartlett, P. D.; Knox, L. H. *Org. Synth.* **1965**, *45*, 14, 55.
(8) Conventional reagent systems for functionalization of alkenes such as NBS/AcOH, PhSeCl/MeOH, and PhSeBr/MeOH similarly reacted with compounds **8a,b** to give good yields of regioselective adducts, but the diastereoselectivity never exceeded 50% de under a wide scope of conditions. We thank F. Ogata of Kumamoto University for her skillful technical assistance in this part of studies.

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