

into amine-HOAc gives clean acylation and *not* alkylation of the amine.¹⁵

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References and Notes

- (1) Presented in part at the 167th National Meeting of the American Chemical Society, Los Angeles, Calif., April 1-5, 1974; Abstract ORGN 98.
- (2) B. Robinson, *Chem. Rev.*, **69**, 785 (1969).
- (3) (a) R. J. Sundberg, "The Chemistry of Indoles," Academic Press, New York, N.Y., 1970, pp 3-11; (b) V. A. Budylin, A. N. Kost, and E. D. Matveeva, *Khim. Geterotsikl. Soedin.*, **55** (1972); *Chem. Abstr.*, **77**, 34240 (1972).
- (4) We find that both indole and *N*-ethylindole undergo deuterium exchange at the 3-position (nmr) with DOAc at 20° to the extent of ~40 and ~50% (mass spectrometry), respectively, after 2 hr.
- (5) J. A. Marshall and W. S. Johnson, *J. Org. Chem.*, **28**, 421 (1963); see also C. Djerassi, H. J. Monteiro, A. Walsler, and L. J. Durham, *J. Amer. Chem. Soc.*, **88**, 1792 (1966).
- (6) R. F. Borch, M. D. Bernstein, and H. D. Durst, *J. Amer. Chem. Soc.*, **93**, 2897 (1971).
- (7) Although diborane-THF reduces indoles to indolines, it does not reduce *N*-alkylindoles: S. A. Monti and R. R. Schmidt, *Tetrahedron*, **27**, 3331 (1971).
- (8) After short reaction periods the *N* unsubstituted indoline can usually be detected (tlc) in the reaction mixture.
- (9) We have also been able to alkylate several aliphatic amines with NaBH₄/RCO₂H (e.g., cyclohexylamine, benzylamine, dibenzylamine, piperidine, pyrrolidine) as part of a study which will be reported separately.
- (10) For example, acetophenone is only 60% reduced by NaBH₄-HOAc at 20° after 2 days, whereas the reduction is very rapid in alcohol solution.
- (11) (a) W. S. Emerson, *Org. React.*, **4**, 174 (1948); (b) J. C. Stowell and S. J. Padegimas, *Synthesis*, 127 (1974); (c) M. L. Moore, *Org. React.*, **5**, 301 (1949); (d) S. H. Pine and B. L. Sanchez, *J. Org. Chem.*, **36**, 829 (1969); (e) R. F. Borch and A. I. Hassid, *ibid.*, **37**, 1673 (1972); (f) K. A. Schellenberg, *ibid.*, **28**, 3259 (1963); (g) R. A. Crochet and C. D. Blanton, *Synthesis*, 55 (1974); (h) Y. Watanabe, M. Yamashita, T. Mitsudo, M. Tanaka, and Y. Takegami, *Tetrahedron Lett.*, 1879 (1974).
- (12) We have isolated acetaldehyde as its 2,4-DNP derivative from the evolved gases in the reaction of NaBH₄-HOAc at 20°. The evolved gases do not themselves alkylate amines in HOAc nor do they reduce carboxylic acids in THF, indicating the absence of diborane in the gaseous effluent.
- (13) T. Reetz, *J. Amer. Chem. Soc.*, **82**, 5039 (1960), reports the isolation of NaBH₃OAc from NaBH₄-HOAc-THF.
- (14) NaBH₃CN in acidic media also reduces iminium ions faster than their carbonyl precursors.^{6,11e}
- (15) J. T. Eaton and G. W. Gribble, unpublished results. We believe that this reaction occurs with the triacyloxyborane or oxybis(diacyloxyborane).¹⁶
- (16) H. Steinberg, "Organoboron Chemistry," Vol. 1, Interscience, New York, N.Y., 1964, Chapter 8.
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Stereochemistry of the Oxythallation of 1,2-Cyclononadiene

Sir:

Although a great many studies on the mechanism of the oxymercuration reaction have been disclosed,¹ there have been comparatively few studies on the analogous oxythallation reaction. The oxythallation reaction with alkenes has been shown to have many similarities to the oxymercuration reaction.² It has been suggested that rearrangement of a π complex to a σ -bonded oxythallation adduct is rate limiting.^{2a} With Tl(III) acetate in aqueous acetic acid, the reaction was shown to be first order in alkene and thallic ion.^{2a}

A correlation of the rate of oxidation of alkenes by Tl³⁺ with Brown's σ^+ values ($\rho^+ = 2.2$)^{2b} and Taft's σ^* values ($\rho^* = -3.2$)^{2c} suggests that there is a high degree of positive charge delocalization in the transition state. In the latter study no kinetic evidence for a thallium ion intermediate was found.

The most notable difference between the two oxythallation reactions is the lack of solvolytic stability of the carbon-thallium bond resulting in dethallation of the organothallium intermediates. In fact, only a few oxythallation adducts of olefins have been isolated. The oxythallation products of styrene³ and isobutylene⁴ suggested that the reaction proceeds in the Markownikov sense. Because of the ease of heterolysis of the C-Tl bond, conclusive evidence for the stereochemistry of this electrophilic addition reaction is still lacking. Norbornene and norbornadiene have been shown to afford *exo cis* adducts on acetoxythallation.⁵ An anti mode of addition to 4-*tert*-butylcyclohexene has been inferred on the basis of indirect evidence.⁶

We chose 1,2-cyclononadiene (**1**)⁷ as a model compound to elucidate the stereochemistry of oxythallation since the vinyl thallium adducts⁸ are readily isolated and characterized. Solvolysis of the C-Tl bond in **4** would afford a relatively unstable vinyl cation. This study also affords a direct comparison with the oxymercuration of **1** which has been thoroughly investigated.^{9,10} The mechanism of the oxythallation of **1** is of particular interest since the oxymercuration of this cyclic allene proceeds by an anti mechanism¹⁰ while the acetoxyplumbation occurs in a *syn* fashion.¹⁰ We now report that oxythallation of optically active (**1**)⁷ affords optically active products by an anti addition.

Treatment of **1** with an equivalent of thallic acetate in glacial acetic acid afforded the oxythallation adduct **4a** (84%).¹¹ Reduction of **4a** with basic NaBH₄ afforded *cis*-3-acetoxycyclononene (**5a**) (61%) that was identical in every respect to an authentic sample prepared by the acetoxymercuration-demercuration¹⁰ of **1**. Acetoxythallation of optically active **1**, $[\alpha]^{25D} -15.6^\circ$ afforded **4a** that had $[\alpha]^{25D} ca. -0.5^\circ$ which on reduction with NaBH₄ afforded **5a**, $[\alpha]^{25D} +0.6^\circ$. The reaction of **1** with Tl(OAc)₃ in methanol also afforded a stable methoxythallation adduct **4b**¹² (76%). Demetalation with NaBH₄ gave *cis*-3-methoxycyclononene (**5b**)¹⁰ (72%). The position of the diacetatothallium moiety was further established by treatment of **4b** with Br₂ in CCl₄ affording *cis*-2-bromo-3-methoxycyclononene (**6**)¹⁰ (82%). Methoxy- and ethoxythallation-dethallation of optically active **1** also afforded optically active allylic ethers (*S*)-(+)-**5** (Table I).

The isolation of an optically active product from these reactions establishes that the planar allylic cation **3** cannot be the sole precursor to **4**. Thus, bridging due to π -complex formation is sufficient to prevent complete carbon-carbon bond rotation affording **3**. The oxythallation of (*S*)-(-)-1,2-cyclononadiene^{10,13} to afford (*S*)-(+)-3-acetoxy- and alkoxy cyclononene¹⁴ must proceed by an anti mode of addition. Our data also show that the relative stereospecificity of the oxythallation reaction is comparable to that of the anti oxymercuration reaction but is considerably less than that observed for the *syn*-acetoxyplumbation of **1**.¹⁵ The optical purity of **5b** and **5c** was further reduced when Tl(NO₃)₃ was used (Table I).¹⁶

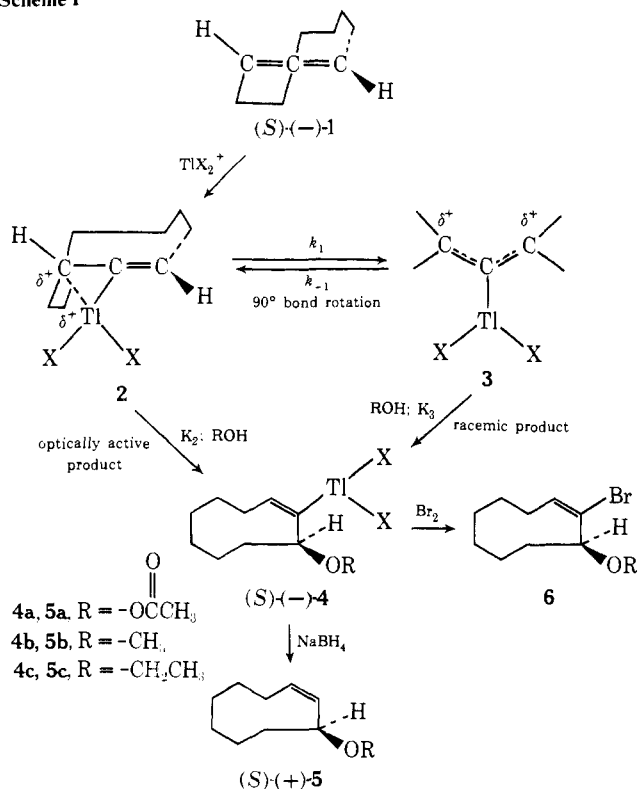
We have also established that the oxythallation adducts **4b** and **4c** (X = OAc or NO₃) are not formed reversibly from either **2** or **3**. Thus, treatment of **4b** in EtOH solvent or **4c** in CH₃OH solvent in the presence of an equivalent of HNO₃ did not result in alkoxy exchange. Similarly, attempts to exchange alkenes by treatment of **4a** (X = NO₃) with 1-octene did not effect an alkene exchange. In contrast, reaction of the methoxymercuration of 1-octene (X =

Table I. Oxymercuration of 1,2-Cyclononadiene

X	Solvent	Catalyst	Time, hr ^a	$[\alpha]^{25D}^b$
		TlX ₃		
OAc	HOAc	BF ₃ · Et ₂ O	20	0.9
OAc	HOAc	BF ₃ · Et ₂ O	72	0.5
OAc	CH ₃ OH	BF ₃ · Et ₂ O	20	2.8
OAc	CH ₃ OH	BF ₃ · Et ₂ O	72	3.3
OAc	CH ₃ CH ₂ OH	BF ₃ · Et ₂ O	20	4.0
OAc	CH ₃ CH ₂ OH	BF ₃ · Et ₂ O		
NO ₃	CH ₃ OH		3	2.2
NO ₃	CH ₃ OH		12	1.2
NO ₃	CH ₃ CH ₂ OH		3	2.7
NO ₃	CH ₃ CH ₂ OH		20	1.1
		HgX ₂		
OAc	HOAc		1	1.7 ^c
OAc	CH ₃ CH ₂ OH	BF ₃ · Et ₂ O	5	3.5 ^c
		PbX ₄		
OAc	HOAc			14.4 ^d

^a All reactions were carried out at 25°. ^b Rotation on **5a-c**. The values have been adjusted to correspond to a rotation of -22.7° for the starting allene **1**. ^c Values taken from ref 10 and adjusted to a rotation for **1** of -22.7°. ^d The initial product was 3-acetoxycyclononyne which was reduced to *cis*-3-acetoxycyclononyne.¹⁰

Scheme I



NO₃) with **1** in CH₃OH resulted in complete liberation of 1-octene and the quantitative formation of **5b**.¹⁷

Our results provide additional evidence that the mechanism of the oxythallation reaction closely resembles that of the oxymercuration reaction where we have provided substantial evidence^{1b,9,10} for a π -complex intermediate. Although our data do not provide direct evidence for the intermediacy of a thallium ion, we wish to propose the mechanism outlined in Scheme I involving formation of the thallium ion **2** which may be in equilibrium with the planar resonance stabilized cation **3**. The observation that the rate of reaction of **1** with Tl(OAc)₃ is markedly increased by inclusion of the Lewis acid catalyst BF₃ · Et₂O is also consistent with kinetic evidence^{2a} which has established that

Tl(OAc)₂⁺ is the major electrophilic species in reactions with alkenes. Finally, these data provide the first direct evidence for the stereochemistry of addition in an oxythallation reaction with an allene.

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- Recrystallization of **4a** from CH₂Cl₂:pentane (1:9) afforded a white solid that had mp 170–171.5 dec and a satisfactory carbon and hydrogen analysis. Mass spectral analysis supported the structural assignment with M - OAc (445) and M - 2 (OAc) (*m/e* 386 and 121). The correct isotopic pattern for thallium was observed with *m/e* 205 and 203 in a 100:41 ratio; nmr (CDCl₃) δ 2.07 (S, 6 H) 2.17 (S, 3 H).
- Recrystallization of **4b** from CH₂Cl₂:Pentane 1:9 afforded a white solid mp 150–154 dec that gave satisfactory carbon and hydrogen analysis. Mass spectral analysis supported the structural assignment with M - (OAc) *m/e* 417 and 415. The correct isotopic pattern was observed with *m/e* 205 and 203 in a 100:42 ratio; nmr (CDCl₃) δ 2.07 (S, 6 H), 2.8 (m, 2.8), 4.95 (m, 1 H). The 3-ethoxy thallium adduct **4c**, mp 128–130 dec, was too unstable to further characterize. However, NaBH₄ reduction of the crude reaction mixture afforded the known compound **5c**. The initial adducts **4a-c** must have the *cis* configuration about the double bond since attack from the inside of the ring is sterically precluded.^{9b}
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- We have previously established that dextrorotatory **5a-c** all have the *S* configuration.¹⁰
- It is also of interest to note that the major product of the oxyplumbation of **1** was 3-acetoxycyclononyne. This difference in product composition reflects the stability of the carbon-metal bond which decreases in the order C-Hg > C-Tl > C-Pb.
- The relative stereospecificity of the ethoxymercuration of **1** was also shown to be reduced when highly ionic mercuric salts were utilized in the reaction. The reduction in optical purity of **5** is due in part to the fact that **1** is completely racemized within 3 hr in CH₃OH in the presence of **4** (X = NO₃). Control experiments have established that **1** is optically stable in the presence of the thallic acetate adduct **4** (X = OAc) and in the presence of an equivalent of HNO₃ in CH₃OH. These data suggest that the dinitratothallium adduct is electrophilic enough to racemize the allene.
- Both alkoxy and alkene exchange reactions with oxymercurials have been reported.¹⁸
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Structure and Absolute Configuration of Delphisine. A New Diterpene Alkaloid from *Delphinium staphisagria*

Sir:

Delphisine, C₂₈H₄₃NO₈, mp 121–122°, $[\alpha]^{26D} +7.1^\circ$ (*c* 4.00, ethanol), has been isolated from the mother liquors