bridge of 9 and the nitrogen bridge of 11 function primarily as slightly electronreceptive substituents. In connection with substituent effects, the oxidation curve of 19 was of interest.

Two half-wave potentials were observed. The lower wave showed $E_{1/2}$ at 1.00 V while the second appeared at $E_{1/2} = 1.87$ V. Two different oxidative processes are indicated. It is interesting to speculate as to whether these two waves reflect the oxidation of the two different cyclopropyl moieties.16

In summary, we have provided a quantitative measure of the ease of oxidation of highly strained poly cyclic compounds. The effect of substituents has been evaluated. We are continuing to study both the mechanistic detail and products of these facile oxidations.

Acknowledgment. We are indebted to the National Science Foundation and the General Electric Foundation for a grant to P.G.G. which supported this investigation.

References and Notes


(8) Simple alkyl-substituted cyclopropanes show half-wave oxidation potentials vs. SCE of 2.0-2.5 V. Unstrained saturated hydrocarbons exhibit half-wave oxidation potentials in excess of 2.5 V.


(13) A detailed study of the relationship of oxidizability to ionization potential of strained polyyclic hydrocarbons has confirmed this point: P. G. Gassman and R. Yamaguchi, submitted for publication.


(15) The second wave which was observed for both 11 and 12 was attributed to the aryl sulfonamide moiety. Little change occurred in the oxidation in changing from 11 to 12.

(16) Simple alkyl-substituted cyclopropanes show half-wave oxidation potentials vs. SCE of 2.0-2.5 V. Unstrained saturated hydrocarbons exhibit half-wave oxidation potentials in excess of 2.5 V.

A New Synthesis of Amides and Macrocyclic Lactams

Summary: New and general routes to amides and lactams of up to 32 atoms in circumference are described based on boron-containing active esters.

Sirs: We wish to report that carboxylic acids react rapidly and smoothly with catecholborane to afford 2-acetyl, 3,2,2-benzodioxaborolanes (1c). As one aspect of a general program to prepare clinically interesting maytansinoids and ansamycins,1 we herein document the use of this mild reaction as the essential carboxyl-activation step for the synthesis of amides and macrocyclic lactams.2

Simple acyloxyboranes such as 1a and 1b react with amines to furnish amides in moderate yield, but uniformly low conversion.3 Mechanistic studies by Pelzer in 1970 revealed that the leaving groups 2a,b ejected in this process fragment to liberate 1 equiv of ROH which competitively destroys the active intermediate by attack at the boron atom of $^1$.

$$RO_{18}BR_2 = + R\text{NH}_2 \rightarrow R\text{CONHR}_2 + HOBR_2$$

We reasoned that acyloxyborane 1e might circumvent these difficulties, since its leaving group, 2-bromo-3,2,2-benzodioxaborolane, ought to resist disproportionation. Moreover, any breakdown of 2c would form a relatively nonnucleophilic phenol still attached to boron. We further expected the aromatic ring's electron-withdrawing character to enhance the reactivity of the active ester. Modulation of this effect through substitution of polar groups on the aren could enable a high degree of control in designing preparatively useful reagents.

Catecholborane (3)5 is available from Aldrich Chemical Company6 and converts carboxylic acids (THF, room temperature, 30-60 min) to the corresponding acyloxybenzodioxaborolanes (IR $\nu_{max}$ 1740 cm$^{-1}$) free of anhydride by-product. At ambient temperatures catecholborane is ideally suited for the C-activation of complex substrates, since it is inert toward alkyl and aryl halides, alkenes, alkynes, amides, anhydrides, disulfides, esters, nitriles, nitro compounds, sulfides, and sulfones.7 Subsequent addition of an amine to 1c rapidly forms the amide in greatly improved yield (Table 1). Even optically active acids such as N-benzyl-L-leucine can be coupled with no measurable loss (<2%) of enantiomeric purity.

<table>
<thead>
<tr>
<th>amine</th>
<th>product</th>
<th>% yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>benzylamine</td>
<td>C$_6$H$_5$CONHCH$_2$Ph</td>
<td>92</td>
</tr>
<tr>
<td>pyrrolidine</td>
<td>C$_6$H$_5$CONH</td>
<td>85</td>
</tr>
<tr>
<td>butylamine</td>
<td>C$_6$H$_5$CONHCH$_2$CH$_2$CH$_3$</td>
<td>84</td>
</tr>
<tr>
<td>morpholine</td>
<td>C$_6$H$_5$CONH</td>
<td>74</td>
</tr>
<tr>
<td>benzylmethylamine</td>
<td>C$_6$H$_5$CON(CH$_2$CH$_3$)</td>
<td>74</td>
</tr>
<tr>
<td>glycine ethyl ester</td>
<td>C$_6$H$_5$CONHCH$_2$CO$_2$CH$_3$</td>
<td>68</td>
</tr>
</tbody>
</table>

* Obtained by inverse addition of the acyloxyborane to the amine (2 equiv) in THF at -78 °C. a Product identity was established by comparison with authentic samples. In some cases filtration through a short column of silica gel was necessary to obtain pure product.

---

Table I. Formation of Amides from Nonanoic Acid Using Catecholborane

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Received July 5, 1978
Samples. Dimers were fully characterized by IK, NMK, and mass acid and benzylamine in THF simulates lactamization con-
somewhat superior coupling reagent.

of catecholborane to a homogeneous 1:1 mixture of nonanoic acid and small amounts of pyridine (2-3 equiv) accelerate them,
zylamide in 85% yield. These "in situ" couplings are general
conditions and produces the desired nonanoic acid N-ben-

Our interest in closing rings at the site of an amide bond
requires a reagent that is capable of carboxyl activation with-
out interference by a basic amino group. The direct addition
catecholborane to a homogenous 1:1 mixture of nonanoic acid
benzylamine in THF simulates lactamization condi-

Our contrast with similar studies on the formation of
macrocyclic lactones10 and may reflect more stringent
gometric demands imposed on the ring and on the ring-

S-Oxides of Tetrathiafulvalenes

Summary: The first tetrathiafulvalene S-oxides have been
synthesized. These include the mono S-oxides of tetrathia-
fulvalene, dibenzotetrafialfulvalene, and tetraakis(carbomethoxy)tetrathiafulvalene. The polargraphic properties
of these novel sulfoxides are described.

Sir: Tetrathiafulvalene (1, TTF) and its derivatives have been
the subject of intensive chemical and physical study in recent
years, due to the fact that many compounds of this group can
form crystalline, electrically conducting charge-transfer
salts.1,2 This property is dependent upon the relative ease with
which the TTF system can be oxidized by a variety of means
among others including mercury(II) ions, diphenylamine,
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Acknowledgment is made to the Donors of the Petroleum
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Society, for support of this research. We also thank the Na-
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