INHIBITORS OF TRANSPETIDASE

New β-lactams of the general structure:

wherein R represents H or an acyl moiety known from the penicillin or cephalosporin art, R' is hydrogen, lower alkoxy, lower alkoxyalkyl, lower alkyl, phenylthio or lower alkylmercapto, R'' is lower alkyl, the broken line represents an optional double bond, and acyloxyethyl esters thereof. All compounds are effective antibacterials.
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Detailed Description of the Invention

Many cephalosporin and penicillin derivatives have been synthesized in the past 30 years and many of them have found their way into the arsenal of anti-biotic drugs with a broad spectrum of antibacterial activity. However, the bacteria combatted in this fashion have learned to adapt to the attacks by these antibiotics and have formed strains resistant to the antibiotics. It is therefore of great importance to find new antibiotics to which resistance has not yet developed in infectious bacteria. Basic changes in the structure of known antibiotics are particularly well suited to overcome the bacterial resistance to known therapeutics.

The present invention is thus concerned with new antibacterials, compounds of the formula:

\[
\begin{align*}
\text{R-NH} & \quad \text{R'} \\
\text{COOH} & \quad \text{I}
\end{align*}
\]

wherein R represents H or an acyl moiety known from the penicillin or cephalosporin art, R' is hydrogen, loweralkoxy, loweralkoxyalkyl, loweralkyl, phenylmercapt or loweralkylmercapto, R'' is loweralkyl, the broken line represents an optional double bond, and acyloxymethyl esters thereof. Acyl groups found particularly useful are phenacetyl, phenoxyacetyl, cyanoacetyl, thienylacetyl, p-hydroxyphenylmalonoyl, α-aminophenacetyl, α-sulfophenacetyl, N-benzoylglycylphenylglycyl, a moiety of the formula

\[
\begin{align*}
\text{COOH} & \quad \text{NH}_2-\text{CH(CH}_2)_3\text{CO}-, \\
\text{CO}-\text{NH}-\text{CH}-\text{CO}-, \\
\text{CO}-\text{NH}-\text{CH}-\text{CO}-, \\
\text{Ph} & \quad \text{Ph}
\end{align*}
\]

30
(ROCH₂CH₂)₂N-SO₂\text{Ph}

\[
\text{NH}_2\text{-S-}\text{C-CO-}
\]

\text{wherein Y is 0 or NOR}^{\text{N}}.

or a mercaptoacetyl of the formula \( R^o \text{SCH}_2 \text{CO-} \) wherein \( R^o \) is phenyl, 4-pyridyl, 2-chloro-2-butene, allyl or n-butyl.

The compounds wherein \( R \neq H \) and \( R' \) is phenyl-mercaptop or alkoxyl and the 2,3-positions are connected by a single bond are less active than the corresponding unsaturated compounds. All the compounds, however, show activity against numerous infectious and other bacteria, as can easily be demonstrated on cultures of pseudomonas strains at concentrations of 1 to 500 ppm. The new compounds will completely prevent any further growth of \text{Staph. aureus} and in the higher concentration ranges mentioned will produce a bactericidal effect.

The above compounds are prepared by the following scheme:

\text{II} \quad \xrightarrow{\text{NaH, DMF}} \quad \text{II} \quad \xrightarrow{\text{R'' Cl}} \quad \text{III} \quad \xrightarrow{\text{1) NH}_2\text{NH}_2 \quad \text{2) HCl \quad 3) NEt}_3} \quad \text{IV} \quad \xrightarrow{\text{N}_3\text{CH}_2\text{COCl \quad NEt}_3} \quad \text{V} \quad \xrightarrow{[H]} \quad \text{VI}
\[ \begin{align*}
R & = \text{varies} \\
R' & = \text{varies} \\
I & = \begin{cases} 
R' & = \text{PhS, saturated} \\
R'' & = \text{loweralkyl} 
\end{cases} \\
R' & = H, \Delta^2 \\
R'' & = \text{loweralkyl}
\end{align*} \]

In order to illustrate the manufacture of the compounds of this invention, reference is made to the following examples which, however, are not to be interpreted as limitations of the scope of this invention. In all instances, microanalyses are used to verify the identity of the expected compounds.

**Example 1**

a) To a cold solution of 13.1 g of dibenzyl phthalimidalonate in 300 ml dry dimethoxyethane (DME) is slowly added 1.47 g of a 50% sodium hydride-in-oil suspension. After stirring at room temperature for 30 min., 16.2 g 1-chloro-1-phenylthio-2,2-dimethyl-3-ethylenedioxy-propane is added and the mixture is refluxed 30 hrs. and then filtered. The filtrate is condensed under reduced pressure to a volume of 50 ml. This concentrate is added to 250 ml of ice-cold water and extracted with three 200 ml portions of \( \text{CH}_2\text{Cl}_2 \). The organic phase is dried over MgSO\(_4\), evaporated, and the obtained oil is chromatographed over florisil to produce III (\( R'' = \text{CH}_3 \)) in good yield.

b) A solution of 6.6 g of the dibenzylester acetal III in 30 ml THF is refluxed with 500 mg hydrazine hydrate for 90 min. The resulting mixture is poured into ice-cold water and extracted with \( \text{CH}_2\text{Cl}_2 \). The original phase is purified over an alumina column to give the substituted malonic ester III wherein the phthalimino group is replaced by the amino group and \( R'' \) is methyl. A solution of 5.3 g of this aminoester in 30 ml THF is then refluxed for 2 hrs. with 30 ml aqueous 0.5 N HCl. After evaporating the mixture under reduced pressure and placing the residue in 60 ml \( \text{CH}_2\text{Cl}_2 \); 1.5 ml of triethylamine and 50 g anhydrous MgSO\(_4\) are added and the mixture is allowed to stand overnight. Upon subsequent filtration, washing with cold water and evaporation, 4.5 g of the cyclic diester
IV is obtained as an oil in excellent yield.

c) A solution of 9.5 g IV in 200 ml dry CH₂Cl₂ is cooled to -10°C in an ice-methanol bath before 2.8 ml of triethylamine is added, followed by a dropwise addition of a solution of 2.4 g azidoacetyl chloride in 35 ml CH₂Cl₂ over a period of 15 min. The mixture is then stirred another 15 min. and washed with water. Work-up in the fashion of (a) above produces a moderately high yield of V (R¹=Me).

d) To a solution of 5.6 g of the azidoester V in 100 ml glacial acetic acid, 500 mg 10% Pd-on-carbon is added and the mixture is hydrogenated at room temperature for 1 hr., at which time the mixture is filtered and the filtrate is heated for 3 hrs. at 60°C. Solvent removal produces a moderately high yield of 6-amino-1,1-dimethyl-2-phenylthio-4-azabicyclo[2,0,3]heptan-5-one-3-carboxylic acid (VI; R¹=Me).

Example 2

a) To an ice-cold solution of 3 g of compound VI of Example 1 and 1.68 g NaHCO₃ in 50 ml of water is added 2.5 g of N-(phenoxy-methylcarbonyloxy)-succinimide in 50 ml dimethoxyethane. The mixture is stirred for 3 hrs. and the volume is then reduced to about 10 ml under reduced pressure. Water is added and the mixture is extracted with CH₂Cl₂. The aqueous phase is acidified with HCl to pH 6 which produces 1,1-dimethyl-6-phenoxy-acetylamino-2-phenylthio-4-azabicyclo[2,0,3]heptan-5-one-3-carboxylic acid in excellent yield.

b) A solution of 4.4 g of this material in 100 ml CH₂Cl₂ is stirred with 1.7 g m-chloroperbenzoic acid for 16 hrs., before adding 2.2 g of chlorotrimethylsilane and 3 g of triethylamine and refluxing this mixture for 5 hrs. The reaction product is diluted with water and extracted with ether. The organic phase is dried over MgSO₄ and evaporated to produce a solid residue. Repeated precipitation of this crude material from ether/pentane produces pure 1,1-dimethyl-6-phenoxyacetylamino-4-azabicyclo[2,0,3]-2-heptan-5-one-3-carboxylic acid in a moderate yield.
Example 3

By following the preceding Example but substituting the above succinimide with 4.1 g of 1-phenyl-1-(4-ethyl-2,3-dioxo-1-piperazinyl)carboxamidoacetoxyc succimide, one obtains I wherein R is

![Chemical Structure]

R' is phenylthio, R" is methyl and the 5-membered ring is saturated. Further following Example 2 produces moderate yields of I wherein R and R" have the above meaning, R' is H and the 2-3 positions are connected by a double bond.

Example 4

In the described fashion of Example 2, using 5.9 g of

![Chemical Structure]

in place of the mentioned succinimide, the correspondingly N-substituted derivatives I are obtained: in the first step, R' is Ph-S- and the ring is saturated; in the second step, R' becomes H while introducing ring unsaturation (R and R" being as described) with R" being methyl in both instances.

Example 5

1.36 of sulfophenylacetyl chloride in 10 ml ether is dropwise added to a stirred solution of 1.5 g of VI from Example 1 in 50 ml of water containing 200 mg NaOH and 850 mg NaHCO₃ at 0-5°C. After 30 min., the organic layer is
removed and the pH of the aqueous phase is adjusted to 6, followed by lyophylization of the acidified solution. Crystallization from water-pyridine-acetone produces the N-sulfophenylacetyl derivatives of VI (R⁰ and R⁰ as before, no double bond) as colorless needles. Proceeding in the fashion shown in Example 2, compound I is obtained (R=NaO₃S-CHPh—CO—, R'=H, R''=Me with double bond 2-3) in moderate yield.

Example 6
An ice-cold solution of 2.8 g of the compound of Example 1(d) is mixed with 1.68 g NaHCO₃ in 50 ml of water. This mixture is stirred for 3 hrs. with 4 g of the succinimide ester of benzoylglycyl-phenylglycine in 50 ml of dimethoxyethane. The solvent is stripped to about 10 ml under reduced pressure and water is added followed by extraction with CH₂Cl₂. The aqueous phase is acidified with HCl to pH 3, forming a precipitate identified as 6-(N-benzoylglycylphenylglycylamino)-1,1-dimethyl-2-phenylthio-4-azabicyclo[2,0,3]heptan-5-one-3-carboxylic acid.

By treating this material as in Example 2(b), the compound of structure I is obtained wherein R is N-benzoylglycyl-phenylglycyl, R'=H, R''=Me and the 5-membered ring is unsaturated in good yield.

Example 7
By replacing the succinimide used in Example 6 with the succinimide of the acid of structure

\[
\text{NH}_2\begin{array}{c}
\text{N} \\
\text{S} \\
\text{N-OME}
\end{array}
\text{CO-OH}
\]

VII

wherein the amino group is protected by the triphenylmethyl group, one obtains initially the compound of I (R is the acyl group of VII, R' is phenylmercapto and R'' is Me) and after treatment with m-chlorobenzoic acid, the 2-substituent
is removed while a double bond is introduced simultaneously into the 5-membered ring.

Example 8

a) To 4.4 g of the product of Example 2(a) in 40 ml of DMF is added 480 mg sodium hydride as a 50% oil suspension and after 15 min. of stirring, 1.7 g benzylbromide together with a catalytic amount of tetrabutylammonium iodide are added. The mixture is stirred for 4 hrs. and poured into water. Extraction of the aqueous mixture with CH₂Cl₂, drying the extract with MgSO₄ and evaporation produces an oil which is purified on neutral alumina; it is identified as the benzyl ester of the compound of Example 2(a).

b) Treating 5.3 g of this compound in 20 ml carbon tetrachloride with 1.33 g of N-chlorosuccinimide under a sun lamp and with stirring for 5 hrs., filtering the mixture and evaporation produces the 2-chloro-2-phenylmercapto analog of the described benzyl ester in excellent yield calculated from the compound of Example 2(a).

c) A solution of 5.6 g of this compound in 50 ml CH₂Cl₂ is heated for 3 hrs. with 1.1 g of triethylamine. The mixture is then washed with cold water. The organic layer is dried and evaporated to produce a nearly theoretical amount of the analog of the compound of (a) above but containing a double bond between the 2-3 positions.

d) A solution of 1.33 g anhydrous AlCl₃ in nitromethane is added to a solution of 5.3 g of the compound of c) above in 2 g anisole and 20 ml CH₂Cl₂ under ice cooling. After stirring at room temperature for 5 hrs., the mixture is diluted with ethyl acetate, washed with dilute HCl and extracted with 5% aqueous NaHCO₃. The aqueous extract is acidified with HCl and then extracted with ethyl acetate. The original layer is washed with water, dried over MgSO₄ and evaporated to give a solid residue. After recrystallization from acetone/pentane, the pure unsaturated compound I (R=phenoxyacetyl, R'=phenylmercapto, R"= Me) is obtained in good yield.
Example 9

a) When 5.3 g. of the compound of example 8(c) in 50 ml of methanol is stirred with 2.1 g sodium metaperiodate at 0°C for 5 hrs. followed by refluxing for 15 hrs., evaporation and the CH₂Cl₂ extraction procedure of Example 1(a), the analog of Example 8(c) is obtained in good yield. carrying a methoxy group in the 2-position in place of the phenylmercapto group.

b) Removal of the ester group is carried out as in Example 8(d) to produce a good yield of the 2-3 unsaturated I (R=phenoxyacetyl, R'=methoxy, R''=Me).

Example 10

To a solution of 4.5 g. of the compound of Example 9(a) in 30 ml CH₂Cl₂ is added a mixture of 0.75 ml ethanethiol and 1 ml triethylamine. Refluxing for 15 hrs. and evaporation under reduced pressure produces the ethylmercapto-Δ²-analog of the compound of Example 8(c) in almost quantitative yield.

Upon ester group removal as in Example 8(d), unsaturated compound I (R=phenoxyacetyl, R'=EtS, R''=Me) is obtained in very good yield.

Example 11

By following the procedure of Example 9(a) and 9(b) with 5.6 g of the compound of Example 8(c) but using 20 ml of methoxyethanol in place of methanol, compound I (Δ², R=phenoxyacetyl, R'=MeOCH₂CH₂O, R''=Me) is obtained in good yield.

Example 12

To a solution of 5.6 g of the compound of Example 8(b) in 100 ml dry THF at 0°C is added 3.33 ml of a 3-molar solution of methylmagnesium chloride. After stirring for 1 hr., 2.1 g sodium periodate is added and the mixture is refluxed for 15 hrs. This is followed by the usual work-up using CH₂Cl₂ and a carbon column to produce an oil identified as I wherein R is phenoxyacetyl, R' and R'' are methyl, the 5-membered ring is unsaturated and the carboxy
group is esterified with benzyl.

Removal of the benzyl ester group in the fashion of Example 8(d) produces the unsaturated compound I (R=phenoxyacetyl, R'=R"=Me).

Example 13

To 3.2 g of the product in Example 2(b) in 25 ml DME is added 480 mg sodium hydride as a 50% oil suspension and, after 5 minutes of stirring, 1.5 g chloromethyl pivalate is added. After 2 1/2 hrs. the mixture is evaporated and the residue is redissolved in methylene chloride, washed with water, dried and evaporated. It is purified through column chromatography on alumina, yielding the pivaloxymethyl ester of 2(b) (R = PhOCH2CO; R' = H; R" = CH3).

Example 14

In the described procedure as in Example 13, using α-pivaloxy ethyl chloride instead of chloromethyl pivalate, the α-pivaloxy ethyl ester of 2(b) (R = PhOCH2CO, R' = H, R" = CH3) is obtained.

By following Example 13 but substituting the product of Example 2(b) by the compounds of Examples 3-12, the corresponding pivaloxymethyl esters of the shown free acids are obtained.

In similar fashion, the use of the succinimino esters or acid chlorides of various other acyl groups frequently used in the cephalosporin or penicillin series, leads to the saturated compounds of structure I wherein R' is phenylthio, alkoxy, alkylthio, alkoxyalkyl and R" is any loweralkyl, and ultimately to the 2-3 unsaturated (or Δ²) compounds and their acyloxymethyl esters with R' = H, alkyl, phenylmercapto, alkoxy, alkylmercapto or alkoxyalkoxy, showing the following acyl groups in the 6-position:

R = phenacetyl
    = phenoxyacetyl
    = cyanoacetyl
    = thienylacetyl
    = p-hydroxyphenylmalonoyl
In all cases, the saturated and unsaturated 2-substituted or unsubstituted compounds, are active against pseudomonas. The 2-unsubstituted compounds are best obtained from the 2-phenylmercapto-Δ2-compounds in yields of 65-80% and ordinarily are more active, i.e., they require a lower dosage than the 2-phenylmercapto compounds. In vitro activity of the latter compounds are generally found at 100-500 ppm; the unsaturated analogs are active at 1-250 ppm against numerous infectious, gram-positive bacteria.

One of the most important steps of the reaction sequence leading to the new compounds of this invention is the ring closure step for the azetidine ring. The preferred method for this reaction consists in treating compound IV in an inert organic solvent, for instance methylene chloride or DME, with an azidoacetyl halide in the presence of an acid acceptor at a temperature below room temperature, preferably between -25°C and +10°C. Azidoacetyl chloride is an excellent agent for this reaction, although corresponding other acylating agents derived from azidoacetic acid are equally useful. Acid acceptors include...
trialkylamines, such as trimethylamine or triethylamine. The obtained azidoester V is then easily converted to the desired bicyclic, primary amine VI, by hydrogenating V. A preferred method for this step is catalytic hydrogenation, using a noble metal catalyst, although Raney nickel can also be used. Among noble metals, palladium is preferred, although platinum or ruthenium can be used as well.
WE CLAIM:

1. A compound of the formula

\[
R' - \text{NH} - \overset{\text{R}''}{\text{R}} - \text{COOH}
\]

wherein R is hydrogen or an acyl group known from the penicillin and cephalosporin art to impart beneficial antibacterial properties to the molecule, R' is hydrogen, loweralkyl, loweralkoxyalkyl, loweralkoxy, loweralkylmercapto or phenylmercapto, each R'' is loweralkyl, and the broken line represents an optional double bond, and acyl-oxyxymethyl esters thereof.

2. A compound in accordance to Claim 1 wherein said acyl group is phenacetyl, phenoxyacetyl, cyanoacetyl, thienylacetyl, p-hydroxyphenylmalonyl, α-aminophenacetyl, α-sulfophenacetyl, N-benzoylglycylphenylglycyl, a moiety of the formula

\[
\text{COOH} \quad \text{NH}_2 - \text{CH}(\text{CH}_2)_3 \text{CO}^- ,
\]

\[
\text{Et-N} - \overset{\text{N} \text{C-NH-CH-CO}^-}{\text{N-CO-NH-CH-CO}^-} ,
\]

\[
\text{HOCH}_2\text{CH}_2\text{N-SO}_2\text{N-CO-NH-CH-CO}^- ,
\]

\[
\text{NH}_2 \overset{\text{Y}}{\text{C-CO}-}
\]

wherein Y is 0 or NOR,

or a mercaptoacetethyl of the formula R'SCH2CO-wherein R° is phenyl, 4-pyridyl, 2-chloro-2-butenyl, allyl or n-butyl.

3. The unsaturated compound of Claim 1 wherein R is H.

4. The compound of Claim 3 wherein each R'' is methyl and R is H.
5. The compound of Claim 2 wherein R is H.

6. The process of preparing a compound of the formula

\[
\begin{array}{c}
\text{NH}_2 \\
\text{H} \\
\text{H} \\
\text{S-Ph} \\
\text{O} \\
\text{N} \\
\text{COOH}
\end{array}
\]

wherein R" is H or loweralkyl, consisting essentially in
reacting a compound of the formula

\[
\begin{array}{c}
\text{R"} \\
\text{R"} \\
\text{S-Ph} \\
\text{N} \\
\text{COOCH}_2\text{Ph} \\
\text{COOCH}_2\text{Ph}
\end{array}
\]
in the presence of an inert organic solvent and an acid
acceptor at a temperature of between -25°C and +10°C with
at least one molar equivalent of an azidoacetyl halide and
subsequently treating the formed azidoester with hydrogen
gas in the presence of a hydrogenation catalyst.

7. The process of Claim 6 wherein said organic
solvent is methylene chloride.

8. The process of Claim 6 wherein said halide is
azidoacetyl chloride.

9. The process of Claim 6 wherein said catalyst
is palladium.
# INTERNATIONAL SEARCH REPORT

## I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl. C07D 487/04, 519/00
U.S. Cl. 260/245.2T; 544/373; 546/123, 272

## II. FIELDS SEARCHED

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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

Chemical Abstracts - 1-azabicyclo[3,2,0]hept-2-ene-2-carboxylic acid 1939-date

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US, A, 4,224,336, Published 23 September 1980, Christensen et al</td>
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- "A" document defining the general state of the art
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- "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance

## IV. CERTIFICATION

Date of the Actual Completion of the International Search 5

11 August 1981

Date of Mailing of this International Search Report 5

18 August 1981

International Searching Authority 1

ISA/US

Signature of Authorized Officer 10

Mary C. Lee

Form PCT/ISA/213 (second sheet) (October 1977)