



(72) BUYNAK, John D., US

(72) BACHMANN, Brian, US

(71) Research Corporation Technologies, Inc., US

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(54) **DERIVES D'ACIDE 7-ALKYLIDENE CEPHALOSPORANIQUE
ET PROCEDES D'UTILISATION DE CE DERNIER**

(54) **7-ALKYLIDENE CEPHALOSPORANIC ACID DERIVATIVES
AND METHODS OF USING THE SAME**

(57) L'invention a pour objet des dérivés du sulfone d'acide 7-alkylidène céphalosporanique et les sels pharmaceutiquement actifs de ces derniers, qui constituent de puissants inhibiteurs des enzymes .beta.-lactamase.

(57) Derivatives of 7-alkylidene cephalosporanic acid sulfone and the pharmaceutically active salts thereof are found to be potent inhibitors of .beta.-lactamase enzymes.

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(21) International Application Number: PCT/US95/15608 (22) International Filing Date: 11 December 1995 (11.12.95) (30) Priority Data: 08/354,850 9 December 1994 (09.12.94) US (71) Applicant: SOUTHERN METHODIST UNIVERSITY [US/US]; P.O. Box 750132, Dallas, TX 75275 (US). (72) Inventors: BUYNAK, John, D.; 10842 Hayfield Drive, Dallas, TX 75238 (US). BACHMANN, Brian; Apartment #8, 6415 Airline Extension, Dallas, TX 75205 (US). (74) Agents: OBLON, Norman, F. et al.; Oblon, Spivak, McClell- land, Maier & Neustadt, P.C., 4th floor, 1755 Jefferson Davis Highway, Crystal Square Five, Arlington, VA 22202 (US).		(81) Designated States: AL, AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, LS, MW, SD, SZ, UG). Published <i>With international search report.</i>
(54) Title: 7-ALKYLIDENE CEPHALOSPORANIC ACID DERIVATIVES AND METHODS OF USING THE SAME (57) Abstract Derivatives of 7-alkylidene cephalosporanic acid sulfone and the pharmaceutically active salts thereof are found to be potent inhibitors of β -lactamase enzymes.		

TITLE OF THE INVENTION

7-ALKYLIDENE CEPHALOSPORANIC ACID DERIVATIVES
AND METHODS OF USING THE SAME

BACKGROUND OF THE INVENTION5 Field of the Invention:

The present invention relates to novel compounds which are β -lactamase inhibitors, pharmaceutical compositions containing the same and methods of inhibiting β -lactamases. More specifically this invention is concerned with novel 7-alkylidene cephalosporins and pharmaceutically acceptable salts thereof.

Description of the Background:

The most important mechanism of microbial resistance to β -lactam antibiotics is the bacterial production of β -lactamases, enzymes which hydrolytically destroy β -lactam antibiotics, such as penicillins and cephalosporins. This type of resistance can be transferred horizontally by plasmids that are capable of rapidly spreading the resistance, not only to other members of the same strain, but even to other species. Due to such rapid gene transfer, a patient can become infected with different organisms, each possessing the same β -lactamase.

β -lactamase enzymes have been organized into four molecular classes: A, B, C, and D based on amino acid sequence. Class A, which includes RTEM and the β -lactamase of *Staphylococcus aureus*, class C, which includes the lactamase derived from P99 *Enterobacter cloacae*, and class D are serine hydrolases. Class A

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enzymes have a molecular weight of about 29 kDa and preferentially hydrolyze penicillins. The class B lactamases are metalloenzymes and have a broader substrate profile than the proteins in the other classes. Class C enzymes include the chromosomal cephalosporinases of gram-negative bacteria and have molecular weights of approximately 39 kDa. The recently recognized class D enzymes exhibit a unique substrate profile which differs significantly from both class A and class C.

The class C cephalosporinases, in particular, are responsible for the resistance of gram-negative bacteria to a variety of both traditional and newly designed antibiotics. The *Enterobacter* species, which possess a class C enzyme, are now the third greatest cause of hospital-acquired infections in the United States. This class of enzymes often has poor affinities for inhibitors of the class A enzymes, such as clavulanic acid, a commonly prescribed inhibitor, and to common *in vitro* inactivators, such as 6- β -iodopenicillanate.

One strategy for overcoming rapidly evolving bacterial resistance is the synthesis and administration of β -lactamase inhibitors. Frequently, β -lactamase inhibitors do not possess antibiotic activity themselves and are thus administered together with an antibiotic. One example of such a synergistic mixture is "augmentin", which contains the antibiotic amoxicillin and the β -lactamase inhibitor, clavulanic acid.

It is thus desirable to find novel β -lactamase inhibitors which can be coadministered with a β -lactam antibiotic.

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SUMMARY OF THE INVENTION

Accordingly, one object of the present invention is to provide novel β -lactamase inhibitors.

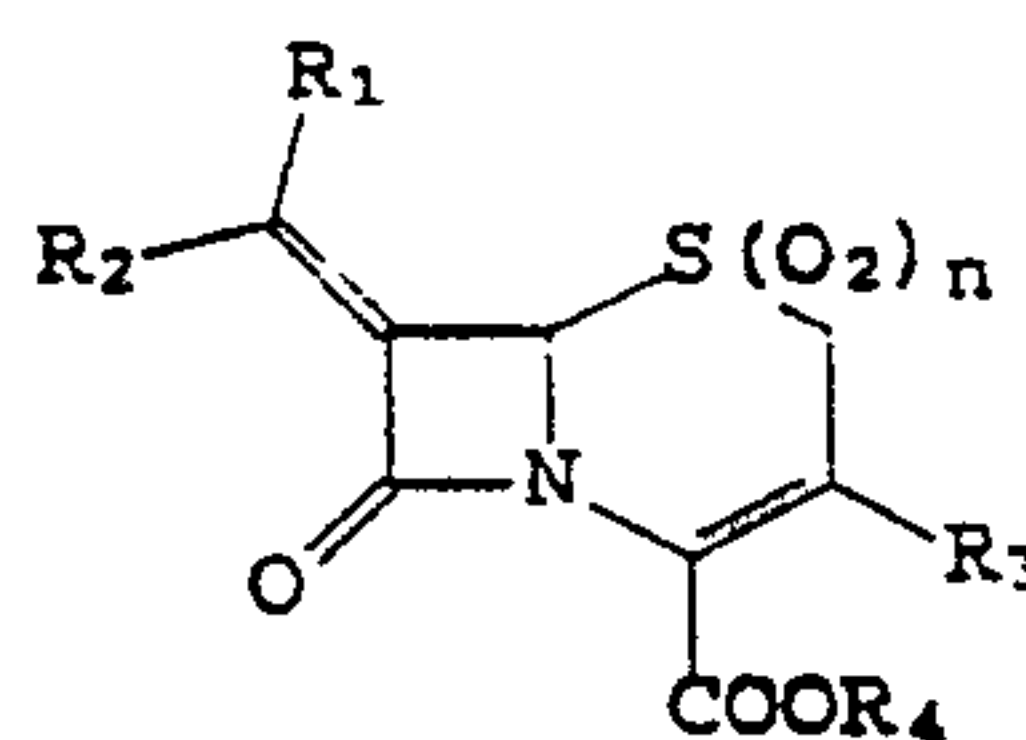
It is another object of the present invention to provide pharmaceutical compositions useful for inhibiting a β -lactamase.

It is another object of the present invention to provide pharmaceutical compositions with increased β -lactam antibiotic activity.

It is another object of the present invention to provide methods of inhibiting a β -lactamase.

It is another object of the present invention to provide methods of enhancing the biological activity of a β -lactam antibiotic.

These and other objects, which will become apparent during the following detailed description, have been achieved by the inventors' discovery that compounds of the formula (1)



1

wherein n is 0 or 1 (the sulfide or the sulfone, respectively);

R_1 and R_2 are the same or different and are selected from the group consisting of

- hydrogen;
- linear or branched C_{1-10} -alkyl;
- halogen;

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- d) hydroxy-C₁₋₁₀-alkyl;
 - e) C₁₋₁₀-alkoxy;
 - f) C₂₋₁₀-alkanoyloxy;
 - g) C₂₋₁₀-alkene;
 - 5 h) C₂₋₁₀-alkene substituted with one or more groups selected from the group consisting of chlorine, fluorine, bromine or phenyl;
 - i) C₁₋₁₀-alkoxycarbonyl;
 - j) C₁₋₁₀-alkoxycarbamido;
 - k) N-C₁₋₁₀-alkoxy-N-C₁₋₁₀-alkylaminocarbonyl;
 - 10 l) halo-C₁₋₁₀-alkyl;
 - m) C₆₋₁₀-aryl;
 - n) C₆₋₁₀-aryl substituted with one or more groups selected from the group consisting of ethyl, n-propyl, isopropyl, amino, methylamino and dimethylamino;
 - 15 o) a C₂₋₁₀-heterocycle having from 1-3 heteroatoms selected from the group consisting of O, N and S; and,
 - p) -COOH or -COOY, wherein Y is pharmaceutically acceptable cation;
- R₃ is selected from the group consisting of
- 20 1) -COOH;
 - 2) chlorine or fluorine;
 - 3) trifluoromethyl;
 - 4) -CHO; and,
 - 5) -CH₂M where M is selected from the group consisting of
- 25 a) hydrogen;
 - b) halogen;
 - c) hydroxy;
 - d) C₁₋₁₀-alkoxy;

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e) C_{6-10} -aryloxy;f) C_{6-10} -aryl- C_{1-10} -alkoxy;

g) mercapto;

h) mercapto substituted with one or more groups selected
 5 from the group consisting of methyl, ethyl or phenyl;

i) C_{2-10} -acylthio;j) C_{2-10} -acyloxy or carbamoyloxy;

k) C_{2-10} -acyloxy or carbamoyloxy substituted with one or
 more groups selected from the group consisting of -COOH,
 10 aminophenyl, phenyl, C_{1-5} -alkyl, chlorine, bromine or fluorine;

l) a quaternary ammonium salt;

m) amino or amido; and,

n) amino or amido substituted with one or more groups
 selected from the group consisting of C_{1-10} -alkyl groups;

15 R_4 is selected from the group consisting of

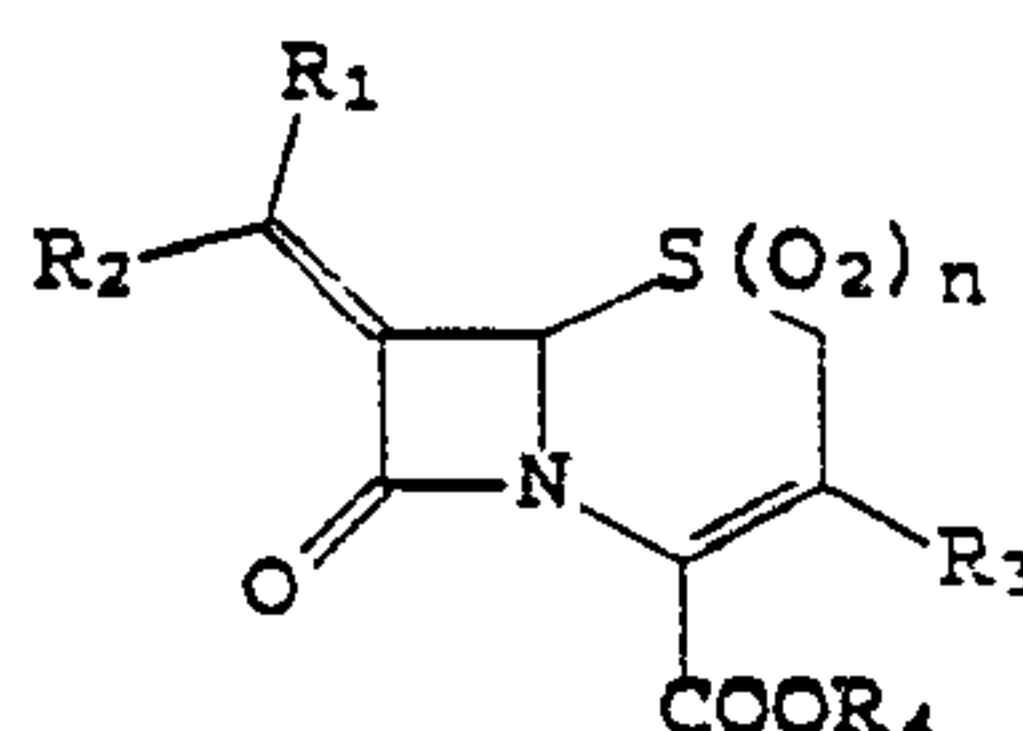
a) hydrogen; and,

b) pharmaceutically acceptable cations;

are effective β -lactamase inhibitors.

20 DETAILED DESCRIPTION OF THE INVENTION

Thus, in a first embodiment, the present invention provides
 novel compounds of the formula (1)



1

wherein n is 0 or 1;

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R_1 and R_2 are the same or different and are selected from the group consisting of

- a) hydrogen;
- b) linear or branched C_{1-10} -alkyl, preferably, C_{1-6} -alkyl, more preferably, methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, n-pentyl, cyclopropyl, cyclopentyl, or cyclohexyl, most preferably t-butyl;
- c) halogen, preferably Br or Cl;
- d) hydroxy- C_{1-10} -alkyl, preferably, hydroxy- C_{1-6} -alkyl, more preferably, hydroxymethyl, 1-hydroxyethyl or 2-hydroxyethyl;
- e) C_{1-10} -alkoxy, preferably, C_{1-6} -alkoxy, more preferably, t-butoxy or methoxy;
- f) C_{2-10} -alkanoyloxy, preferably, C_{2-6} -alkanoyloxy, more preferably, acetoxymethyl or propanoyloxy;
- g) C_{2-10} -alkene, preferably, C_{2-6} -alkene, more preferably, ethylene, 1-propylene or 2-propylene;
- h) substituted C_{2-10} -alkene, preferably, C_{2-6} -alkene, more preferably ethylene, 1-propylene or 2-propylene, wherein said substituents are one more groups selected from the group consisting of chlorine, fluorine, bromine or phenyl;
- i) C_{1-10} -alkoxycarbonyl, preferably, C_{1-6} -alkoxycarbonyl, more preferably, methoxycarbonyl or t-butoxycarbonyl;
- j) C_{1-10} -alkoxycarbamido, preferably, C_{1-6} -alkoxycarbamido, more preferably, methoxycarbamido, ethoxycarbamido or n-propoxycarbamido;
- k) N- C_{1-10} -alkoxy-N- C_{1-10} -alkylaminocarbonyl, preferably, N-

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C₁₋₆-alkoxy-N-C₁₋₆-alkylaminocarbonyl, more preferably, N-methoxy-N-methylaminocarbonyl, N-ethoxy-N-methylaminocarbonyl, N-methoxy-N-ethylaminocarbonyl or N-ethoxy-N-ethylaminocarbonyl;

l) halo-C₁₋₁₀-alkyl, preferably, halo-C₁₋₆-alkyl, more preferably, chloromethyl, 1-chloroethyl or 2-chloroethyl;

m) C₆₋₁₀-aryl group, preferably, phenyl, tolyl, anisoyl, mesityl, and xylyl;

n) substituted C₁₋₁₀-alkyl, preferably, phenyl, tolyl, anisoyl, mesityl, and xylyl, wherein said substituents are one or more groups selected from the group consisting of ethyl, n-propyl, isopropyl, amino, methylamino and dimethylamino;

o) a C₂₋₁₀-heterocycle having from 1-3 heteratoms selected from the group consisting of O, N and S, preferably, triazolyl, triazinyl, oxazolyl, isoxazolyl, oxazolidinoyl, isoxazolidinoyl, thiazolyl, isothiazoyl, pyrazolyl, imidazolyl, pyrrolyl, pyrazinyl, pyridinyl, morpholinyl, quinolinyl, isoquinolinyl, indolyl, and pyrimidinyl, more preferably, pyridinyl; and,

p) -COOH or -COOY, wherein Y is a pharmaceutically acceptable cation, preferably, sodium, potassium, calcium, or any other pharmaceutically acceptable cation known in the art;

R₃ is selected from the group consisting of

1) -COOH;

2) Cl or F;

3) trifluoromethyl;

4) -CHO; and,

5) -CH₂M, wherein M is selected from the group consisting of

a) hydrogen;

b) halo, preferably F, Cl, Br, or I;

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c) hydroxy;

d) C₁₋₁₀-alkoxy, preferably, C₁₋₆-alkoxy, more preferably, methoxy, ethoxy, n-propoxy or isopropoxy;

5 e) C₆₋₁₀-aryloxy, preferably, C₆₋₁₀-aryloxy, more preferably, phenoxy or naphthoxy;

f) C₆₋₁₀-aryl-C₁₋₁₀-alkoxy, preferably, C₆₋₁₀-aryl-C₁₋₆-alkoxy, more preferably, phenylmethoxy, 1-phenylethoxy or 2-phenylethoxy;

g) mercapto, preferably, thiol;

10 h) substituted mercapto, preferably, thiol, wherein said substituents are selected from the group consisting of methyl, ethyl or phenyl;

i) C₂₋₁₀-acylthio, preferably C₂₋₆-acylthio, more preferably, acetylthio or propanoylthio;

15 j) C₂₋₁₀-acyloxy or carbamoyloxy, preferably, C₂₋₆-alkanoyloxy, C₆₋₁₀-aryl-carbonyloxy, carbamoyloxy or thiocarbamoyloxy, more preferably, acetoxo or benzoyloxy;

k) substituted C₂₋₁₀-acyloxy or carbamoyloxy, preferably, C₂₋₆-alkanoyloxy, C₆₋₁₀-aryl-carbonyloxy, N-C₁₋₆-alkylcarbamoyloxy, N,N-di-C₁₋₆-alkylcarbamoyloxy, thiocarbamoyloxy, N-C₁₋₆-alkylthiocarbamoyloxy or N,N-di-C₁₋₆-alkylthiocarbamoyloxy, more preferably, acetoxo, α-aminophenylacetoxo, benzoyloxy, benzyloxycarbonyloxy, succinoyloxy, N-methylcarbamoyloxy, N-ethylcarbamoyloxy, N,N-dimethylcarbamoyloxy, N,N-diethylcarbamoyloxy, N-methylthiocarbamoyloxy, N-ethylthiocarbamoyloxy, N,N-dimethylthiocarbamoyloxy, N,N-diethylthiocarbamoyloxy, wherein said substituents are one or more groups selected from the group consisting of -COOH, aminophenyl, phenyl, methyl, ethyl, chlorine, bromine or fluorine;

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l) a quaternary ammonium salt, preferably trimethyl ammonium chloride or triethyl ammonium chloride;

m) amino or amido group, preferably -NH_2 or -CONH_2 ; and,

5 n) substituted amino or amido group, preferably -NH_2 or -CONH_2 , wherein said substituents are one or two C_{1-10} -alkyl groups, preferably C_{1-6} -alkyl groups, more preferably, methyl, ethyl, *n*-propyl, isopropyl or *n*-butyl;

R_4 is selected from the group consisting of

a) hydrogen; and,

10 b) pharmaceutically acceptable cations, preferably, sodium, potassium or calcium.

In a preferred embodiment, *n* is 0, R_2 is hydrogen and R_1 is selected from the group consisting of *t*-butyl, phenyl, pyridyl, COMe and *N*-methyl-*N*-methoxy-aminocarbonyl.

15 In a more preferred embodiment, *n* is 0, R_2 is hydrogen, and R_1 is selected from the group consisting of CO_2 -*t*-Bu and CHO.

In another preferred embodiment, *n* is 1, R_2 is hydrogen, and R_1 is selected from the group consisting of CO_2Me , CH_2OH and *t*-butyl.

20 In another more preferred embodiment, *n* is 1, R_2 is hydrogen and R_1 is selected from the group consisting of phenyl, pyridyl and CO_2 -*t*-butyl.

In another preferred embodiment, *n* is 0 and R_1 and R_2 are the same and are selected from the group consisting of bromine and chlorine.

25 In another preferred embodiment, *n* is 1 and R_1 and R_2 are the same and are selected from the group consisting of bromine and chlorine.

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In another preferred embodiment, n is 0, R_1 is hydrogen, and R_2 is bromine.

In another preferred embodiment, n is 1, R_1 is hydrogen, and R_2 is selected from the group consisting of phenyl and bromine.

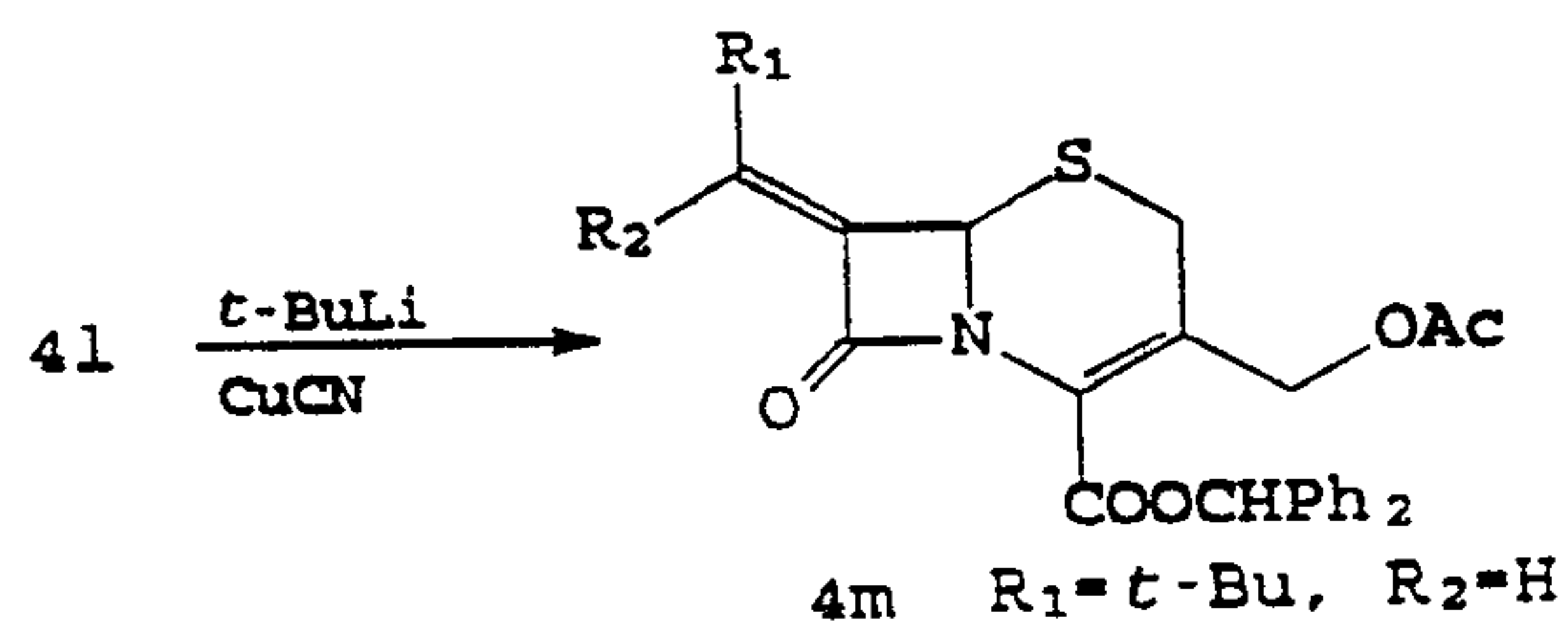
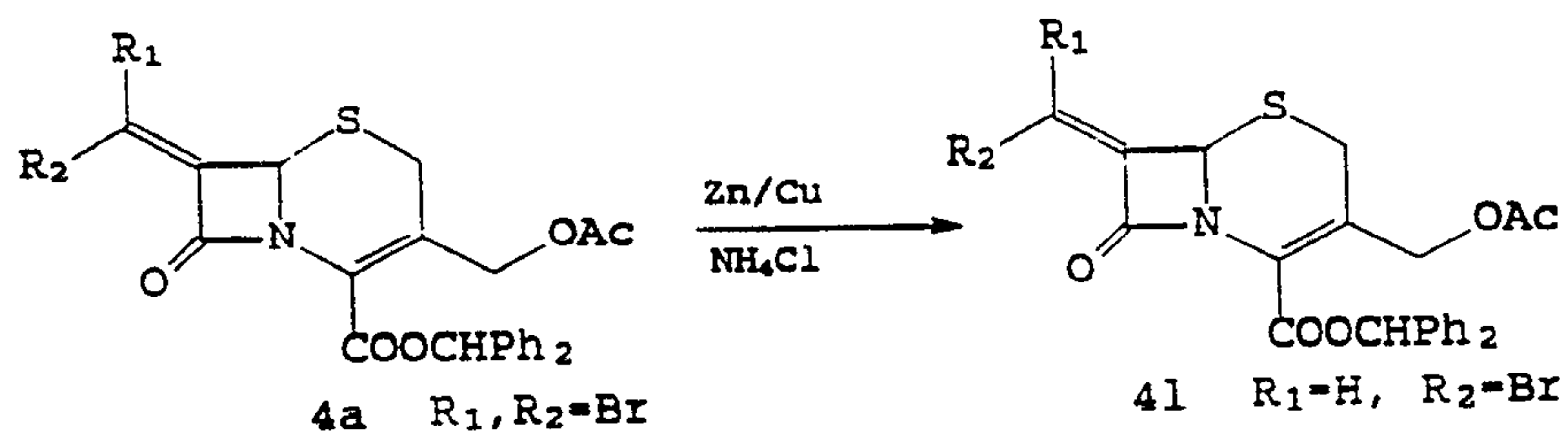
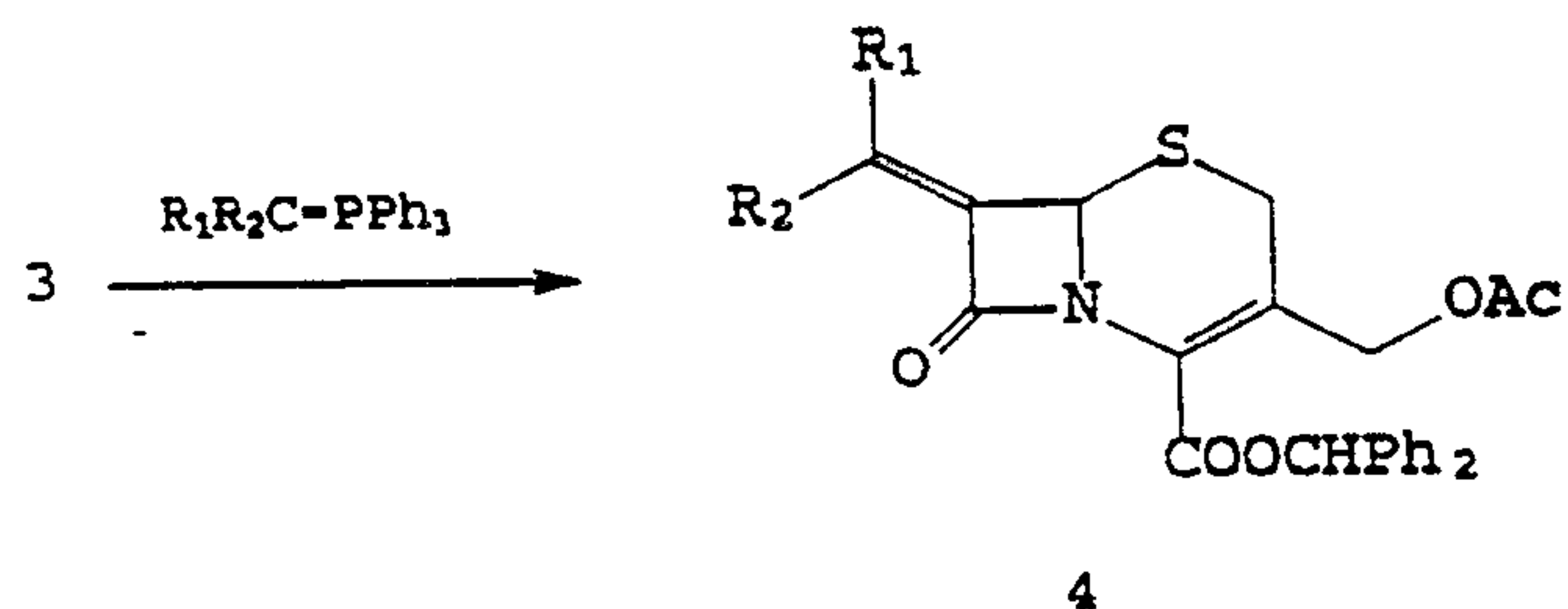
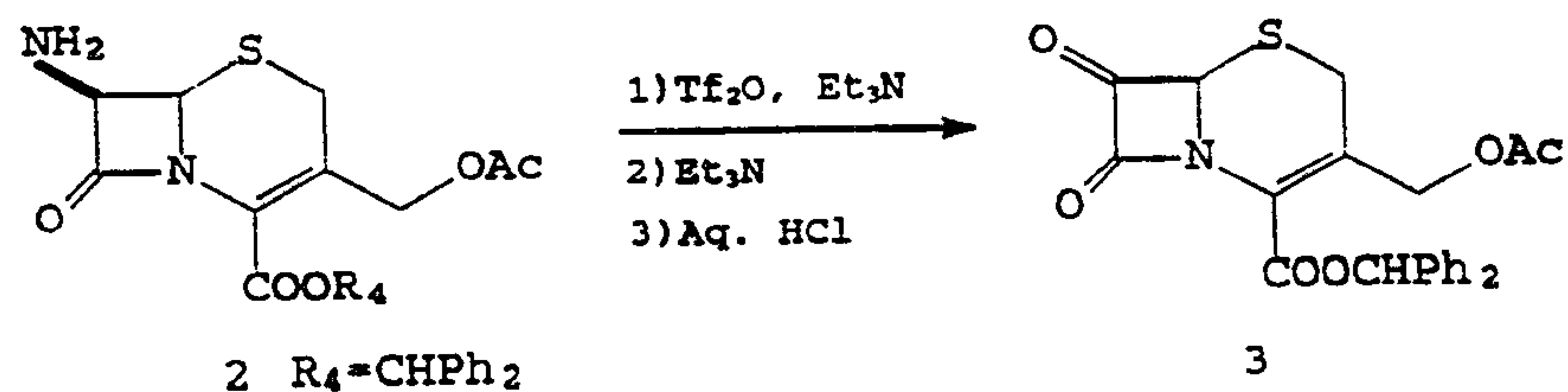
5 In a most preferred embodiment, n is 1, R_1 is pyridyl, R_2 is hydrogen, R_3 is $-\text{CH}_2\text{OAc}$ and R_4 is sodium.

Compounds according to formula (1) were obtained as follows.

7-Aminocephalosporanic acid (commercially available from Aldrich), esterified with diphenyl diazomethane (2), was treated
10 with excess triethylamine and trifluoromethanesulfonic anhydride and the resultant trifluorosulfonyl imine was hydrolyzed to produce benzhydryl 7-oxocephalosporanate 3. (See Hagiwara, D.F.; Sawada, K.; Ohnami, T.; Aratani, M.; Hashimoto, M. *J. Chem Soc. Chem. Commun.* 1982, 578.) Due to its instability, 3 was used
15 directly in the next step without purification.

The 7-alkylidenecephalosporanates 4 were prepared by treating 7-oxocephalosporanate 3 with the corresponding Wittig reagent at -78°C . Compounds 4 a-k were prepared in the standard manner with the exceptions of 4b, 4j, 4l, and 4m. Compound 4b
20 required the addition of the Zn/Cu couple to 3 in the presence of CCl_4 and PPh_3 to lead to its formation. Compound 4j was prepared by the reduction of 4i with NaCNBH_3 . Compound 4a was reduced by the Zn/Cu couple to produce monobromomethylenecephem 4l, which was further treated with $t\text{-BuLi}$ and CuCN to give compound 4m as
25 shown below.

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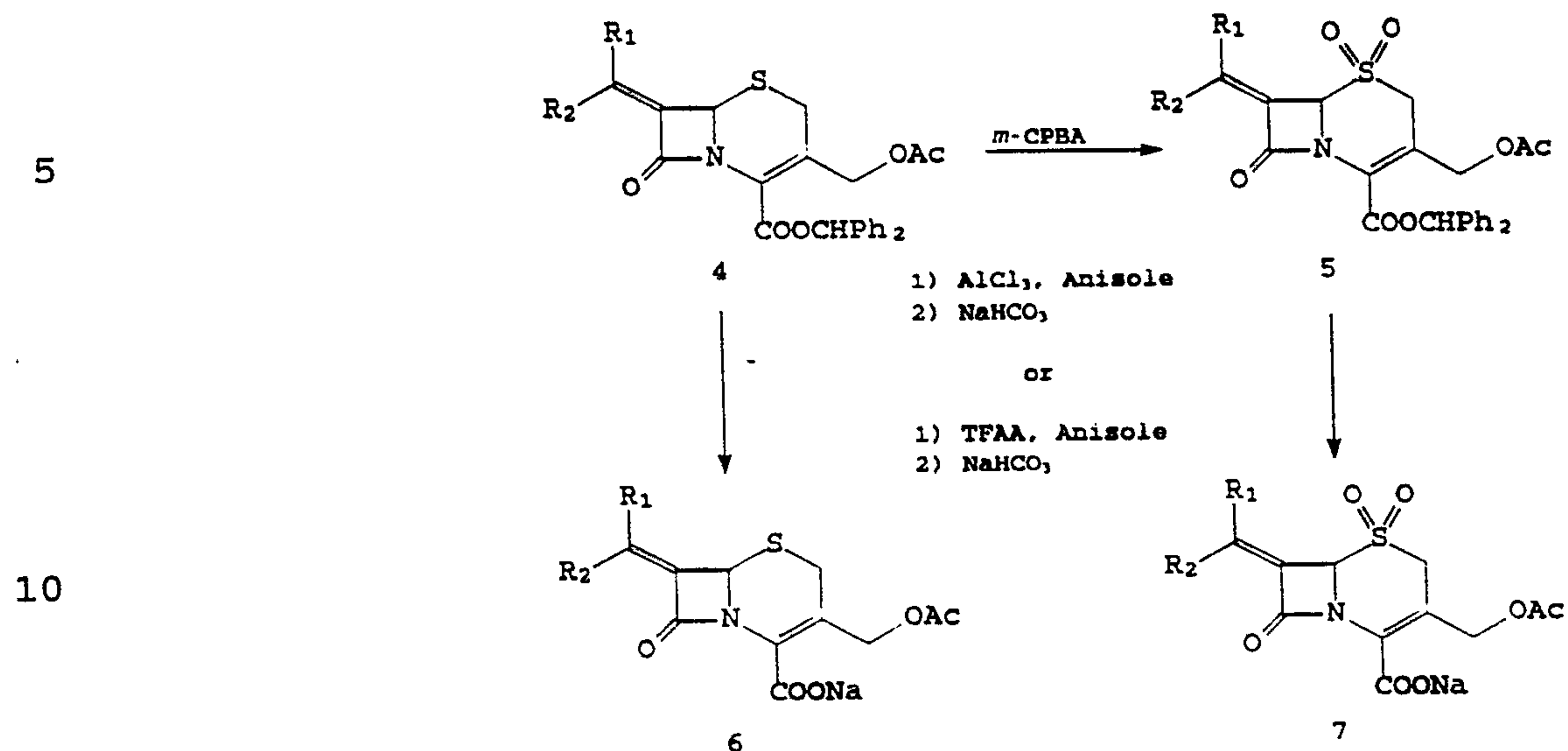


no.	R_1	R_2	no.	R_1	R_2
4a	Br	Br	4g	$\text{CO}_2\text{C}(\text{CH}_3)_3$	H
4b	Cl	Cl	4h	COCH_3	H
4c	H	Ph	4i	CHO	H
4d	Ph	H	4j	CH_2OH	H
4e	Py	H	4k	$\text{CON}(\text{CH}_3)(\text{OCH}_3)$	H
4f	CO_2CH_3	H	4l	H	Br
			4m	t-Butyl	H

Many of the compounds in the series 4 were oxidized with excess *m*-CPBA yielding the corresponding sulfones 5.

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Deprotection of compounds 4 and 5 gave the corresponding sodium salts 6 and 7 as shown below.



	no.	R ₁	R ₂	no.	R ₁	R ₂
15	6a	Br	Br	7a	Br	Br
	6b	Cl	Cl	7b	Cl	Cl
	6e	Py	H	7c	H	Ph
	6f	CO ₂ CH ₃	H	7d	Ph	H
20	6g	CO ₂ C(CH ₃) ₃	H	7e	Py	H
	6h	COCH ₃	H	7g	CO ₂ C(CH ₃) ₃	H
	6i	CHO	H	7j	CH ₂ OH	H
	6k	CON(Me)(OMe)	H	7l	H	Br
	6l	H	Br	7m	t-Bu	H
25	6m	t-Bu	H			

Compounds containing R_1 and R_2 groups (i.e., alkoxy or alkene) not shown above may be synthesized by using an appropriate Wittig reagent $\text{R}_1\text{R}_2\text{C}=\text{PPH}_2$. The Wittig reagents $\text{ROCH}=\text{PPh}_2$ and $\text{H}_2\text{C}=\text{CH}-\text{CH}=\text{PPh}_2$ may be used to make the 7-alkyoxymethylene and 7-alkenylmethylene compounds, respectively.

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In addition to the Wittig reaction, the Peterson olefination procedure may be used to form 7-substituted methylene compounds from the oxocephalosporanate 3. For example, $(RO)(SiMe_3)CHLi$ or $(haloalkyl)(SiMe_3)CHLi$ may add to 3 to form the 7-alkoxymethylene or 7-halomethylmethylene compounds, respectively.

The 7-alkanoylmethylene species may be made by forming the vinyl anion and reacting it with a desirable alkanoyl halide. The vinyl anion may be made by a standard lithium-halogen (or magnesium-halogen) exchange reaction, for example, reaction of 4a with methyl lithium. The lithium vinyl group may then be functionalized by reaction with an alkoxycarbonyl chloride.

The 7-carboxylmethylene compounds (R_1 or $R_2 = COOH$ or $COOY$) may be formed by hydrolysis of the corresponding ester, preferably, the corresponding t-butyl ester.

The compounds wherein R_3 is a halogen may be formed by displacement of the -OAc group with ethylxanthate ($EtOCS_2K$). Raney-Nickel desulfurization ($H_2/Ra-Ni$) would yield the exocyclic alkene which may then be ozonized to the 3-hydroxy cephem. Reaction with a halogenating reagent would provide the 3-halo species. For example, PCl_5 may be used to convert the 3-OH group into a 3-Cl group. The 3-methyl species may be obtained by the rearrangement of the exocyclic alkene, formed by Raney-Nickel desulfurization, by reaction with Et_3N . The 3-hydroxymethyl species may be obtained by hydrolysis of the -OAc group with NaOH or an appropriate enzyme. The 3-halomethyl species may be formed by reaction of the 3-hydroxymethyl species with a halogenating reagent. For example, PCl_5 may be used to form the 3-chloromethyl species.

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The compounds wherein M is alkoxy, aryloxy, or arylalkoxy may be obtained by reaction of the 3-hydroxymethyl species with tosyl chloride and displacement of the resultant tosylate with an oxide. For example, sodium methoxide may be used to obtain the 3-methoxymethyl species. The compounds wherein M is mercapto may be formed by reaction of the 3-chloromethyl compound with sodium sulfhydryde (NaSH). This compound may further be derivatized with an alkylhalide to form a substituted mercapto or an acylchloride to form an acylthio group.

The species wherein M is an amino group may be formed by the Gabriel Synthesis, i.e., reaction of the 3-chloromethyl compound with potassium phthalimide and hydolysis of the product with acid to yield the 3-aminomethyl compound. The 3-ammoniomethyl compound may be formed by reaction of the 3-aminomethyl compound with methyl chloride to form the 3-trimethylammoniomethyl chloride.

The compound wherein M is an amido group (CONH_2) may be formed by displacement of the tosylate described above with cyanide, e.g., KCN, followed by hydrolysis of the resulting nitrile to the amide.

The aforementioned salts of 7-alkylidene cepheems were evaluated as inhibitors of the Class C β -lactamase of *Enterobacter cloacae* P99 and TEM2 by relative IC_{50} analysis. The IC_{50} value represents the concentration of inhibitor required to effect a 50% loss of activity of free enzyme. The IC_{50} value of each compound was determined as follows. Following a 10 minute incubation of a dilute solution of enzyme (2.56 nM) and inhibitor (<0.64 mM), a 50 mL aliquot of this incubation mixture was then

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further diluted into 1 mL nitrocefin solution, and the rate of hydrolysis was measured during a 1 minute period by monitoring the absorbance of nitrocefin as a function of time. In addition, the IC₅₀ values of tazobactam and clavulanic acid were determed as relative controls. The data is presented in Table 1 below.

Table 1. *E. cloacae* P99 and SC 12368, and *E. coli*. W3310 β -lactamase inhibitory activity

Compound	n	R ₁	R ₂	IC ₅₀ (nM) <i>E. cloacae</i> P99	IC ₅₀ (nM) <i>E. Coli</i> WC3310	IC ₅₀ (nM) <i>E. cloacae</i> SC12368
tazobactam				943	25	4000
Clavulanic acid				>20000	60	>20000
6a	0	Br	Br	>20000	>20000	>20000
6b	0	Cl	Cl	>20000	>20000	>20000
6d	0	Ph	H	>20000	>20000	>20000
6e	0	2'-Py	H	>20000	>20000	>20000
6g	0	CO ₂ C(CH ₃) ₃	H	2500	>20000	>20000
6h	0	COCH ₃	H	>20000	>20000	>20000
6i	0	CHO	H	8200	>20000	16500
6k	0	CON(CH ₃)(OCH ₃)	H	>20000	>20000	>20000
6l	0	H	Br	>20000	>20000	>20000
6m	0	t-Bu	H	>20000	>20000	>20000
7a	1	Br	Br	>20000	>20000	>20000
7b	1	Cl	Cl	>20000	8300	>20000
7c	1	H	Ph	>20000	>20000	>20000
7d	1	Ph	H	6250	>20000	6800
7e	1	2'-Py	H	25	800	25
7f	1	CO ₂ CH ₃	H	>20000	8	>20000
7g	1	CO ₂ C(CH ₃) ₃	H	7800	5	5900
7j	1	CH ₂ OH	H	>20000	>20000	>20000
7l	1	H	Br	>20000	>20000	>20000
7m	1	t-Bu	H	>20000	>20000	>20000

Compound 7e, 7-(Z)-[(2-pyridyl)methylene] cephalosporanic acid sulfone, was determined to be more potent than tazobactam, showing a 20 fold increase in activity. In general, it was found that the sulfones were more potent than their corresponing sulfide analogs. One striking example of this is the 1300 fold increase in activity of 7e, the pyridyl sulfone, over it's sulfide 6e.

In a second embodiment, the present invention provides pharmaceutical compositions useful for inhibiting a β -lactamase. The present pharmaceutical compositions comprise at least one of

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the present 7-vinylidene cephalosporins and at least one pharmaceutically acceptable carrier.

The present compositions may be employed in capsule form or as tablets, powders or liquid solutions or as suspensions or elixirs. They may be administered orally, intravenously or intramuscularly. The present compositions are preferably presented in a form suitable for absorption by the gastrointestinal tract.

Tablets and capsules for oral administration may be in unit dose presentation form, and may contain conventional pharmaceutical carriers such as binding agents, for example, syrup, acacia, gelatin, sorbitol, tragacanth, or polyvinylpyrrolidone; fillers, for example, lactose, sugar, maize-starch, calcium phosphate, sorbitol or glycine, lubricants, for example, magnesium stearate, talc, polyethylene glycol, silica; disintegrants, for example, potato starch; or acceptable wetting agents such as sodium lauryl sulphate. The tablets may be coated according to methods well known in the art. Oral liquid preparations may be in the form of aqueous or oily suspensions, solutions, emulsions, syrups, elixirs, etc. or may be presented as a dry product, for reconstruction with water or other suitable vehicle before use. Such liquid preparations may contain conventional additives such as suspending agents, for example, sorbitol syrup, methyl cellulose, glucose/sugar syrup, gelatin, hydroxyethylcellulose, carboxymethyl cellulose, aluminum stearate gel or hydrogenated edible fats; emulsifying agents, for example lecithin, sorbitan monooleate or acacia; non-aqueous vehicles, which may include edible oils, for example, almond oil,

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fractionated coconut oil, oily esters, propylene glycol, or ethyl alcohol; preservatives, for example, methyl or propyl p-hydroxybenzoates or sorbic acid. Suppositories will contain conventional suppository bases, e.g., cocoa butter or other glyceride.

Compositions for injection may be presented in unit does form in ampules, or in multidose containers with an added preservative. The compositions may take such forms as suspensions, solutions, emulsions in oily or aqueous vehicles, and may contain formulatary agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient may be in powder form for reconstitution with a suitable vehicle, e.g., sterile, pyrogen-free water, before use.

The present compositions may also be prepared in suitable forms for absorption through the mucous membranes of the nose and throat or bronchial tissues and may conveniently take the form of powder or liquid sprays or inhalants, lozenges, throat paints, etc. For medication of the eyes or ears, the preparations may be presented as individual capsules, in liquid or semi-solid form, or may be used as drops, etc. Topical applications may be formulated in hydrophobic or hydrophilic bases as ointments, creams, lotions, paints, powders, etc.

Also, in addition to a carrier, the present compositions may include other ingredients such as stabilizers, binders, antioxidants, preservatives, lubricators, suspending agents, viscosity agents or flavoring agents and the like.

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For veterinary medicine, the composition may, for example, be formulated as an intramammary preparation in either long acting or quick-release bases.

5 The dosage to be administered depends to a large extent upon the condition of the subject being treated and the weight of the subject, the route and frequency of administration, the parenteral route being preferred for generalized infections and the oral route for intestinal infections.

10 The instant compositions may be administered in several unit dosage forms as, for example, in solid or liquid orally ingestible dosage form. The compositions per unit dosage, whether liquid or solid may contain from 0.1% to 99% of active material (the present 7-vinylidene cephalosporins and optional antibiotic), the preferred range being from about 10-60%. The
15 composition will generally contain from about 15 mg to about 1500 mg by weight of active ingredient based upon the total weight of the composition; however, in general, it is preferable to employ a dosage amount in the range of from about 250 mg to 1000 mg. In parenteral administration the unit dosage is usually the pure
20 compound in a slightly acidified sterile water solution or in the form of a soluble powder intended for solution.

The present β -lactamase inhibitors will be particularly useful in the treatment of infections caused by *Enterobacter*, *Citrobacter*, and *Serratia*. These bacteria have the ability to
25 attach to the epithelial cells of the bladder or kidney (causing urinary tract infections) and are resistant to multiple antibiotics including amoxicillin and ampicillin. The present β -lactamase inhibitors would also be useful in the treatment of

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infections caused by highly resistant Pneumococci. Such diseases include otitis media, sinusitis, meningitis (both in children and adults), bacteremia, and septic arthritis. Resistant pneumococcal strains have surfaced in many parts of the world. For example, in Hungary, 58% of *S. pneumoniae* are resistant to penicillin, and 70% of children who are colonized with *S. pneumoniae* carry resistant strains that are also resistant to tetracycline, erythromycin, trimethoprin/sulfamethoxazole (TMP/SMX), and 30% resistant to chloroanphenicol. *Klebsiella pneumoniae* (resistant via the production of β -lactamase) have caused hospital outbreaks of wound infection and septicemia.

Thus, in a third embodiment, the present invention provides pharmaceutical compositions with increased β -lactam antibiotic activity. This pharmaceutical composition is as defined above, but in addition to at least one of the present 7-vinylidene cephalosporins and at least one a pharmaceutically acceptable carrier, the compositions also contains at least one β -lactam antibiotic. The β -lactam antibiotic may be any of the above-noted antibiotics or any other known in the art, preferably amoxicillin or piperacillin, and its selection will depend upon what indication is necessary.

In a fourth embodiment, the present invention provides a method of inhibiting a β -lactamase, comprising administering to a patient in need thereof an effective amount of at least one of the present 7-vinylidene cephalosporins. The method of administration may be any of the above-noted methods or any other known to one of skill in the art.

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In a fifth embodiment, the present invention provides a method of enhancing the biological activity of a β -lactam antibiotic by coadministering to a patient in need thereof, an effective amount of one of the present 7-vinylidene cephalosporins and an effective amount of at least one β -lactam antibiotic. The method of administration may be any of the above-noted methods or any other known to one of skill in the art. The β -lactam antibiotic may be any of the above-noted β -lactam antibiotics or any other known in the art.

Other features of the invention will become apparent in the course of the following descriptions of exemplary embodiments which are given for illustration of the invention and are not intended to be limiting thereof.

EXAMPLES

EXAMPLE 1

Benzhydryl 7 β -aminocephalosporanate (2)

To a suspension of 7-aminocephalosporanic acid (130.4 g, 0.48 mol) in methanol (480 mL) was added a solution of diphenyldiazomethane (93.0 g, 0.48 mol) in CH_2Cl_2 , prepared by the oxidation of benzophenone hydrazone by mercury oxide at room temperature. The reaction was then mechanically stirred at room temperature for 44 hours. The remaining solid was removed by filtration. The resultant filtrate was concentrated in vacuo and purified by column chromatography (10% CH_3OH in CH_2Cl_2) to afford the desired ester as pale yellow solid (86.1 g, 41% yield). R_f = 0.44 in 1:9 $\text{CH}_3\text{OH}:\text{CH}_2\text{Cl}_2$; mp. 45-46 °C; IR (CHCl_3) 2980, 1780, 1730 cm^{-1} ; ^1H NMR (CDCl_3) δ 8.41 (2H, bs), 7.22 (10H, m), 6.91 (1H, s),

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5.27 (1H, d, $J = 2.8$ Hz), 5.15 (1H, d, A of ABq, $J = 14$ Hz), 4.94 (1H, s), 4.84 (1H, d, B of ABq, $J = 14$ Hz), 3.73 (1H, d, A of ABq, $J = 17$ Hz), 3.33 (1H, d, B of ABq, $J = 17$ Hz), 1.92 (3H, s); ^{13}C NMR (CDCl_3) δ 169.8, 168.8, 160.6, 138.9, 138.7, 129.5, 129.3, 129.1, 128.7, 128.5, 127.97, 127.61, 127.52, 127.18, 126.52, 126.06, 125.4, 79.0, 63.3, 62.6, 58.5, 25.7, 20.1.

EXAMPLE 2

Benzhydryl 7-oxocephalosporanate (3)

The title compound was prepared by modifying the procedure of Hagiwara et al. To a solution of benzhydryl 7 β -aminocephalosporanate, (5.9 g, 13.5 mmol) in anhydrous CH_2Cl_2 (70 mL) at -78°C , triethylamine (5.6 mL, 40.4 mmol) was added dropwise with stirring. After 5 minutes, trifluoromethanesulfonic anhydride (6.8 mL, 40.4 mmol) was added dropwise to this solution over a 5 minute period. The reaction mixture was allowed to warm slowly to 0°C over a 1 hour period. It was then recooled to -78°C and triethylamine (5.6 mL, 40.4 mmol) was added over approximately 10 minutes. The reaction mixture was stirred at -78°C for an additional 30 minutes and poured into 200 mL cold 0.5 N HCl. The resultant mixture was further stirred until the ice melted. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (150 mL). The combined organic layers were washed with cold 0.5 N HCl (3 X 100 mL), dried (Na_2SO_4), and concentrated (at room temperature or below) to produce the title compound (5.8 g, 98% yield) as a brown solid which was used without further purification. IR (CHCl_3) 3005, 1830, 1790, 1740 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.39 (10H, m), 7.05 (1H, s), 5.32 (1H, s), 5.07 (1H, d, A of ABq, $J = 14$

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Hz), 4.85 (1H, d, B of ABq, J = 14 Hz), 3.64 (1H, d, A of ABq, J = 18 Hz), 3.44 (1H, d, B of ABq, J = 18 Hz), 2.05 (3H, s); ¹³C NMR (CDCl₃) δ 188.4 (s), 170.3 (s), 160.1 (s), 158.7 (s), 138.8 (s), 138.6 (s), 128.4, 128.2, 128.1, 127.7, 126.9, 126.2, 80.1 (d), 65.8 (d), 62.6 (t), 27.7 (t), 20.4 (q).

EXAMPLE 3

Benzhydryl 7-(dibromomethylene) cephalosporanate (4a)

To the solution of Ph₃P (12.0 g, 45.8 mmol) in anhydrous CH₂Cl₂ (75 mL) was added CBr₄ (7.6 g, 22.9 mmol) in one portion at 0 °C. The mixture was stirred at room temperature for 30 minutes. The reaction mixture was then cooled to -78 °C and a cold (-78 °C) solution of benzhydryl 7-oxocephalosporanate 3 (5.00 g, 11.4 mmol) in anhydrous CH₂Cl₂ (40 mL) was added. After stirring at -78 °C for 30 minutes, the reaction was concentrated in vacuo and purified by column chromatography (CH₂Cl₂) to give a pale yellow solid (4.1 g, 61% yield). R_f = 0.55 in CH₂Cl₂, mp 58-60 °C; IR (CHCl₃) 3030, 1780, 1745 cm⁻¹; ¹H NMR (CDCl₃) δ 7.37 (10H, m), 6.96 (1H, s), 5.19 (1H, s), 4.97 (1H, d, A of ABq, J = 13 Hz), 4.72 (1H, d, B of ABq, J = 13 Hz), 3.52 (1H, d, A of ABq, J = 18 Hz), 3.32 (1H, d, A of ABq, J = 18 Hz), 2.00 (3H, s); ¹³C NMR (CDCl₃) δ 170.2 (s), 160.5 (s), 155.6 (s), 142.6 (s), 139.1 (s), 138.9 (s), 128.4, 128.0, 127.9, 127.0, 126.7, 125.2 (s), 92.6 (s), 79.9 (d), 63.0 (t), 60.1 (d), 27.0 (t), 20.5 (q).
Anal. Calcd for C₂₄H₁₉NO₅SBr₂: C, 48.57; H, 3.20; N, 2.36; Found: C, 48.52; H, 3.17; N, 2.19.

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EXAMPLE 4

Benzhydryl 7-(dichloromethylene) cephalosporanate (4b)

CCl₄ (2 mL, 20.7 mmol) was added into a solution of PPh₃ in anhydrous CH₃CN (50 mL) and stirred at room temperature for 30 minutes. This solution was transferred into a solution of benzhydryl 7-oxocephalosporanate 3 (3.0 g, 8.9 mmol) in anhydrous CH₃CN (20 mL) and Zn/Cu (1.0 g, 15 mmol) was added. This reaction mixture was further stirred at room temperature for 40 minutes. The unreacted Zn/Cu was removed by filtration and the filtrate was concentrated and purified by column chromatography (CH₂Cl₂) to yield a pale yellow solid (2.70 g, 78%). R_f = 0.73 in CH₂Cl₂; mp 48-50 °C; IR (CHCl₃) 3050, 1780, 1740, 940 cm⁻¹; ¹H NMR (CDCl₃) δ 7.38 (10H, m), 6.99 (1H, s), 5.29 (1H, s), 5.02 (1H, d, A of ABq, J = 13 Hz), 4.76 (1H, d, B of ABq, J = 13 Hz), 3.57 (1H, d, A of ABq, J = 18 Hz), 3.88 (1H, d, B of ABq, J = 18 Hz), 2.04 (3H, s); ¹³C NMR (CDCl₃) δ 170.0 (s), 160.2 (s), 154.5 (s), 138.8 (s), 138.7 (s), 136.2 (s), 128.1, 127.7, 127.2, 126.6, 126.2, 124.7 (s), 123.6 (s), 79.8 (d), 62.8 (t), 57.4 (d), 26.9 (t), 20.3 (q); high-resolution mass spectrum for [C₂₄H₁₉NO₅SCl₂Na]⁺, i.e. [M+Na]⁺, m/z calcd 526.0259, found 526.0251.

EXAMPLE 5

Benzhydryl 7-[(E)-benzylidene] cephalosporanate and benzhydryl 7-[(Z)-benzylidene] cephalosporanate (4c)

To a solution of triphenylbenzyl phosphonium bromide (11.44 g, 26.4 mmol) in anhydrous THF (50 mL) was added a solution of n-BuLi (14.5 mL, 29.0 mmol) at -78 °C. The mixture was stirred at room temperature for 30 minutes. The resulting red colored

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solution was recooled to -78°C and was added to a cold (-78°C) solution of 7-oxocephalosporanate 3 (10.5 g, 24.0 mmol) in anhydrous THF (25 mL) and stirred at -78°C for 5 minutes. The cold reaction mixture was then poured into ice cold saturated NH_4Cl solution (25 mL) and the layers were separated. The aqueous layer was extracted with ether (2x50 mL). The combined organic layers were washed with water (25 mL), dried (Na_2SO_4), concentrated and purified by column chromatography (CH_2Cl_2 : Hexane, 3:1) to give the *E*-isomer (0.83 g, 40%), and the *Z*-isomer (1.26 g, 60%) as white fluffy solid.

7-(*E*)-isomer. $R_f = 0.60$ in CH_2Cl_2 ; mp $59-61^{\circ}\text{C}$; IR (CHCl_3) 3015 , 1760 , 1730 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.83 (2H, m), 7.26 (13H, m), 6.93 (1H, s), 6.53 (1H, s), 4.99 (1H, s), 4.78 (1H, d, A of ABq, $J = 13\text{ Hz}$), 4.53 (1H, d, B of ABq, $J = 13\text{ Hz}$), 3.39 (1H, d, A of ABq, $J = 18\text{ Hz}$), 3.19 (1H, d, B of ABq, $J = 18\text{ Hz}$), 1.85 (3H, s); ^{13}C NMR (CDCl_3) δ 170.2 (s), 161.1 (s), 158.7 (s), 139.3 (s), 139.1 (s), 136.0 (s), 134.0 (d), 133.1, 130.3, 128.6, 128.3, 128.0, 127.7, 127.0, 121.7 (s), 79.6 (d), 63.1 (t), 56.1 (d), 27.9 (t), 20.5 (q). Anal. Calcd for $\text{C}_{30}\text{H}_{25}\text{NO}_5\text{S}$: C, 70.45; H, 4.89; N, 2.74. Found: C, 70.80; H, 5.03; N, 2.95.

7-(*Z*)-isomer. $R_f = 0.50$ in CH_2Cl_2 ; mp $45-47^{\circ}\text{C}$; IR (CHCl_3) 3025 , 1790 , 1760 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.43 (15H, m), 7.21 (1H, d, $J = 1.18\text{ Hz}$), 7.07 (1H, s), 5.50 (1H, d, $J = 1.23\text{ Hz}$), 5.00 (1H, d, A of ABq, $J = 13\text{ Hz}$), 4.75 (1H, d, B of ABq, $J = 13\text{ Hz}$), 3.65 (1H, d, A of ABq, $J = 18\text{ Hz}$), 3.41 (1H, d, B of ABq, $J = 18\text{ Hz}$), 2.04 (3H, s); ^{13}C NMR (CDCl_3) δ 170.3 (s), 161.0 (s), 160.2 (s), 139.3 (s), 139.1 (s), 135.8 (s), 132.4 (d), 130.5, 129.7, 129.0, 128.3, 128.1, 127.9, 127.7, 127.0, 121.7 (s), 79.7 (d), 63.1 (t), 57.7

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(d), 28.0 (t), 20.5 (q); high-resolution mass spectrum for $[C_{30}H_{25}NO_5SNa]^+$, i.e. $[M+Na]^+$, m/z calcd 534.1351, found 534.1352.

EXAMPLE 6

Benzhydryl 7-[(Z)-(2'-pyridyl)methylene] cephalosporanate (4e)

5 To a solution of 2-picolyl chloride hydrochloride (13.1 g, 80 mmol) in water (20 mL) was added into K_2CO_3 (11.0 g, 80 mmol). After the carbonate was completely dissolved, the solution was extracted with ether (3x10 mL). The combined organic layers were washed with saturated NaCl solution (1x30 mL), dried (Na_2SO_4) and
10 concentrated to give picolyl chloride (9.2 g, 90%). Picolyl chloride (8.9 g, 70 mmol), triphenylphosphine (18.3 g, 70 mmol) and 1,4-dioxane (30 mL) were mixed and refluxed for 24 hours. The reaction mixture was washed with ether (2x30 mL) and the remaining solid was dried in vacuo to give a white solid (25.5 g,
15 94%). A mixture of 2-picolyltriphenylphosphonium chloride (5.8 g, 15 mmol) and sodium amide (0.58, 15 mmol) in THF (15 mL) was stirred at room temperature for 30 minutes. The resulting brown suspension was cooled to $-78^\circ C$ and a solution of benzhydryl 7-oxocephalosporanate 3 (6.6 g, 15 mmol) in THF (15 mL) was added
20 in one portion and the mixture was stirred at $-78^\circ C$ for 15 minutes. The reaction was quenched by the addition of saturated ammonium chloride solution (10 mL) and the reaction mixture extracted with EtOAc (2x20 mL). The combined organic layers were washed with water (2 x 40 mL), dried over $MgSO_4$, concentrated and
25 purified by column chromatography to obtain a yellow solid (2.9 g, 38%). $R_f = 0.28$ in 2% EtOAc in CH_2Cl_2 ; mp $181-183^\circ C$; IR ($CHCl_3$) 3060, 1810, 1750 cm^{-1} ; ^1H NMR ($CDCl_3$) δ 8.68 (1H, d), 7.72 (1H, t), 7.35 (12H, m), 7.15 (1H, s), 7.10 (1H, s), 5.66 (1H, s),

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4.96 (1H, d, A of ABq, 13 Hz), 4.73 (1H, d, B of ABq, J = 13 Hz),
3.63 (1H, d, A of ABq, J = 18 Hz), 3.63 (1H, D, B of ABq, J = 18
Hz), 2.01 (3H, s); ^{13}C NMR (CDCl_3) δ 170.3 (s), 161.0 (s), 160.2
(s), 151.6 (d), 150.1 (s), 140.6 (s), 139.3 (s), 139.1 (s), 136.6
5 (d), 128.3, 127.9, 127.8, 127.6, 127.2, 126.9, 125.8 (s), 123.9
(s), 123.5 (s), 79.5 (d), 63.0 (t), 58.5 (d), 28.0 (t), 20.5 (q);
high-resolution mass spectrum for $[\text{C}_{29}\text{H}_{24}\text{N}_2\text{O}_5\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$,
m/z calcd 535.1304, found 535.1300.

EXAMPLE 7

10 Benzhydryl 7-[(Z)-methoxycarbonylmethylene] cephalosporanate (4f)

To a solution of benzhydryl 7-oxocephalosporanate (1.0 g,
2.3 mmol) in anhydrous CH_2Cl_2 (20 mL) at -78°C was added
methyl(triphenylphosphoranylidene)acetate (0.67 g, 2.0 mmol).
The mixture was then stirred at -78°C for 30 minutes. Acetic
15 acid (0.5 mL) was added to quench the reaction and the reaction
mixture was concentrated and purified by column chromatography to
give title compound as a pale yellow solid (0.67 g, 68%). R_f =
0.42 in 2% EtOAc in CH_2Cl_2 ; mp $47-49^\circ\text{C}$; IR (CHCl_3) 3050, 1790,
1730 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.36 (10H, m), 7.00 (1H, s), 6.49 (1H,
20 s), 5.50 (1H, s), 5.00 (1H, d, A of ABq, J = 13.48 Hz), 4.76 (1H,
d, B of ABq, J = 13.47 Hz), 3.84 (3H, s), 3.64 (1H, d, A of ABq,
J = 18.75 Hz), 3.39 (1H, d, B of ABq, J = 18.75 Hz), 2.03 (3H,
s); ^{13}C NMR (CDCl_3) δ 170.3 (s), 163.8 (s), 160.6 (s), 157.5 (s),
152.6 (s), 139.2 (s), 139.0 (s), 128.6, 128.3, 127.9, 127.6,
25 127.3, 126.90, 125.45 (s), 117.51 (d), 79.90 (d), 62.96 (t),
57.88 (d), 52.48 (q), 27.91 (t), 20.59 (q). Anal. Calcd for
 $\text{C}_{26}\text{H}_{23}\text{NO}_7\text{S}$: C, 63.29; H, 4.66; N, 2.84. Found: C, 63.47; H, 4.73;
N, 2.87.

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EXAMPLE 8

Benzhydryl 7-[(Z)-t-butoxycarbonylmethylene]
cephalosporanate (4g)

To a solution of benzhydryl 7-oxocephalosporanate in example
5 2 (4.0 g, 9.2 mmol) in anhydrous CH_2Cl_2 (40 mL) at -78°C was
added a solution of t-butyl(triphenyl-phosphoranylidene)acetate
(3.45 g, 9.15 mmol in 40 mL CH_2Cl_2). The mixture was then
stirred at -78°C for 30 minutes. Acetic acid (1 mL) was added
to quench the reaction and the reaction mixture was concentrated
10 and purified by column chromatography to give title compound as a
pale yellow solid (yield = 55%). $R_f = 0.52$ in 2% EtOAc in CH_2Cl_2 .
mp $48-50^\circ\text{C}$; IR (CHCl_3) $3050, 1780, 1730\text{ cm}^{-1}$; ^1H NMR (CDCl_3) δ
7.36 (10H, m), 7.00 (1H, s), 6.39 (1H, s), 5.47 (1H, s), 5.00
(1H, d, A of ABq, $J = 13.48\text{ Hz}$), 4.77 (1H, d, B of ABq, $J =$
15 13.48 Hz), 3.62 (1H, d, A of ABq, $J = 18\text{ Hz}$), 3.38 (1H, d, B of
ABq, $J = 18\text{ Hz}$), 2.02 (3H, s), 1.54 (9H, s); ^{13}C NMR (CDCl_3) δ
170.2 (s), 162.4 (s), 160.5 (s), 157.8 (s), 150.1, (s), 139.0
(s), 138.8 (s), 128.3, 128.0, 127.9, 127.5, 126.9, 125.0 (s),
119.9 (d), 82.9 (s), 79.7 (d), 62.8 (t), 57.5 (d), 28.0 (q), 27.9
20 (t), 20.4 (q). Anal. Calcd for $\text{C}_{29}\text{H}_{29}\text{NO}_5\text{S}$: C, 65.05; H, 5.42; N,
2.62. Found: C, 64.50; H, 5.42, N, 2.62.

EXAMPLE 9

Benzhydryl 7-[(Z)-acetylmethylene] cephalosporanate (4h)

This compound was prepared as described for compound example
25 8 (yield = 58%). $R_f = 0.29$ in 2% EtOAc in CH_2Cl_2 ; mp $49-50^\circ\text{C}$; IR
(CHCl_3) $3000, 1770, 1720\text{ cm}^{-1}$; ^1H NMR (CDCl_3) δ 7.36 (10H, m), 7.00
(1H, s), 6.48 (1H, s), 5.50 (1H, s), 5.00 (1H, d, A of ABq, $J =$
13.47 Hz), 4.77 (1H, d, B of ABq, $J = 13.48\text{ Hz}$), 3.63 (1H, d, A

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of ABq, $J = 18.75$ Hz), 3.38 (1H, d, B of ABq, $J = 18.75$ Hz). 2.39 (3H, s), 2.02 (3H, s). ^{13}C NMR (CDCl_3) δ 195.8 (s), 170.3 (s), 160.6 (s), 158.5 (s), 149.5 (s), 139.3 (s), 139.1 (s), 128.5, 127.8, 127.1, 126.9, 126.3, 125.6 (s), 122.7 (d), 79.8 (d), 63.0 (t), 58.0 (d), 30.9 (q), 28.0 (t), 20.7 (q). Anal. Calcd for $\text{C}_{26}\text{H}_{23}\text{NO}_6\text{S}$: 65.41, 4.82, 2.94. Found: C, 65.89; H, 4.87; N, 3.11.

EXAMPLE 10

Benzhydryl 7-[(Z)-formylmethylene] cephalosporanate (4i)

This compound was prepared as described for compound example 10 8 (yield = 46%). $R_f = 0.37$ in 2% EtOAc in CH_2Cl_2 ; mp 113-115 °C; IR (CHCl_3) 3050, 1780, 1730, 1700 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.39 (10H, m), 6.99 (1H, s), 6.60 (1H, d, $J = 6.17$ Hz), 5.45 (1H, s), 5.00 (1H, d, A of ABq, $J = 13.51$ Hz), 4.75 (1H, d, B of ABq, 13.55 Hz), 3.64 (1H, d, A of ABq, $J = 18.59$ Hz), 3.41 (1H, d, B of ABq, $J = 18.61$ Hz), 2.00 (3H, s); ^{13}C NMR (CDCl_3) δ 188.2 (d), 170.1 (s), 160.3 (s), 157.0 (s), 154.7 (s), 138.9 (s), 138.8 (s), 128.4, 128.1, 128.0, 127.6, 126.9, 126.7, 125.0 (s), 123.5 (d), 79.9 (d), 62.4 (t), 56.4 (d), 28.1 (t), 20.4 (q); high-resolution mass spectrum for $[\text{C}_{25}\text{H}_{21}\text{NO}_5\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 486.0987, found 468.0981.

EXAMPLE 11

Benzhydryl 7-[(Z)-hydroxymethylmethylene] cephalosporanate (4j)

To a solution of the formylmethylene cephalosporanate described in example 10 (0.75 g, 1.62 mmol) in methanol (10 mL) and acetic acid (1 mL) was added NaCNBH_3 (0.51 g, 8.1 mmol) in one portion, and stirred at room temperature for 30 minutes. The reaction mixture was concentrated in vacuo, and the residue was dissolved in EtOAc (25 mL) and water (10 mL). The aqueous layer

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was exacted with EtOAc (1 x 30 mL), and the combined organic layer was washed with water (1 x 30 mL), dried (Na_2SO_4), concentrated and purified by column chromatography to give a white solid (0.71g, 94%). $R_f = 0.3$ in 10% EtOAc in CH_2Cl_2 ; mp 58-60 °C; ^1H NMR (CDCl_3) δ 7.39 (10H, s), 7.01 (1H, s), 6.51 (1H, s), 5.29 (1H, s), 4.94 (1H, d, A of ABq, $J = 13.16$ Hz), 4.71 (1H, d, B of ABq, $J = 13.18$ Hz), 4.60 (1H, d, A of ABq, $J = 20.83$ Hz), 4.42 (1H, d, B of ABq, $J = 20.22$ Hz), 3.56 (1H, d, A of ABq, $J = 18.37$ Hz), 3.33 (1H, d, B of ABq, $J = 18.09$ Hz), 2.01 (3H, s); ^{13}C NMR (CDCl_3) δ 170.5 (s), 161.2 (s), 159.9 (s), 139.0 (s), 138.8 (s), 137.4 (s), 131.8 (d), 128.3, 128.0, 127.9, 127.6, 127.4, 126.8, 122.2 (s), 79.6 (d), 63.0 (t), 60.0 (t), 56.9 (d), 28.0 (t), 20.5 (q); high-resolution mass spectrum for $[\text{C}_{25}\text{H}_{23}\text{NO}_5\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 488.1144, found 488.1138.

EXAMPLE 12

Benzhydryl 7-[(Z)-N-methoxy-N-methylaminocarbonylmethylene]
cephalosporanate (4k)

To a solution of benzhydryl 7-oxocephalosporanate (1.0 g, 2.3 mmol) in anhydrous CH_2Cl_2 (20 mL) at -78 °C was added N-methoxy-N-methyl-2-(triphenyl-phosphoranylidene)acetamide (0.73 g, 2.0 mmol). The mixture was stirred at -78 °C for 10 minutes, and then warmed to 0 °C and further stirred for 15 minutes. Acetic acid (0.5 mL) was added to quench the reaction, and the reaction mixture was concentrated and purified by column chromatography (2% EtOAc in CH_2Cl_2) to give title compound as a pale yellow solid (0.53 g, 51%). IR (CHCl_3) 3050, 1780, 1730 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.35 (10H, m), 7.06 (1H, s), 7.00 (1H, s), 5.56 (1H, s), 4.96 (1H, d, A of ABq, $J = 13.40$ Hz), 4.75 (1H, d,

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B of ABq, $J = 13.52$ Hz), 3.75 (3H, s), 3.64 (1H, d, B of ABq, $J = 18.43$ Hz), 3.37 (1H, d, B of ABq, $J = 18.97$ Hz), 3.28 (3H, s), 2.01 (3H, s); ^{13}C NMR (CDCl_3) δ 170.4 (s), 163.1 (s), 160.8 (s), 158.5 (s), 151.2 (s), 139.2 (s), 139.0 (s), 128.5, 128.4, 128.1, 128.0, 127.8, 127.0, 124.8 (s), 115.6 (d), 79.8 (d), 63.0 (t), 62.4 (q), 58.0 (d), 32.2 (q), 28.1 (t), 20.6 (q).

EXAMPLE 13

Benzhydryl 7-[(*E*)-bromomethylene] cephalosporanate (41)

To a solution of 7-(dibromomethylene) cephalosporanate (1.19 g, 2 mmol) in methanol (20 mL) and THF (10 mL) was added NH_4Cl (8.56 g, 16 mmol) in one portion at 0 °C. The mixture was stirred for 5 minutes. Zn/Cu (5.20 g, 8 mmol) was added in one portion and further stirred at room temperature for 30 minutes. The solvent was removed, and residue was extracted with ether (2 x 20 mL). The obtained ether was washed with water (1 x 20 mL) and brine (1 x 10 mL), dried (Na_2SO_4), concentrated and purified by column chromatography (CH_2Cl_2) to give a white solid (0.86 g, 83% yield). $R_f = 0.41$ in CH_2Cl_2 ; mp 48-50 °C; IR (CHCl_3) 3025, 1780, 1730 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.32 (10H, m), 6.96 (1H, s), 6.44 (1H, s), 5.05 (1H, s) 4.92 (1H, d, A of ABq, $J = 13.37$ Hz), 4.67 (1H, d, B of ABq, $J = 13.36$ Hz), 3.46 (1H, d, A of ABq, $J = 18.31$ Hz), 3.26 (1H, d, B of ABq, $J = 18.37$ Hz), 1.96 (3H, s); ^{13}C NMR (CDCl_3) δ 170.15 (s), 160.60 (s), 157.04 (s), 141.77 (s), 139.05 (s), 138.86 (s), 128.32, 127.97, 127.89, 127.49, 126.92, 123.30 (s), 107.94 (d), 79.82 (d), 62.90 (t), 58.02 (d), 27.68 (t), 20.42 (q). Anal. Calcd for $\text{C}_{24}\text{H}_{20}\text{NO}_5\text{SBr}$: C, 56.03; H, 3.89; N, 2.72. Found: C, 56.29; H, 3.87; N, 2.63.

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EXAMPLE 14

Benzhydryl 7-[(Z)-t-butylmethylene] cephalosporanate (4m)

To a suspension of CuCN (1.65 g, 3.2 mmol) in anhydrous THF (50 mL) at -78 °C was added t-BuLi (3.8 mL, 4.2 mmol). The cooling bath was removed until all the solid had gone into the solution. This cuprate solution was cooled to -78 °C and a solution of benzhydryl 7-(E)-bromomethylene cephalosporanate (1.65 g, 3.2 mmol in anhydrous THF, 15 mL) at -78 °C was cannulated to the cuprate solution as fast as possible. The solution was stirred at -78 °C for 1 minutes before quenching with saturated NH₄Cl solution (20 mL). The reaction mixture was extracted with ether (50 mL). The combined organic layers were washed with cold saturated NH₄Cl (2 x 10 mL), dried over Na₂SO₄, concentrated, and purified by column chromatography (CH₂Cl₂) to give a white solid (1.23 g, 78% yield). R_f = 0.64 in CH₂Cl₂; mp 120-121 °C; IR (CHCl₃) 2950, 1765, 1730 cm⁻¹; ¹H NMR (CDCl₃) δ 7.35 (10H, m), 7.00 (1H, s), 6.00 (1H, s), 4.93 (1H, s), 4.86 (1H, d, A of ABq, J = 13.07 Hz), 4.63 (1H, d, B of ABq, J = 13.05 Hz), 3.48 (1H, d, A of ABq, J = 18.30 Hz), 3.28 (1H, d, B of ABq, J = 18.32 Hz), 1.96 (3H, s), 1.24 (9H, s); ¹³C NMR (CDCl₃) δ 170.30 (s), 161.44 (s), 158.31 (s), 147.87 (d), 139.30 (s), 139.08 (s), 135.76 (s), 128.31, 128.02, 127.80, 127.03, 121.01 (s), 79.50 (d), 63.10 (t), 55.72 (d), 34.43 (s), 29.83 (q), 27.86 (t), 20.50 (q). Anal. Calcd for C₂₈H₂₉NO₅S: C, 68.43; H, 5.91; N, 2.85. Found: C, 67.98; H, 5.90; N, 2.72.

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EXAMPLE 15

Benzhydryl 7-[dibromomethylene] cephalosporanate sulfone (5a)

To a solution of the corresponding sulfide 4a (0.3 g, 0.5 mmol) in CH_2Cl_2 (10 mL) and pH = 6.4 Buffer solution (10 mL) was added m-CPBA (85%, 0.35 g, 2.0 mmol) in one portion. The mixture was stirred at room temperature for 40 minutes, and then ether (50 mL) was added. After separating layers, the organic layers were washed with saturated NaHCO_3 (3 x 30 mL), dried (NaSO_4), concentrated and purified by column chromatography to yield a white solid (2.5 g, 79%). R_f = 0.50 in 2% EtOAc in CH_2Cl_2 ; mp 62-64 °C; IR (CHCl_3) 3030, 1800, 1740, 1350, 1130 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.36 (10H, m), 6.95 (1H, s), 5.20 (1H, s), 5.03 (1H, d, A of ABq, J = 14.18 Hz), 4.68 (1H, d, B of ABq, J = 14.16 Hz), 4.02 (1H, d, A of ABq, J = 18.38 Hz), 3.77 (1H, d, B of ABq, J = 18.40 Hz), 2.02 (3H, s); ^{13}C NMR (CDCl_3) δ 170.1 (s), 159.6 (s), 154.8 (s), 138.8 (s), 138.7 (s), 135.2 (s), 128.6, 128.3, 127.5, 127.1, 126.4, 125.5 (s), 124.1(s), 98.2 (s), 80.8 (d), 73.0 (d), 62.0 (t), 52.1 (t), 20.5 (q). Anal. Calcd for $\text{C}_{24}\text{H}_{19}\text{NO}\cdot\text{SBr}_2$: C, 46.08; H, 3.04; N, 2.24; Br, 25.60. Found: C, 46.29; H, 3.09; N, 2.13, Br, 26.18.

EXAMPLE 16

Benzhydryl 7-[dichloromethylene] cephalosporanate sulfone (5b)

This compound was prepared from the corresponding sulfide 4b as described for the compound in example 15 to give a white solid (yield = 81%). R_f = 0.38 in 2% EtOAc in CH_2Cl_2 ; mp 64-66 °C; IR (CHCl_3) 3050, 1800, 1740, 1350, 1140 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.35 (10H, m), 6.95 (1H, s), 5.28 (1H, s), 5.05 (1H, d, A of ABq, J = 14.14 Hz), 4.65 (1H, d, B of ABq, J = 13.90 Hz), 4.03 (1H, d, A of

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ABq, $J = 18.08$ Hz), 3.80 (1H, B of ABq, 17.74 Hz), 2.04 (3H, s);
 ^{13}C NMR (CDCl_3) δ 170.2 (s), 159.6 (s), 153.9 (s), 138.6 (s),
 138.5 (s), 134.3 (s), 130.2 (s), 128.9, 128.6, 128.3, 127.6,
 127.3, 127.1, 124.3 (s), 80.7 (d), 70.7 (d), 61.9 (t), 51.7 (t),
 20.5 (q). Anal. Calcd for $\text{C}_{24}\text{H}_{19}\text{NO}\cdot\text{SCl}$: C, 53.73; H, 3.54; N,
 2.61. Found: C, 53.36; H, 3.78; N, 2.47.

EXAMPLE 17

Benzhydryl 7-[(E)-benzylidene] cephalosporanate sulfone (5c)

This compound was prepared from the sulfide 4c (0.51 g, 1.0
 mmol) as described for the compound in example 15 to give a white
 solid (0.350 g, yield = 65%). $R_f = 0.27$ in CH_2Cl_2 . mp 194-196 °C;
 IR (CHCl_3) 2975, 1775, 1730, 1340, 1125 cm^{-1} ; ^1H NMR (CDCl_3) δ 8.00
 (2H, m), 7.41 (13H, m), 7.03 (1H, s), 6.94 (1H, s), 5.24 (1H, s),
 5.04 (1H, d, A of ABq, $J = 13.91$ Hz), 4.70 (1H, d, B of ABq, $J =$
 13.98 Hz), 4.05 (1H, d, A of ABq, $J = 17.96$ Hz), 3.77 (1H, d, B
 of ABq, $J = 18.13$ Hz), 2.05 (3H, s). ^{13}C NMR (CDCl_3) δ 170.3 (s),
 160.1(s), 157.7 (s), 138.9 (s), 138.8 (s), 138.5(d), 132.5,
 131.5, 131.0, 128.9, 128.6, 128.3, 127.7, 127.1, 126.7, 122.8
 (s), 80.4 (d), 69.5 (d), 62.1 (t), 51.2 (t), 20.5 (q); high-
 resolution mass spectrum for $[\text{C}_{30}\text{H}_{25}\text{NO}\cdot\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z
 calcd 566.1249, found 566.1248.

EXAMPLE 18

Benzhydryl 7-[(Z)-benzylidene] cephalosporanate sulfone (5d)

This compound was prepared from the sulfide 4d (0.68 g, 1.3
 mmol) as described for the compound in example 15 to give a white
 solid (yield = 57%, 0.410 g). $R_f = 0.40$ in CH_2Cl_2 . MP 61-63 °C.
 IR (CHCl_3) 3025, 2925, 1780, 1730, 1340, 1130 cm^{-1} ; ^1H NMR (CDCl_3)
 δ 7.42 (15H, m), 7.12 (1H, s), 6.98 (1H, s), 5.53 (1H, s), 4.95

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(1H, d, A of ABq, $J = 13.80$ Hz), 4.65 (1H, d, B of ABq, $J = 13.92$ Hz), 4.04 (1H, d, A of ABq, $J = 18.33$ Hz), 3.77 (1H, d, B of ABq, $J = 18.50$ Hz), 1.96 (3H, s); ^{13}C NMR (CDCl_3) δ 170.1 (s), 159.9 (s), 159.7 (s), 138.8 (s), 138.7 (s), 134.12 (s), 131.6 (d), 131.0, 129.8, 129.1, 128.4, 128.2, 128.1, 127.6, 127.0, 126.7, 126.2, 121.8 (d), 80.3 (d), 71.7 (d), 691.9 (t), 51.6 (t), 20.3 (q); high-resolution mass spectrum for $[\text{C}_{30}\text{H}_{25}\text{NO}_7\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 566.1249, found 566.1262.

EXAMPLE 19

10 Benzhydryl 7-[(Z)-(2'-pyridyl)methylene] cephalosporanate sulfone (5e)

This compound was prepared from the corresponding sulfide 4e (0.45 g, 0.88 mmol) as described for the compound in example 15 to give a white solid (yield = 90%). $R_f = 0.26$ in 2% EtOAc in CH_2Cl_2 ; mp 120-122 °C; IR (CHCl_3) 2975, 2950, 1780, 1720, 1340, 1130 cm^{-1} ; ^1H NMR (CDCl_3) δ 8.67 (1H, d), 7.71 (1H, t), 7.40 (13H, m), 7.00 (1H, s), 5.91 (1H, s), 5.14 (1H, d, A of ABq, $J = 14.07$ Hz), 4.80 (1H, B of ABq, $J = 14.06$ Hz), 4.11 (1H, d, A of ABq, $J = 17.58$ Hz), 3.78 (1H, d, B of ABq, $J = 17.58$ Hz), 2.05 (3H, s); high-resolution mass spectrum for $[\text{C}_{29}\text{H}_{24}\text{N}_2\text{O}_7\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 567.1202, found 567.1198.

EXAMPLE 20

Benzhydryl 7-[(Z)-*t*-butoxycarbonylmethylene] cephalosporanate sulfone (5g)

25 This compound was prepared from the corresponding sulfide 4g as described for the compound in example 15 to give a white solid (yield = 73%). $R_f = 0.68$ in 5% EtOAc in CH_2Cl_2 ; mp 58-60 °C. IR (CHCl_3) 3025, 1800, 1730, 1350, 1160 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.36

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(10H, m), 6.98 (1H, s), 6.59 (1H, s), 5.58 (1H, s), 5.14 (1H, d, A of ABq, $J = 14.35$ Hz), 4.80 (1H, d, B of ABq, $J = 14.35$ Hz), 4.12 (1H, d, A of ABq, $J = 17.58$ Hz), 3.77 (1H, d, B of ABq, $J = 17.87$ Hz), 2.04 (3H, s). ^{13}C NMR (CDCl_3) δ 170.0 (s), 161.5 (s), 159.4 (s), 157.1 (s), 142.3 (s), 138.6 (s), 138.5 (s), 128.8, 128.4, 128.3, 127.2, 127.0, 125.9 (s), 123.5 (d), 83.8 (s), 80.2 (d), 71.6 (d), 61.3 (t), 52.8 (t), 27.6 (q), 20.2 (q); high-resolution mass spectrum for $[\text{C}_{29}\text{H}_{29}\text{NO}_9\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 590.1461, found 590.1447.

10

EXAMPLE 21

Benzhydryl 7-[(Z)-acetylmethylene] cephalosporanate sulfone (5h)

This compound was prepared from the corresponding sulfide 4h as described for the compound in example 15 to give a white solid (yield = 79%). $R_f = 0.66$ in 25% EtOAc in CH_2Cl_2 ; mp 176-178 °C; IR (CHCl_3) 3050, 1800, 1730, 1350, 1140 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.38 (10H, m), 6.99 (1H, s), 6.94 (1H, s), 5.64 (1H, s), 5.13 (1H, d, A of ABq, $J = 14.51$ Hz), 4.81 (1H, d, B of ABq, $J = 14.41$ Hz), 4.12 (1H, d, A of ABq, $J = 17.91$ Hz), 3.80 (1H, d, B of ABq, $J = 17.94$ Hz), 2.46 (3H, s), 2.07 (3H, s). ^{13}C NMR (CDCl_3) δ 194.7 (s), 170.1 (s), 159.5 (s), 157.5 (s), 141.2 (s), 138.7 (s), 138.6 (s), 128.6, 128.3, 127.5, 127.1, 126.8 (s), 125.3 (d), 80.5 (d), 72.2 (d), 61.7 (t), 53.1 (t), 31.0 (q), 20.5 (q); high-resolution mass spectrum for $[\text{C}_{26}\text{H}_{23}\text{NO}_9\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 532.1042, found 532.1045.

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EXAMPLE 22

Benzhydryl 7-[(Z)-hydroxymethylmethylen] cephalosporanate
sulfone (5j)

This compound was prepared from the corresponding sulfide 4j
5 as described in the compound in example 15 to give a white solid
(yield = 68%). $R_f = 0.32$ in 25% EtOAc in CH_2Cl_2 ; mp 58-60 °C; IR
(CHCl_3) 3050, 1780, 1730, 1330, 1130 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.36
(10H, m), 6.97 (1H, s), 6.81 (1H, s), 5.53 (1H, s), 5.05 (1H, d,
A of ABq, $J = 14.06$ Hz), 4.74 (1H, d, B of ABq, $J = 14.06$ Hz),
10 4.61 (1H, d, A of ABq, $J = 19.04$ Hz), 3.98 (1H, d, B of ABq, $J =$
19.03 Hz), 4.06 (1H, d, A of ABq, $J = 17.0$ Hz), 3.76 (1H, d, B of
ABq, $J = 17.80$ Hz), 2.04 (3H, s); ^{13}C NMR (CDCl_3) δ 170.4 (s),
160.0 (s), 158.6 (s), 138.9 (s), 138.8 (s), 136.8 (d), 128.6,
128.1, 127.8, 127.6, 127.5, 127.2, 126.7, 124.3 (s), 80.8 (d),
15 71.4 (d), 61.9 (t), 60.7 (t), 51.4 (t), 20.6 (q); high-resolution
mass spectrum for $[\text{C}_{25}\text{H}_{23}\text{NO}_5\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd
488.1144, found 488.1138.

EXAMPLE 23

Benzhydryl 7-[(Z)-N-methoxy-N-methylaminocarbonylmethylene]
20 cephalosporanate sulfone (5k)

This compound was prepared from the corresponding sulfide 4k
as described for the compound in example 15 to give a white solid
(yield = 68%). $R_f = 0.44$ in 25% EtOAc in CH_2Cl_2 ; mp 81-82 °C; IR
(CHCl_3) 3050, 1800, 1740, 1360, 1140 cm^{-1} ; ^1H NMR (CDCl_3) δ 7.36
25 (10H, m), 7.28 (1H, s), 6.98 (1H, s), 5.72 (1H, s), 5.10 (1H, d,
A of ABq, $J = 14.06$ Hz), 4.82 (1H, d, B of ABq, $J = 14.35$ Hz),
4.11 (1H, d, A of ABq, $J = 16.70$ Hz), 3.78 (1H, d, B of ABq, $J =$
17.58 Hz), 3.78 (3H, s), 3.31 (3H, s), 2.06 (3H, s); ^{13}C NMR

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(CDCl₃) δ 170.1 (s), 162.1 (s), 159.7 (s), 157.8 (s), 142.78 (s), 138.9 (s), 138.8 (s), 128.7, 128.4, 127.7, 127.4, 127.1, 126.9, 125.7 (s), , 119.3 (d), 80.3 (d), 72.3 (d), 62.5 (q), 61.8 (t), 52.9 (t), 32.3 (q), 20.5 (q); high-resolution mass spectrum for
5 [C₂₇H₂₆N₂O₉SNa]⁺, i.e. [M+Na]⁺, m/z calcd 577.1257, found 577.1247.

EXAMPLE 24

Benzhydryl 7-[(E)-bromomethylene] cephalosporanate sulfone (5l)

This compound was prepared from the corresponding sulfide 4l as described for the compound in example 15 to give a white solid
10 (yield = 71%). R_f = 0.43 in 2% EtOAc in CH₂Cl₂; mp 80-82 °C; IR (CHCl₃) 3030, 1800, 1730, 1350, 1130 cm⁻¹; ¹H NMR (CDCl₃) δ 7.33 (10H, m), 6.94 (1H, s), 6.91 (1H, s), 5.10 (1H, s), 5.00 (1H, d, A of ABq, J = 14.19 Hz), 4.67 (1H, d, B of ABq, J = 14.17 Hz), 3.97 (1H, A of ABq, J = 18.06 Hz), 3.69 (1H, d, B of ABq, J =
15 18.17 Hz), 1.99 (1H, s); ¹³C NMR (CDCl₃) δ 170.1 (s), 159.7 (s), 156.3 (s), 138.7 (s), 138.6 (s), 134.0 (s), 128.4, 128.1, 127.3, 126.9, 125.7, 124.9 (s), 112.5 (d), 80.57 (d), 70.9 (d), 61.8 (t), 51.2 (t), 20.4 (q). Anal. Calcd for C₂₄H₂₀NO₇SBr: C, 52.75; H, 3.66; N, 2.56. Found: C, 52.78, H, 3.75; N, 2.77.

20

EXAMPLE 25

Benzhydryl 7-[(Z)-t-butylmethylene] cephalosporanate sulfone (5m)

This compound was prepared from the corresponding sulfide 4m as described in the compound in example 15 to give a white solid
25 (yield = 84%). R_f = 0.48 in 2% EtOAc in CH₂Cl₂; mp 147-149 °C; IR (CHCl₃) 3050, 3000, 1785, 1740, 1340, 1130 cm⁻¹; ¹H NMR (CDCl₃) δ 7.37 (10H, m), 6.97 (1H, s), 6.26 (1H, d, J = 1.0 Hz), 5.01 (1H, d, J = 1.0 Hz), 4.97 (1H, d, A of ABq, J = 13.86 Hz), 4.65 (1H, d, B of ABq, J = 13.83 Hz), 3.96 (1H, d, A of ABq, J = 18.27 Hz),

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3.82 (1H, d, B of ABq, $J = 17.95$), 2.01 (3H, s), 1.29 (9H, s);
 ^{13}C NMR (d^6 -acetone) δ 170.40 (s), 160.92 (s), 158.49 (s), 152.29
(d), 140.44 (s), 140.24 (s), 128.89, 128.63, 128.00, 127.58,
126.43, 124.24 (s), 80.42 (d), 69.70 (d), 62.41 (t), 51.15 (t),
5 35.40 (s), 29.67 (q), 20.33 (q); high-resolution mass spectrum
for $[\text{C}_{28}\text{H}_{29}\text{NO}_7\text{SNa}]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z calcd 546.1562, found
546.1551.

EXAMPLE 26

Sodium salt of 7-[dibromomethylene] cephalosporanic acid (**6a**)

10 To a solution of benzhydryl 7-dibromomethylene
cephalosporanate **4a** (0.3 g, 0.5 mmol) in anhydrous CH_2Cl_2 (10 mL)
was added anisole (0.54 mL, 5 mmol) at -78°C followed by the
addition of AlCl_3 solution (1.25 mL, 1.25 mmol) in one portion.
The mixture was stirred at -78°C for 15 minutes and poured into
15 rapidly stirred cold water (30 mL) containing NaHCO_3 (0.42 g, 5
mmol), followed by the addition of EtOAc (30 mL). It was further
stirred for 5 minutes and filtered using celite 545. The aqueous
layer was separated and concentrated in vacuo to about 2 mL and
purified by reverse phase chromatography followed by
20 lyophilization to yield a pink solid (180 mg, 80%). $R_f = 0.62$ in
10% EtOH in water; UV: $\lambda_{\text{max}} = 252$ nm (50 mM phosphate buffer, pH =
7.2), $\epsilon = 14,434 \text{ cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1730, 1600, 1390
 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 5.42 (1H, s), 4.91 (1H, d, A of ABq, $J =$
12.15), 4.71 (1H, d, B of ABq, $J = 11.89$ Hz), 3.50 (1H, d, A of
25 ABq, $J = 17.39$ Hz), 3.22 (1H, d, B of ABq, $J = 17.72$ Hz), 1.99
(3H, s); high-resolution mass spectrum for $[\text{C}_{11}\text{H}_9\text{NO}_5\text{SBr}_2\text{Na}_2]^+$, i.e.
 $[\text{M}+\text{Na}]^+$, m/z calcd 469.8285, found 469.8277.

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EXAMPLE 27

Sodium salt of 7-[dichloromethylene] cephalosporanic acid (**6b**)

This compound was prepared from the corresponding ester **4b** (0.3 g, 0.6 mmol) as described in the compound in example 26 to give a pale yellow fluffy solid (yield = 62%). $R_f = 0.66$ in 10% EtOH in water; UV: $\lambda_{max} = 242$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 11,789$ cm⁻¹·mol⁻¹·l; IR (KBr) 2950, 1740, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 5.52 (1H, s), 4.93 (1H, d, A of ABq, J = 12.09 Hz), 4.73 (1H, d, B of ABq, J = 12.70 Hz), 3.53 (1H, d, A of ABq, J = 17.65 Hz), 3.27 (1H, d, B of ABq, J = 17.62 Hz), 1.99 (3H, s); high-resolution mass spectrum for [C₁₁H₉NO₅SCl₂Na]⁺, i.e. [M+H]⁺, m/z calcd 359.9473, found 359.9476.

EXAMPLE 28

Sodium salt of 7-[(Z)-(2'-pyridyl)methylene] cephalosporanic acid (**6c**)

This compound was prepared from the corresponding ester **4c** (0.4 g, 0.78 mmol) as described for the compound in example 26 to give a yellow solid (149 mg, 52%). $R_f = 0.56$ in 10% EtOH in water; UV: $\lambda_{max} = 296$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 11,257$ cm⁻¹·mol⁻¹·l; IR (KBr) 2950, 1720, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 8.64 (1H, d), 7.83 (1H, t), 7.63 (1H, d), 7.37 (1H, t), 7.34 (1H, s), 5.63 (1H, s), 4.92 (1H, d, A of ABq, J = 11.43 Hz), 4.77 (1H, d, B of ABq, J = 12.30 Hz), 3.56 (1H, d, A of ABq, J = 17.57 Hz), 3.27 (1H, d, B of ABq, J = 17.78 Hz), 2.00 (3H, s); high-resolution mass spectrum for [C₁₆H₁₄N₂O₅SNa]⁺, i.e. [M+H]⁺, m/z calcd 369.0518, found 369.0506.

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EXAMPLE 29

Sodium salt of 7-[(Z)-methoxycarbonylmethylene] cephalosporanic
acid (6f)

To a solution of benzhydryl 7-(Z)-(methoxycarbonylmethylene)
5 cephalosporanate 4f (0.25 g, 0.51 mmol) in anisole (1.1 mL, 15.3
mmol) at 0 °C was added trifluoroacetic acid (4.6 mL, 59.7 mmol).
The mixture was stirred for 10 minutes, concentrated in vacuo,
dissolved in 40 mL EtOAc, and then poured into rapidly stirred
NaHCO₃ solution (0.5 g in 30 mL H₂O). The aqueous layer was
10 separated, concentrated in vacuo to 2 mL and further purified by
reverse phase chromatography (R_f = 0.84 in 5% EtOH in water)
followed by lyophilization to yield a pale yellow fluffy solid
(158 mg, 89%). UV: λ_{max} = 226 nm (50 mM phosphate buffer, pH =
7.2), ϵ = 12,254 cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1730, 1600, 1400
15 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 6.47 (1H, s), 5.54 (1H, s), 4.93 (1H, d,
A of ABq, J = 11.71 Hz), 4.79 (1H, d, B of ABq, J = 11.72 Hz),
3.37 (3H, s), 3.58 (1H, d, A of ABq, J = 18.31 Hz), 3.27 (1H, d,
B of ABq, J = 17.58 Hz), 2.01 (3H, s); high-resolution mass
spectrum for [C₁₃H₁₃NO₇SN⁺Na]⁺, i.e. [M+H]⁺, m/z calcd 350.0310,
20 found 350.0310.

EXAMPLE 30

Sodium salt of 7-[(Z)-t-butoxycarbonylmethylene] cephalosporanic
acid (6g)

This compound was prepared from the corresponding ester 4g
25 (0.3 g, 0.56 mmol) as described for example 29 to give a yellow
fluffy solid (176 mg, 81%). R_f = 0.53 in 5% EtOH in water;
UV: λ_{max} = 225 nm (50 mM phosphate buffer, pH = 7.2), ϵ = 11,324

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cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1720, 1600, 1400 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 6.26 (1H, s), 5.47 (1H, s), 4.92 (1H, d, A of ABq, J = 12.00 Hz), 4.72 (1H, d, B of ABq, J = 12.13 Hz), 3.56 (1H, d, A of ABq, J = 18.09 Hz), 3.22 (1H, d, B of ABq, J = 17.74 Hz), 1.99 (3H, s), 1.47 (9H, s); high-resolution mass spectrum for [C₁₆H₁₈NO₅SN₂]⁺, i.e. [M+Na]⁺, m/z calcd 414.0600, found 414.0604.

EXAMPLE 31

Sodium salt of 7-[(Z)-acetylmethylene] cephalosporanic acid (6h)

This compound was prepared from the corresponding ester 4h (0.4 g, 0.84 mmol) as described for example 29 to give a yellow fluffy solid (217 mg, 78%). R_f = 0.8 in 5% EtOH in water; UV: λ_{max} = 235 nm (50 mM phosphate buffer, pH = 7.2), ε = 9,031 cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1750, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 6.68 (1H, s), 5.56 (1H, s), 4.93 (1H, d, A of ABq, J = 12.02 Hz), 4.75 (1H, d, B of ABq, J = 11.20 Hz), 3.56 (1H, d, A of ABq, J = 17.00 Hz), 3.25 (1H, d, B of ABq, J = 17.80 Hz), 2.34 (3H, s), 2.00 (3H, s); high-resolution mass spectrum for [C₁₃H₁₃NO₅SN₂]⁺, i.e. [M+H]⁺, m/z calcd 334.0361, found 334.0360.

EXAMPLE 32

Sodium salt of 7-[(Z)-hydroxymethylmethylene] cephalosporanic acid (6j)

This compound was prepared from the corresponding ester 4j (0.15 g, 0.32 mmol) as described for example 29 to give a white fluffy solid (110 mg, 81%). R_f = 0.86 in water; UV: λ_{max} = 222 nm (50 mM phosphate buffer, pH = 7.2), ε = 8,768 cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1750, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 6.32 (1H, s), 5.27 (1H, s), 4.90 (1H, d, A of ABq, J = 12.29 Hz), 4.68 (1H, d, B of ABq, J = 12.61 Hz), 4.15 (2H, s), 3.45 (1H, d, A of ABq,

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$J = 17.46$ Hz), 3.22 (1H, d, B of ABq, $J = 16.80$ Hz), 1.97 (3H, s); high-resolution mass spectrum for $[C_{12}H_{13}NO_5SNa]^+$, i.e. $[M+H]^+$, m/z calcd 322.0361, found 322.0348.

EXAMPLE 33

5 Sodium of salt of 7-[(Z)-N-methoxy-N-methylamino-carbonylmethylene] cephalosporanic acid (6k)

This compound was prepared from the corresponding ester 4k as described for example 29 to give yellow a fluffy solid (yield = 55%). $R_f = 0.81$ in 5% EtOH in water; UV: $\lambda_{max} = 231$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 11,300$ cm⁻¹.mol⁻¹.l; IR (KBr) 10 2950, 1720, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 6.84 (1H, s), 5.44 (1H, s), 4.89 (1H, d, A of ABq, $J = 11.88$ Hz), 4.72 (1H, d, B of ABq, $J = 11.90$ Hz), 3.72 (3H, s), 3.51 (1H, d, A of ABq, $J = 17.96$ Hz), 3.17 (3H, s), 3.15 (1H, d, B of ABq, $J = 17.54$ Hz), 15 1.98 (3H, s)

EXAMPLE 34

Sodium salt of 7-[(E)-bromomethylene] cephalosporanic acid (6l)

This compound was prepared from the corresponding ester 4l (0.4 g, 0.78 mmol) as described for the compound in example 26 to 20 yield a white fluffy solid (192 mg, 67%). $R_f = 0.77$ in 10% EtOH in water; UV: $\lambda_{max} = 243$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 10,478$ cm⁻¹.mol⁻¹.l; IR (KBr) 2950, 1730, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 7.21 (1H, s), 5.28 (1H, s), 4.93 (1H, d, A of ABq, $J = 11.83$ Hz), 4.70 (1H, d, B of ABq, 11.76 Hz), 3.48 (1H, d, A of ABq, $J = 17.60$ Hz), 3.21 (1H, d, B of ABq, $J = 17.31$ Hz), 1.98 25 (3H, s); high-resolution mass spectrum for $[C_{11}H_9NO_5SBrNa_2]^+$, i.e. $[M+Na]^+$, m/z calcd 391.9178, found 391.9180.

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EXAMPLE 35

Sodium salt of 7-[(Z)-t-butylmethylen] cephalosporanic acid (6m)

This compound was prepared from the corresponding ester 4m (0.4 g, 0.81 mmol) as described for the compound in example 26 to obtain a white fluffy solid (105 mg, 37%). $R_f = 0.55$ in 10% EtOH in water; UV: $\lambda_{max} = 228$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 12,760$ cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1730, 1600, 1390 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 5.98 (1H, s), 5.00 (1H, s), 4.90 (1H, d, A of ABq, J = 11.56 Hz), 4.68 (1H, d, B of ABq, J = 11.78 Hz), 3.43 (1H, d, A of ABq, J = 17.78 Hz), 3.17 (1H, d, B of ABq, J = 17.45 Hz), 1.98 (3H, s), 1.17 (9H, s); high-resolution mass spectrum for [C₁₅H₁₉NO₅SNa]⁺. i.e. [M+H]⁺, m/z calcd 348.0877, found 348.0870.

EXAMPLE 36

Sodium salt of 7-[dibromomethylene]

cephalosporanic acid sulfone (7a)

This compound was prepared from the corresponding ester 5a (0.3 g, 0.5 mmol) as described in the compound in example 26 to give a white fluffy solid (110 mg, 48%). $R_f = 0.83$ in 10% EtOH in water; UV: $\lambda_{max} = 260$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 12,535$ cm⁻¹. mol⁻¹. l; IR (KBr) 2950, 1740, 1600, 1390, 1330, 1130 cm⁻¹; ¹H NMR (d⁶-DMSO) δ 5.89 (1H, s), 4.94 (1H, d, A of ABq, J = 12.27 Hz), 4.66 (1H, d, B of ABq, J = 12.43 Hz), 4.12 (1H, d, A of ABq, J = 18.29 Hz), 3.84 (1H, d, B of ABq, J = 17.28 Hz), 1.99 (3H, s); high-resolution mass spectrum for [C₁₁H₉NO₇SBr₂Na]⁺, i.e. [M+H]⁺, m/z calcd 479.8361, found 479.8349.

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EXAMPLE 37

Sodium salt of 7-[dichloromethylene] cephalosporanic acid
sulfone (7b)

This compound was prepared from the corresponding ester 5b
5 (0.4 g, 0.76 mmol) as described in the compound in example 15 to
give a white fluffy solid (yield = 50%). $R_f = 0.84$ in 10% EtOH
in water; UV: $\lambda_{max} = 245$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon =$
16,679 $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1730, 1600, 1390, 1330, 1130
 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 5.99 (1H, s), 4.93 (1H, d, A of ABq, J =
10 12.60 Hz), 4.64 (1H, d, B of ABq, J = 12.30 Hz), 4.15 (1H, d, A
of ABq, J = 17.57 Hz), 3.90 (1H, d, B of ABq, J = 18.16 Hz), 1.97
(3H, s); high-resolution mass spectrum for $[\text{C}_{11}\text{H}_9\text{NO}_2\text{SCl}_2\text{Na}_2]^+$, i.e.
[M+Na] $^+$, m/z calcd 413.9191, found 413.9197.

EXAMPLE 38

15 Sodium salt of 7-[(E)-benzylidene] cephalosporanic acid
sulfone (7c)

This compound was prepared from the corresponding ester 5c
(300 mg, 0.55 mmol) as described for the compound in example 26
to give title compound as a white fluffy solid (30 mg, 13%
20 yield). $R_f = 0.70$ in 5% EtOH in water; UV : $\lambda_{max} = 308$ (50 mM
phosphate buffer, pH = 7.2), $\epsilon = 15515$ $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr)
2950, 1710, 1600, 1390, 1330, 1130 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ
8.05 (2H, m), 7.47 (3H, m), 6.93 (1H, s), 5.72 (1H, s), 4.95 (1H,
d, A of ABq, J = 12.30 Hz), 4.67 (1H, d, B of ABq, J = 12.19 Hz),
25 4.12 (1H, d, A of ABq, J = 17.60 Hz), 3.79 (1H, d, B of ABq, J =
17.63 Hz), 2.00 (3H, s); high-resolution mass spectrum for
[C₁₇H₁₅NO-SNa] $^+$, i.e. [M+H] $^+$, m/z calcd 400.0463, found 400.0451.

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EXAMPLE 39

Sodium salt of 7-[(Z)-benzylidene] cephalosporanic acid
sulfone (7d)

This compound was prepared from the corresponding ester 5d
(250 mg, 0.46 mmol) as described in the compound in example 26 to
give title compound as a white fluffy solid (77 mg, 42% yield).
 $R_f = 0.80$ in 5% EtOH in water; UV : $\lambda_{\max} = 302$ (50 mM phosphate
buffer, $pH = 7.2$), $\epsilon = 20543 \text{ cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1740,
1600, 1390, 1330, 1130 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 7.79 (2H, m), 7.44
(4H, m), 6.34 (1H, s), 4.95 (1H, d, A of ABq, $J = 12.05 \text{ Hz}$), 4.70
(1H, d, B of ABq, $J = 11.75 \text{ Hz}$), 4.12 (1H, d, A of ABq, $J = 17.73$
Hz), 3.88 (1H, d, B of ABq, $J = 17.54 \text{ Hz}$), 2.02 (3H, s); high-
resolution mass spectrum for $[\text{C}_{17}\text{H}_{15}\text{NO}_7\text{SNa}]^+$, i.e. $[\text{M}+\text{H}]^+$, m/z
calcd 400.0463, found 400.0464.

EXAMPLE 40

Sodium salt of 7-[(Z)-(2'-pyridyl)methylene] cephalosporanic acid
sulfone (7e)

This compound was prepared from the corresponding ester 5e
as described in as described for example 29 as a pale yellow
fluffy solid (yield = 67%). $R_f = 0.78$ in 10% EtOH in water; UV:
 $\lambda_{\max} = 301 \text{ nm}$ (50 mM phosphate buffer, $pH = 7.2$), $\epsilon = 8,624 \text{ cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1720, 1600, 1390, 1330, 1130 cm^{-1} ; ^1H NMR
(d^6 -DMSO) δ 8.59 (1H, d), 7.88 (1H, t), 7.72 (1H, d), 7.42 (2H,
m), 6.22 (1H, s), 4.92 (1H, d, A of ABq, $J = 11.43 \text{ Hz}$), 4.72 (1H,
B of ABq, $J = 10.87 \text{ Hz}$), 4.19 (1H, D, A of ABq, $J = 17.58 \text{ Hz}$),
3.77 (1H, d, B of ABq, $J = 18.45 \text{ Hz}$), 2.00 (3H, s); high-
resolution mass spectrum for $[\text{C}_{16}\text{H}_{13}\text{N}_2\text{O}_7\text{SNa}_2]^+$, i.e. $[\text{M}+\text{Na}]^+$, m/z
calcd 423.0239, found 423.0227.

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EXAMPLE 41

Sodium salt of 7-[(Z)-t-butoxymethylene] cephalosporanic acid
sulfone (7g)

This compound was prepared from the corresponding ester 5g
5 (0.3 g, 0.53 mmol) as described in as described for example 29 to
give a white fluffy solid (163 mg, 73%). $R_f = 0.74$ in 5% EtOH in
water; UV: $\lambda_{max} = 226$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon =$
18,171 $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1720, 1600, 1390, 1330, 1130
 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 6.52 (1H, s), 5.97 (1H, s), 4.97 (1H, d,
10 A of ABq, $J = 12.36$ Hz), 4.72 (1H, d, B of ABq, $J = 12.63$ Hz),
4.16 (1H, d, A of ABq, $J = 12.63$ Hz), 3.79 (1H, d, B of ABq, $J =$
18.21 Hz), 1.99 (3H, s), 1.45 (9H, s). high-resolution mass
spectrum for $[\text{C}_{16}\text{H}_{19}\text{NO}_9\text{SNa}]^+$, i.e. $[\text{M}+\text{H}]^+$, m/z calcd 424.0678,
found 424.0684.

15

EXAMPLE 42

Sodium salt of 7-[(Z)-hydroxymethylmethylen] cephalosporanic
acid sulfone (7j)

This compound was prepared from the corresponding ester 5j
(0.2 g, 0.4 mmol) as described in as described for example 29 to
20 give a white fluffy solid (130 mg, 91.5%). $R_f = 0.90$ in water;
 $\lambda_{max} = 223$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon = 9,428$ $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1750, 1600, 1390, 1330, 1130 cm^{-1} ; ^1H NMR
(d^6 -DMSO) δ 6.54 (1H, s), 5.74 (1H, s), 4.89 (1H, d, A of ABq, J
= 12.05 Hz), 4.66 (1H, d, B of ABq, $J = 11.93$ Hz), 4.14 (2H, s),
25 4.08 (1H, d, A of ABq, $J = 19.29$ Hz), 3.73 (1H, d, B of ABq, $J =$
18.25 Hz), 1.99 (3H, s); high-resolution mass spectrum for
 $[\text{C}_{12}\text{H}_{13}\text{NO}_9\text{SNa}]^+$, i.e. m/z calcd 354.0260, found 354.0274.

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EXAMPLE 43

Sodium salt of 7-(*E*)-[bromomethylene] cephalosporanic acid
sulfone (71)

This compound was prepared from the corresponding ester 51
(0.3 g, 0.55 mmol) as described in the compound in example 26 to
yield a white fluffy solid (128 mg, 58%). $R_f = 0.88$ in 10% EtOH
in water; UV: $\lambda_{max} = 246$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon =$
10,856 $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1730, 1600, 1390, 1330, 1130
 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 7.44 (1H, s), 5.79 (1H, s), 4.96 (1H, d,
A of ABq, $J = 12.30$ Hz), 4.68 (1H, d, A of ABq, $J = 12.28$ Hz),
4.03 (1H, d, A of ABq, $J = 18.53$ Hz), 3.82 (1H, d, B of ABq, $J =$
17.69 Hz), 2.00 (3H, s); high-resolution mass spectrum for
[$\text{C}_{11}\text{H}_{10}\text{NO}_7\text{SBrNa}$] $^+$, i.e. $[\text{M}+\text{H}]^+$, m/z calcd 401.9256, found 401.9245.

EXAMPLE 44

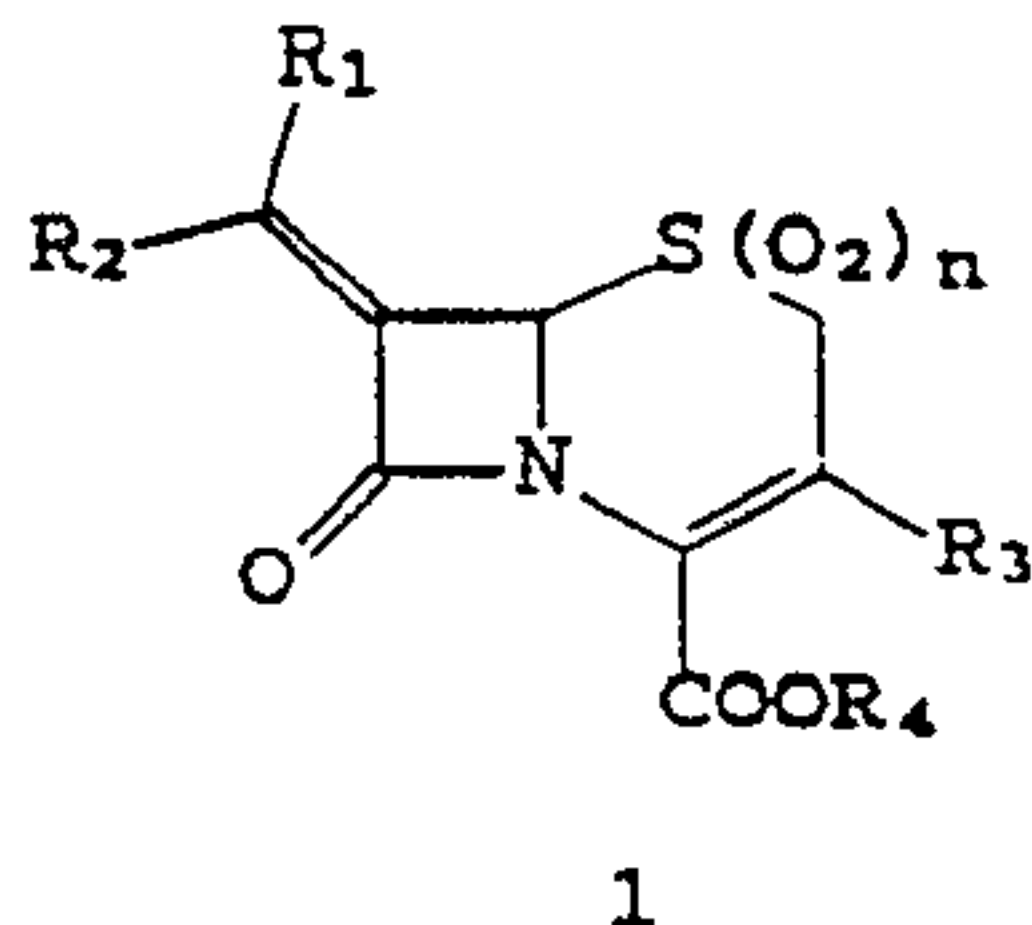
Sodium salt of 7-[(*Z*)-*t*-butylmethylene] cephalosporanic acid
sulfone (7m)

This compound was prepared from the corresponding ester 5m
(0.34 g, 0.65 mmol) as described in the compound in example 26 to
yield a white fluffy solid (2.0 g, 82%). $R_f = 0.79$ in 10% EtOH
in water; UV: $\lambda_{max} = 228$ nm (50 mM phosphate buffer, pH = 7.2), $\epsilon =$
14,215 $\text{cm}^{-1} \cdot \text{mol}^{-1} \cdot \text{l}$; IR (KBr) 2950, 1730, 1600, 1390, 1330, 1130
 cm^{-1} ; ^1H NMR (d^6 -DMSO) δ 6.08 (1H, s), 5.50 (1H, s), 4.91 (1H, d,
A of ABq, $J = 12.24$ Hz), 4.65 (1H, d, B of ABq, $J = 12.26$ Hz),
4.06 (1H, d, A of ABq, $J = 17.41$ Hz), 3.72 (1H, d, B of ABq, $J =$
17.76 Hz), 1.99 (3H, s); high-resolution mass spectrum for
[$\text{C}_{15}\text{H}_{18}\text{NO}_7\text{SNa}$] $^+$, i.e. $[\text{M}+\text{H}]^+$, m/z calcd 380.0775, found 380.0770.

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WHAT IS CLAIMED AS NEW AND DESIRED TO BE SECURED BY LETTERSPATENT OF THE UNITED STATES IS:

1. A compound of formula (1)



wherein n is 0 or 1;

10 R_1 and R_2 are the same or different and are selected from the group consisting of

- a) hydrogen;
- b) linear or branched C_{1-10} -alkyl;
- c) halogen;
- 15 d) hydroxy- C_{1-10} -alkyl;
- e) C_{1-10} -alkoxy;
- f) C_{2-10} -alkanoyloxy;
- g) C_{2-10} -alkene;
- h) C_{2-10} -alkene substituted with one or more groups selected from
- 20 the group consisting of chlorine, fluorine, bromine or phenyl;
- i) C_{1-10} -alkoxycarbonyl;
- j) C_{1-10} -alkoxycarbamido;
- k) N - C_{1-10} -alkoxy- N - C_{1-10} -alkylaminocarbonyl;
- l) halo- C_{1-10} -alkyl;
- 25 m) C_{6-10} -aryl;
- n) C_{6-10} -aryl substituted with one or more groups selected from the group consisting of ethyl, *n*-propyl, isopropyl, amino, methylamino and dimethylamino;

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o) a C₂₋₁₀-heterocycle having from 1-3 heteroatoms selected from the group consisting of O, N and S; and,

p) -COOH or -COOY, wherein Y is pharmaceutically acceptable cation;

5 R₃ is selected from the group consisting of

1) -COOH;

2) chlorine or fluorine;

3) trifluoromethyl;

4) -CHO; and,

10 5) -CH₂M where M is selected from the group consisting of

a) hydrogen;

b) halogen;

c) hydroxy;

d) C₁₋₁₀-alkoxy;

15 e) C₆₋₁₀-aryloxy;

f) C₆₋₁₀-aryl-C₁₋₁₀-alkoxy;

g) mercapto;

h) mercapto substituted with one or more groups selected from the group consisting of methyl, ethyl or phenyl;

20 i) C₂₋₁₀-acylthio;

j) C₂₋₁₀-acyloxy or carbamoyloxy;

k) C₂₋₁₀-acyloxy or carbamoyloxy substituted with one or more groups selected from the group consisting of -COOH, aminophenyl, phenyl, C₁₋₆-alkyl, chlorine, bromine or fluorine;

25 l) a quaternary ammonium salt;

m) amino or amido; and,

n) amino or amido substituted with one or more groups selected from the group consisting of C₁₋₁₀-alkyl groups;

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R₄ is selected from the group consisting of

- a) hydrogen; and,
- b) pharmaceutically acceptable cations.

5 2. The compound of Claim 1, wherein n is 0, R₂ is hydrogen and R₁ is selected from the group consisting of t-butyl, phenyl, pyridyl, COMe and N-methyl-N-methoxy-aminocarbonyl.

3. The compound of Claim 1, wherein n is 0, R₂ is hydrogen, and R₁ is selected from the group consisting of CO₂-t-Bu and CHO.

10 4. The compound of Claim 1, wherein n is 1, R₂ is hydrogen, and R₁ is selected from the group consisting of CO₂Me, CH₂OH and t-butyl.

5. The compound of Claim 1, wherein n is 1, R₂ is hydrogen and R₁ is selected from the group consisting of phenyl, pyridyl and CO₂-t-butyl.

15 6. The compound of Claim 1, wherein n is 0 and R₁ and R₂ are the same and are selected from the group consisting of bromine and chlorine.

20 7. The compound of Claim 1, wherein n is 1 and R₁ and R₂ are the same and are selected from the group consisting of bromine and chlorine.

8. The compound of Claim 1, wherein n is 0, R₁ is hydrogen, and R₂ is bromine.

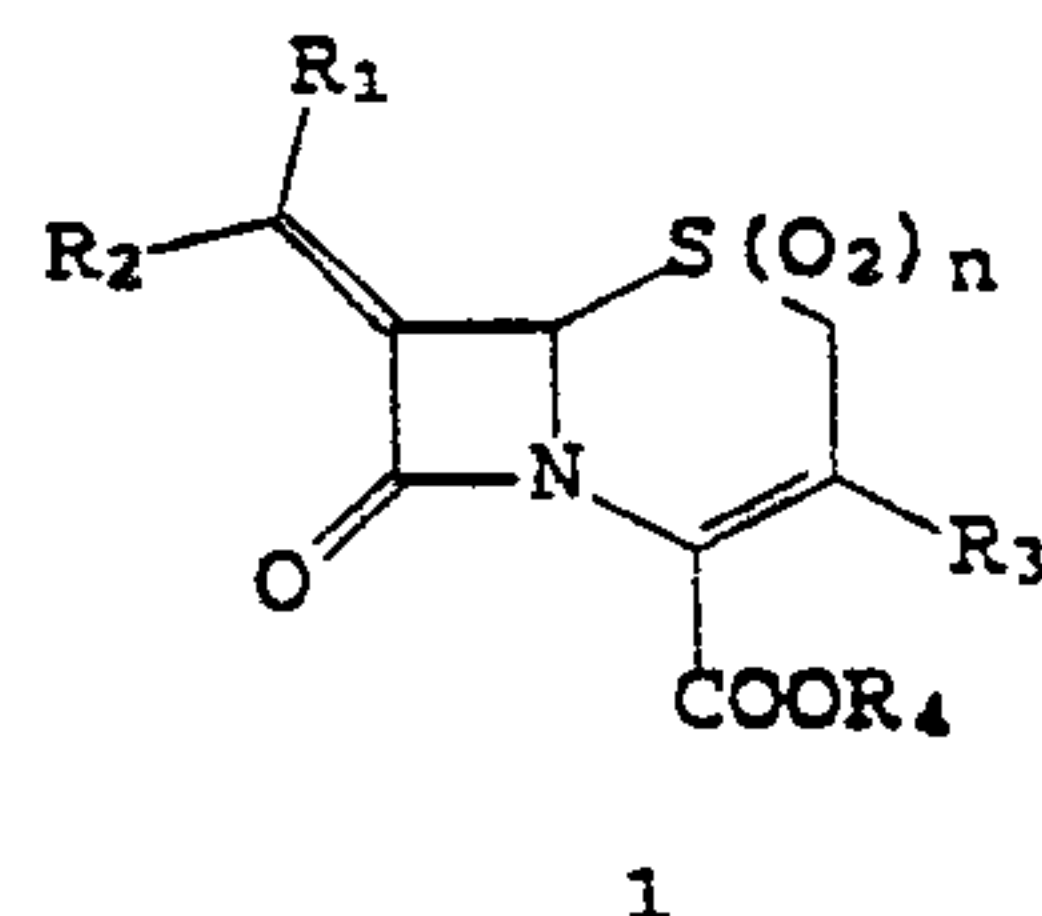
25 9. The compound of Claim 1, wherein n is 1, R₁ is hydrogen, and R₂ is selected from the group consisting of phenyl and bromine.

10. The compound of Claim 1, wherein n is 1, R₁ is pyridyl, R₂ is hydrogen, R₃ is -CH₂OAc and R₄ is sodium.

11. A pharmaceutical composition, comprising:

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a compound of formula (1)



wherein n is 0 or 1;

R₁ and R₂ are the same or different and are selected from the group consisting of

- a) hydrogen;
- b) linear or branched C₁₋₁₀-alkyl;
- c) halogen;
- d) hydroxy-C₁₋₁₀-alkyl;
- e) C₁₋₁₀-alkoxy;
- f) C₂₋₁₀-alkanoyloxy;
- g) C₂₋₁₀-alkene;
- h) C₂₋₁₀-alkene substituted with one or more groups selected from the group consisting of chlorine, fluorine, bromine or phenyl;
- i) C₁₋₁₀-alkoxycarbonyl;
- j) C₁₋₁₀-alkoxycarbamido;
- k) N-C₁₋₁₀-alkoxy-N-C₁₋₁₀-alkylaminocarbonyl;
- l) halo-C₁₋₁₀-alkyl;
- m) C₆₋₁₀-aryl;
- n) C₆₋₁₀-aryl substituted with one or more groups selected from the group consisting of ethyl, n-propyl, isopropyl, amino, methylamino and dimethylamino;
- o) a C₂₋₁₀-heterocycle having from 1-3 heteroatoms selected from the group consisting of O, N and S; and,

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p) $-\text{COOH}$ or $-\text{COOY}$, wherein Y is pharmaceutically acceptable cation;

R_3 is selected from the group consisting of

1) $-\text{COOH}$;

5 2) chlorine or fluorine;

3) trifluoromethyl;

4) $-\text{CHO}$; and,

5) $-\text{CH}_2\text{M}$ where M is selected from the group consisting of

a) hydrogen;

10 b) halogen;

c) hydroxy;

d) C_{1-10} -alkoxy;

e) C_{6-10} -aryloxy;

f) C_{6-10} -aryl- C_{1-10} -alkoxy;

15 g) mercapto;

h) mercapto substituted with one or more groups selected from the group consisting of methyl, ethyl or phenyl;

i) C_{2-10} -acylthio;

j) C_{2-10} -acyloxy or carbamoyloxy;

20 k) C_{2-10} -acyloxy or carbamoyloxy substituted with one or more groups selected from the group consisting of $-\text{COOH}$, aminophenyl, phenyl, C_{1-6} -alkyl, chlorine, bromine or fluorine;

l) a quaternary ammonium salt;

m) amino or amido; and,

25 n) amino or amido substituted with one or more groups selected from the group consisting of C_{1-10} -alkyl groups;

R_4 is selected from the group consisting of

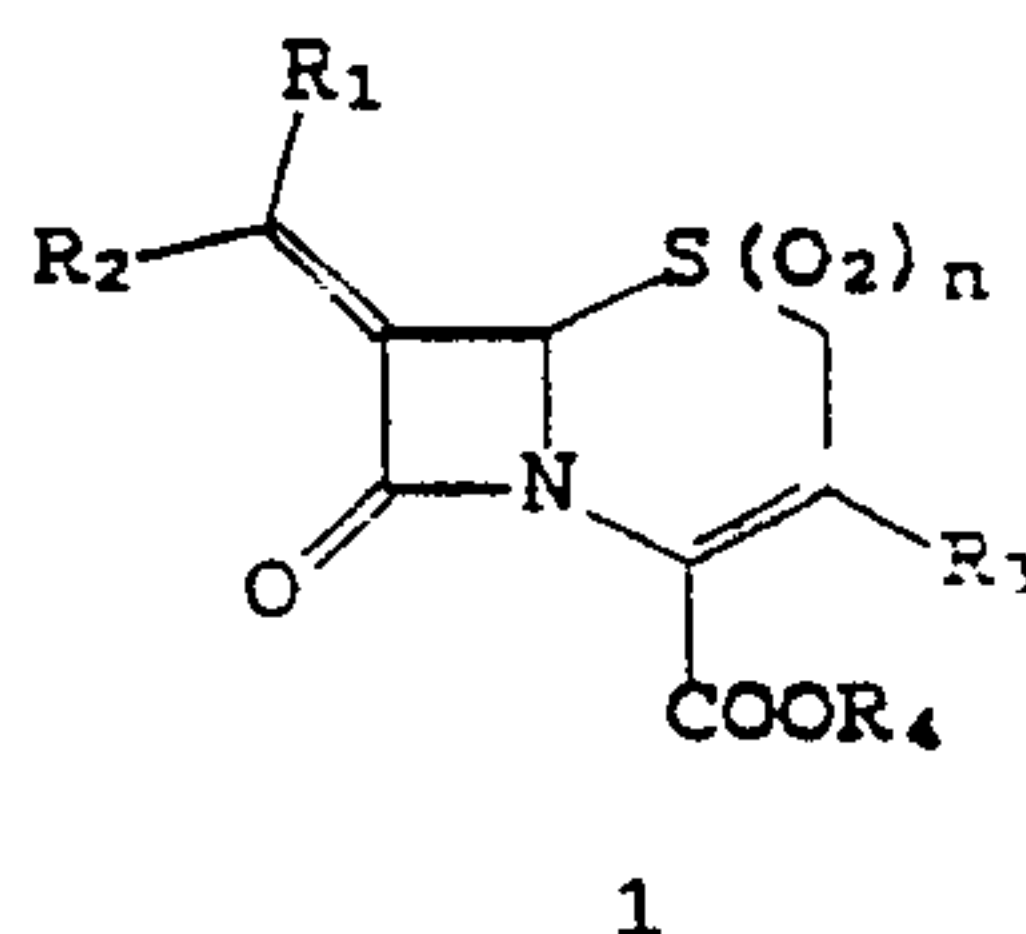
a) hydrogen; and,

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- b) pharmaceutically acceptable cations; and
a pharmaceutically acceptable carrier.

12. A pharmaceutical composition according to Claim 11,
further comprising a β -lactam antibiotic.

13. A method of inhibiting β -lactamases, comprising:
administering to a patient in need thereof an effective
amount of at least one compound of formula (1)



wherein n is 0 or 1;

R₁ and R₂ are the same or different and are selected from
the group consisting of

- a) hydrogen;
- b) linear or branched C₁₋₁₀-alkyl;
- c) halogen;
- d) hydroxy-C₁₋₁₀-alkyl;
- e) C₁₋₁₀-alkoxy;
- f) C₂₋₁₀-alkanoyloxy;
- g) C₂₋₁₀-alkene;
- h) C₂₋₁₀-alkene substituted with one or more groups selected from
the group consisting of chlorine, fluorine, bromine or phenyl;
- i) C₁₋₁₀-alkoxycarbonyl;
- j) C₁₋₁₀-alkoxycarbamido;
- k) N-C₁₋₁₀-alkoxy-N-C₁₋₁₀-alkylaminocarbonyl;
- l) halo-C₁₋₁₀-alkyl;

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m) C₆₋₁₀-aryl;

n) C₆₋₁₀-aryl substituted with one or more groups selected from the group consisting of ethyl, n-propyl, isopropyl, amino, methylamino and dimethylamino;

5 o) a C₂₋₁₀-heterocycle having from 1-3 heteroatoms selected from the group consisting of O, N and S; and,

p) -COOH or -COOY, wherein Y is pharmaceutically acceptable cation;

R₃ is selected from the group consisting of

10 1) -COOH;

2) chlorine or fluorine;

3) trifluoromethyl;

4) -CHO; and,

5) -CH₂M where M is selected from the group consisting of

15 a) hydrogen;

b) halogen;

c) hydroxy;

d) C₁₋₁₀-alkoxy;

e) C₆₋₁₀-aryloxy;

20 f) C₆₋₁₀-aryl-C₁₋₁₀-alkoxy;

g) mercapto;

h) mercapto substituted with one or more groups selected from the group consisting of methyl, ethyl or phenyl;

i) C₂₋₁₀-acylthio;

25 j) C₂₋₁₀-acyloxy or carbamoyloxy;

k) C₂₋₁₀-acyloxy or carbamoyloxy substituted with one or more groups selected from the group consisting of -COOH, aminophenyl, phenyl, C₁₋₆-alkyl, chlorine, bromine or fluorine;

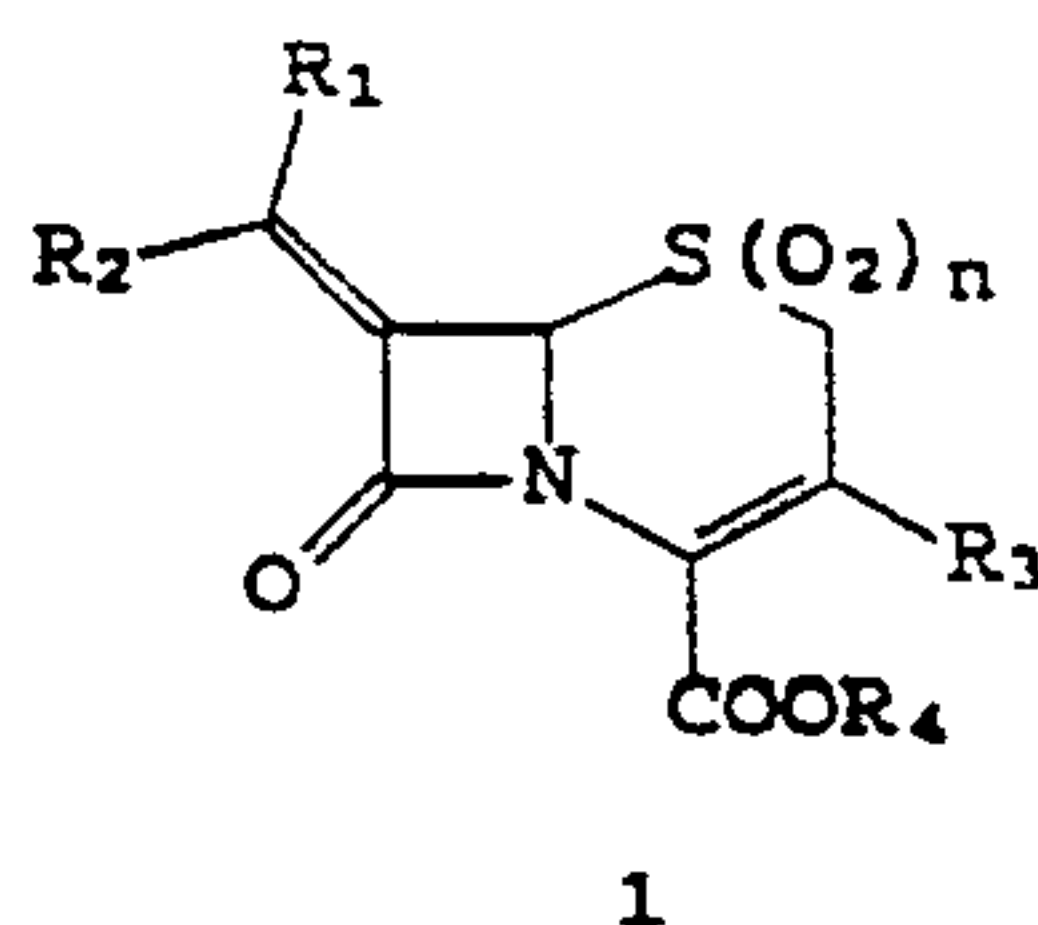
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l) a quaternary ammonium salt;
 m) amino or amido; and,
 n) amino or amido substituted with one or more groups
 selected from the group consisting of C₁₋₁₀-alkyl groups;

5 R₄ is selected from the group consisting of
 a) hydrogen; and,
 b) pharmaceutically acceptable cations.

14. A method of enhancing the biological activity of a β -
 lactam antibiotic, comprising:

10 coadministering to a patient in need thereof an effective
 amount of a compound of formula (1)



wherein n is 0 or 1;

R₁ and R₂ are the same or different and are selected from
 the group consisting of

- 20 a) hydrogen;
 b) linear or branched C₁₋₁₀-alkyl;
 c) halogen;
 d) hydroxy-C₁₋₁₀-alkyl;
 e) C₁₋₁₀-alkoxy;
 25 f) C₂₋₁₀-alkanoyloxy;
 g) C₂₋₁₀-alkene;
 h) C₂₋₁₀-alkene substituted with one or more groups selected from
 the group consisting of chlorine, fluorine, bromine or phenyl;

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- i) C_{1-10} -alkoxycarbonyl;
- j) C_{1-10} -alkoxycarbamido;
- k) $N-C_{1-10}$ -alkoxy- $N-C_{1-10}$ -alkylaminocarbonyl;
- l) halo- C_{1-10} -alkyl;
- 5 m) C_{6-10} -aryl;
- n) C_{6-10} -aryl substituted with one or more groups selected from the group consisting of ethyl, n-propyl, isopropyl, amino, methylamino and dimethylamino;
- o) a C_{2-10} -heterocycle having from 1-3 heteroatoms selected from the group consisting of O, N and S; and,
- 10 p) $-COOH$ or $-COOY$, wherein Y is pharmaceutically acceptable cation;

R_3 is selected from the group consisting of

- 1) $-COOH$;
- 15 2) chlorine or fluorine;
- 3) trifluoromethyl;
- 4) $-CHO$; and,
- 5) $-CH_2M$ where M is selected from the group consisting of
 - a) hydrogen;
 - 20 b) halogen;
 - c) hydroxy;
 - d) C_{1-10} -alkoxy;
 - e) C_{6-10} -aryloxy;
 - f) C_{6-10} -aryl- C_{1-10} -alkoxy;
 - 25 g) mercapto;
 - h) mercapto substituted with one or more groups selected from the group consisting of methyl, ethyl or phenyl;
 - i) C_{2-10} -acylthio;

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j) C_{2-10} -acyloxy or carbamoyloxy;

k) C_{2-10} -acyloxy or carbamoyloxy substituted with one or more groups selected from the group consisting of -COOH, aminophenyl, phenyl, C_{1-6} -alkyl, chlorine, bromine or fluorine;

5 l) a quaternary ammonium salt;

m) amino or amido; and,

n) amino or amido substituted with one or more groups selected from the group consisting of C_{1-10} -alkyl groups;

R_4 is selected from the group consisting of

10 a) hydrogen; and,

b) pharmaceutically acceptable cations; and

a pharmaceutically acceptable carrier.