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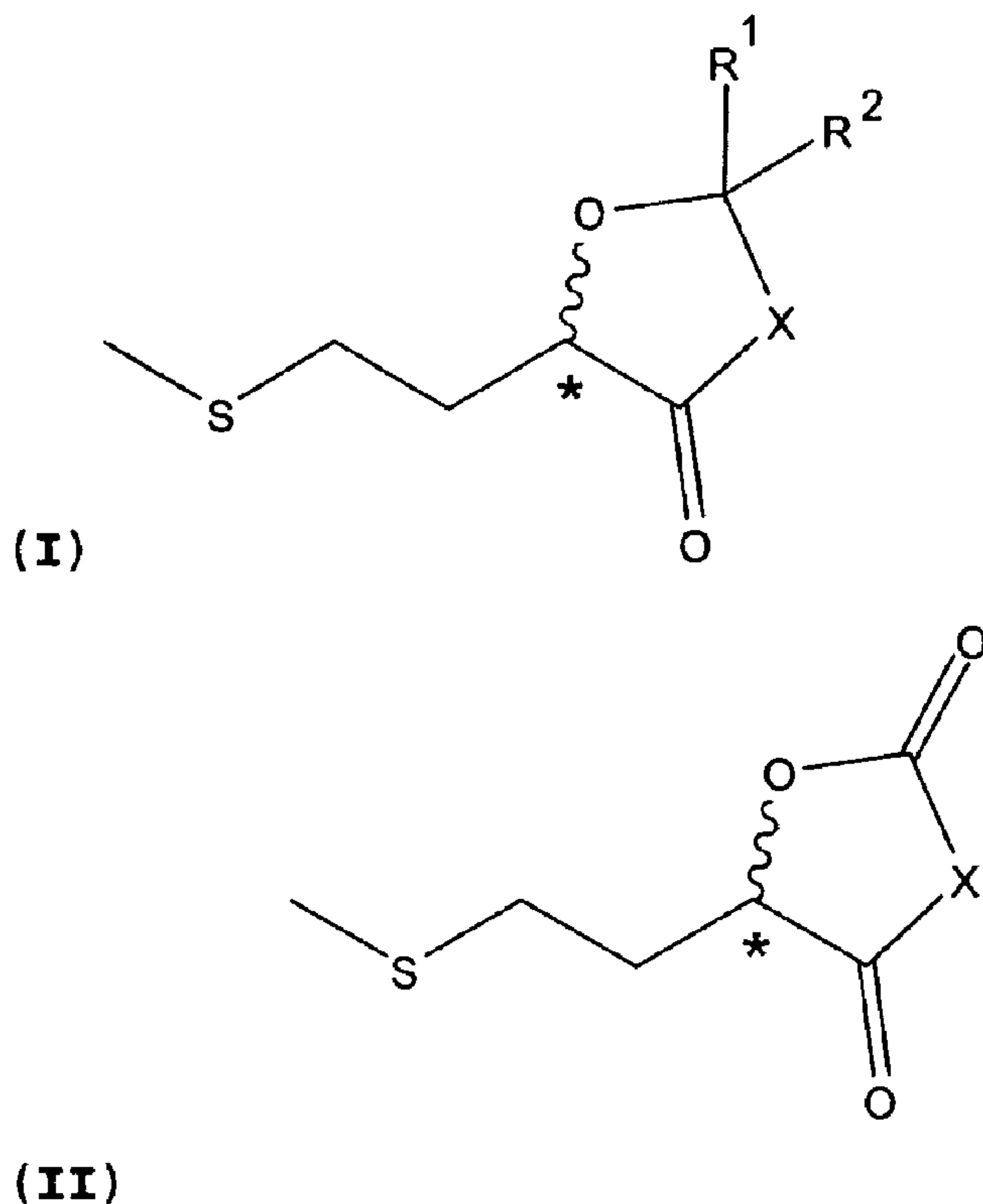
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(54) Titre : HETEROCYCLENE SUBSTITUE PAR UN GROUPE 2-METHYLTHIOETHYLE EN TANT QU'ADDITIF POUR
L'ALIMENTATION ANIMALE

(54) Title: 2-METHYLTHIOETHYL-SUBSTITUTED HETEROCYCLES AS FEED ADDITIVES



(57) Abrégé/Abstract:

The object of the invention is a chemical compound of the general formula (I) or (II), where X = O or NR and R = H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, aryl, in particular phenyl, or aralkyl, in particular benzyl, and where R¹, R² are the same or different and are H, an optionally branched C₁-C₆ alkyl, C₃-C₆-cycloalkyl, allyl, aryl, in particular phenyl, or aralkyl, in particular benzyl, or R¹ and R² together alternatively are a C₁-C₆-alkyl-substituted C₂ to C₆ alkylene group, the use of said compound for the nutrition of farm animals, as well as a method for the production thereof.

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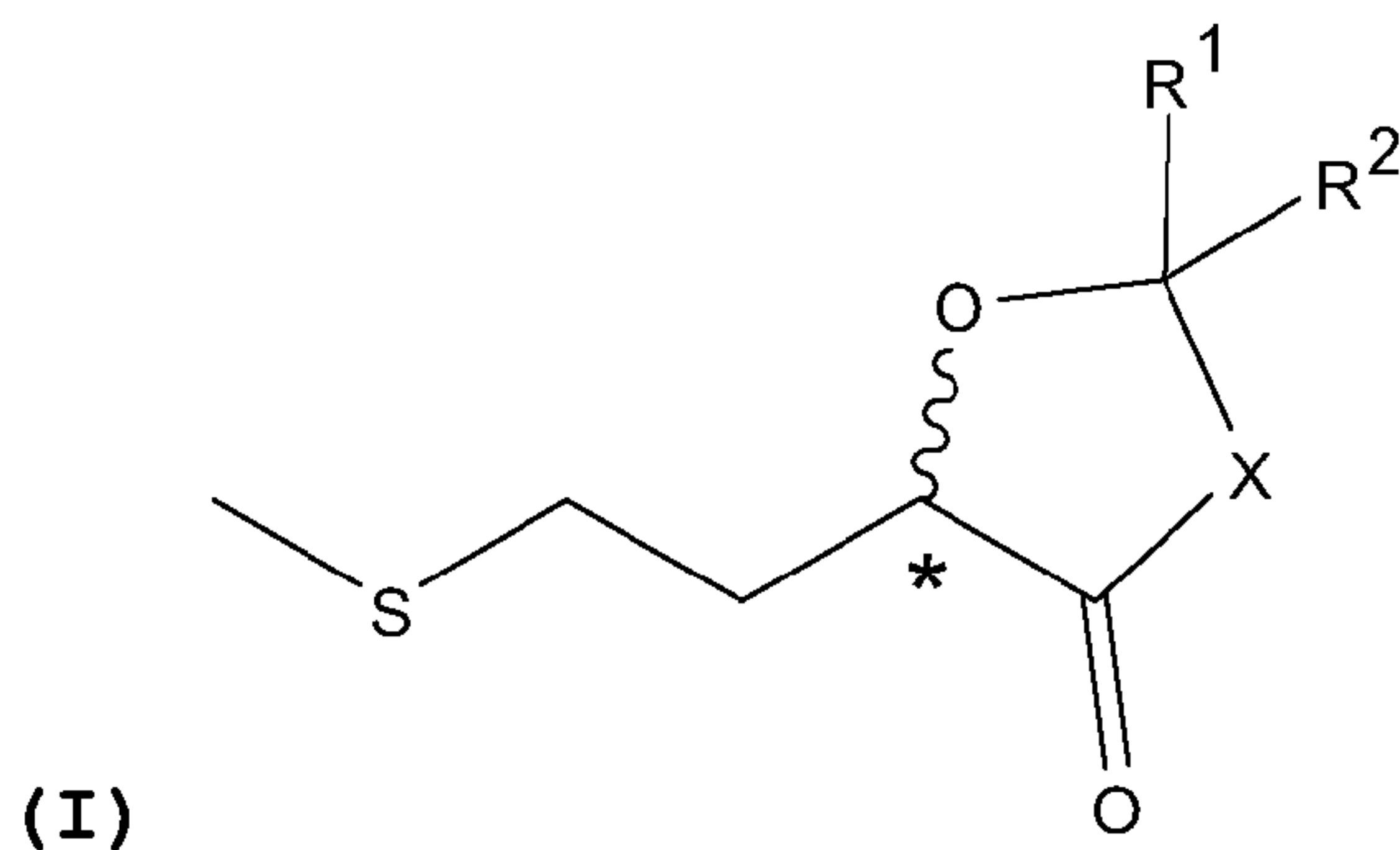
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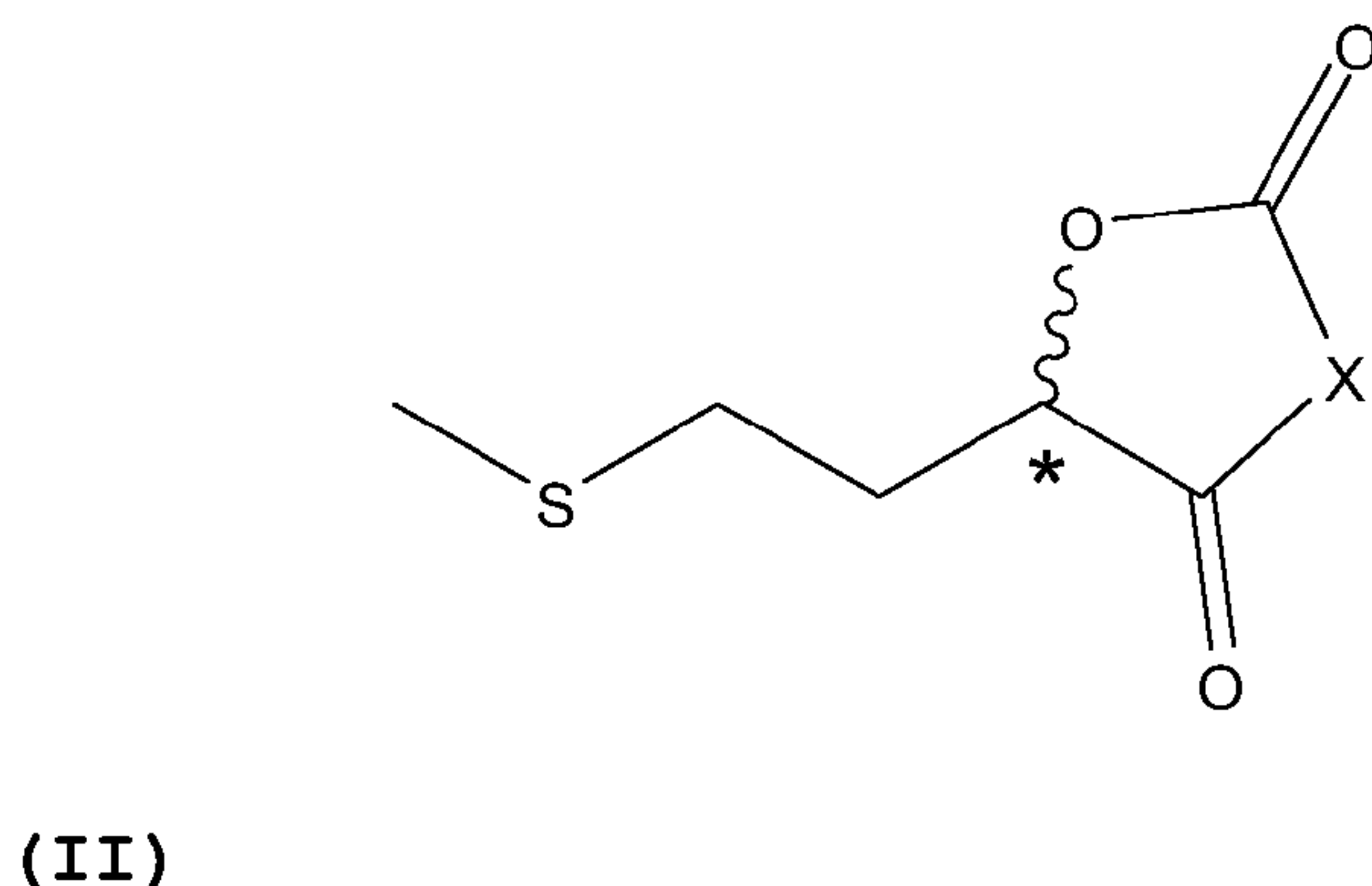
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(54) Title: 2-METHYLTHIOETHYL-SUBSTITUTED HEYRROCYCLES AS FEED ADDITIVES

(54) Bezeichnung: 2-METHYLTHIOETHYL-SUBSTITUIERTE HETEROCYCLLEN ALS FUTTERMITTELADDITIVE



(57) Abstract: The object of the invention is a chemical compound of the general formula (I) or (II), where X = O or NR and R = H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, aryl, in particular phenyl¹, or aralkyl, in particular benzyl, and where R¹, R² are the same or different and are H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, allyl, aryl, in particular phenyl², or aralkyl, in particular benzyl, or R¹ and R² together alternatively are a C₁-C₆-alkyl-substituted C₂ to C₆ alkylene group, the use of said compound for the nutrition of farm animals, as well as a method for the production thereof.



(57) Zusammenfassung: Gegenstand der Erfindung ist eine chemische Verbindung der allgemeinen Formel (I) oder (II), wobei X = O oder NR ist und R = H, ein ggf. verzweigtes C₁-C₆-Alkyl, C₃-C₆-Cycloalkyl, Aryl, insbesondere Phenyl, oder Aralkyl, insbesondere Benzyl, ist und wobei R¹, R² gleich oder verschieden ist und jeweils H, ein ggf. verzweigtes C₁-C₆-Alkyl, C₃-C₆-Cycloalkyl, Allyl-, Aryl, insbesondere Phenyl, oder Aralkyl, insbesondere Benzyl, oder R¹ und R² zusammen eine ggf. C₁-C₆-alkylsubstituierte C₂- bis C₆-Alkylengruppe ist, deren Verwendung zur Ernährung von Nutztieren, sowie ein Verfahren zu deren Herstellung.

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2-Methylthioethyl-substituted heterocycles as feed additives

Introduction

5 The present invention relates to novel 2-methylthioethyl-substituted heterocycles and derivatives thereof and also production thereof and use thereof as feed additives, in particular for the nutrition of farm animals such as, for example, hens, pigs, ruminants, but also fish and crustacea
10 (seafood).

Prior art

Essential amino acids such as methionine, lysine or threonine are, as feed additives, very important components of animal nutrition. Their supplementation makes possible,
15 firstly, more rapid growth of the animals, but secondly also more efficient feed utilization. This is a great economic advantage. The markets for feed additives are of great industrial and economic importance. In addition, they are strong growth markets which is due, not least, to the
20 increasing importance of countries such as, for example, China and India.

WO 2004008874 discloses, inter alia, that methionine (2-amino-4-methylthiobutyric acid) is the first limiting amino acid for many animal species. For instance, in dairy
25 cattle, for example, efficient milk production with respect to the amount and quality, is greatly dependent on a sufficient feed of methionine. The methionine requirement of high-performance dairy cattle cannot be covered in this case by the microbial protein formed in the rumen or by
30 protein from the feed which is not broken down in the rumen (Graulet et al., *J. Animal and Feed Sciences* (2004), 269). It is therefore advantageous to supplement methionine to the feed in order to increase the economic efficiency of milk production and quality of the milk.

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In the case of monogastric animals such as, for example, poultry and pigs, D,L-methionine and the Methionine Hydroxy Analog (MHA) having the chemical name D,L-2-hydroxy-4-methylthiobutyric acid (HMB), are conventionally used as
5 feed additives. The available amount of L-methionine is thereby increased in the organism which is then available to the animal for growth.

In contrast thereto, supplementation of the feed with methionine is not effective in ruminants, since the
10 majority is broken down by microbes in the rumen of ruminants. Owing to this breakdown, therefore, only a fraction of the supplied methionine passes into the small intestine of the animal, where generally the methionine is absorbed into the blood.

15 WO 99/04647 describes the use of MHA for ruminants. Therein it is asserted that MHA is only partly broken down in the rumen and therefore at least 20-40% of the supplemented MHA, after absorption in the small intestine, can pass into the metabolism. In numerous other publications, in
20 contrast, the mode of action of MHA in ruminants is discussed differently. Thus, for example, WO 200028835 describes that MHA can only successfully pass through the rumen and finally arrive in the small intestine for absorption when MHA is administered in very large amounts
25 of 60-120 g/day/animal. However, this is no longer economically efficient.

In order that methionine products such as D,L-methionine or *rac*-MHA are available to ruminants with high efficiency, a form protected from rumen breakdown must be used. The
30 challenge in this case is to find a suitable methionine product which gives the methionine a rumen stability which is as high as possible and nevertheless ensures high and efficient absorption of the methionine in the intestine. In this case there are a plurality of possibilities of giving
35 the D,L-methionine or *rac*-MHA these properties:

a) Physical protection:

By applying a suitable protective layer or distributing the methionine in a protective matrix, a high rumen stability can be achieved. As a result the methionine can pass
5 through the rumen virtually without loss. In the further course, the protective layer is then opened or removed, for example, in the abomasum by acid hydrolysis and the released methionine can then be absorbed by the animal in the small intestine. The protective layer or matrix can
10 consist of a combination of a plurality of substances such as, for example, lipids, inorganic materials and carbohydrates. For example, the following product forms are commercially available:

- 15 i) Met-Plus™ from Nisso America, is a lipid-protected methionine having a D,L-methionine content of 65%. The protective matrix consists of the calcium salts of long-chain fatty acids such as, for example, lauric acid. Butylated hydroxytoluene acts as preservative.
- 20 ii) Mepron® M85 from Degussa AG is a carbohydrate-protected methionine which has a core of D,L-methionine, starch and stearic acid. Ethylcellulose is used as protective layer. The product has a content of 85% D,L-methionine.
- 25 iii) Smartamine™ M from Adisseo is a polymer-protected methionine. The pellets, in addition to stearic acid, contain at least 70% D,L-methionine. The protective layer contains vinylpyridine-styrene copolymer.

Although physical protection prevents the microbial breakdown of methionine in the rumen and as a result the
30 supply and utilization of methionine can be increased in the animal, there are some serious disadvantages.

The production or coating of methionine is usually a technically complicated and complex process and is

therefore expensive. In addition, the surface coating of the finished pellets can easily be damaged by mechanical stress and abrasion during feed administration, which can lead to reduction or complete loss of the protection.

5 Therefore, it is also not possible to process the protected methionine pellets into a larger mixed-feed pellet and repellet them, since as a result, again the protective layer would break up by the mechanical stress. This greatly restricts the use of such products, since the mixed feed
10 pelleting is a widespread method of feed processing.

b) Chemical protection:

Increased rumen stability of methionine can, in addition to the purely physical possible methods of protection, also be achieved by modifying the chemical structure, for example
15 by esterifying the carboxylic acid group. Currently, the following products are commercially available or are described in the literature:

i) Methionine esters such as, for example, D,L-tert-butylmethionine: The esters were tested and demonstrated
20 only moderate rumen stability (Loerch and Oke; "Rumen Protected Amino Acids in Ruminant Nutrition" in "Absorption and Utilization of Amino Acids" Vol. 3, 1989, 187-200, CRC Press Boca Raton, Florida). For D,L-tert-butylmethionine, in contrast, in WO 0028835, a biological value of 80% was
25 published.

ii) Metasmart™ from Adisseo is the racemic isopropyl ester of MHA (HMBi). This compound is also marketed under the trademark "Sequent" by the American company Novus. WO
00/28835 published a biological value of at least 50% for
30 HMBi in ruminants. In this case, especially, the surprisingly rapid absorption of the hydrophobic HMBis through the rumen wall plays a decisive role. The ester can then be hydrolyzed to MHA in the blood and, after oxidation and subsequent transamination, converted to L-methionine.

Patent EP 1358805 published a comparable biological value for HMBi. In these studies, HMBi was applied to a porous carrier. In a further publication, the European Commission reported that again approximately 50% HMBi is absorbed
5 through the rumen wall (European Commission: Report of the Scientific Committee on Animal Nutrition on the Use of HMBi; 25 April 2003). Graulet et al. published in 2004 in the Journal of Animal and Feed Science (269), the fact that via the lipophilic properties of the isopropyl group of
10 HMBi, better diffusion through the rumen wall is made possible.

For the production of HMBi, two different processes have been published. For instance, HMBi, on the one hand, can be synthesized directly in one stage from the corresponding
15 cyanohydrine (WO 00-59877). The esterification to give the isopropyl ester proceeds in this case *in situ*, without MHA having to be isolated in advance. Another process, in contrast, esterifies pure MHA with isopropanol (WO 01-58864 and WO 01-56980). In both cases, for the synthesis, Prussic
20 acid is used which is expensive and, in addition, involves a great hazard potential.

The aquafarming sector (Food and Agriculture Organization of the United Nation (FAO) Fisheries Department "State of World Aquaculture 2006", 2006, Rome. International Food
25 Policy Research Institute (IFPRI) "Fish 2020: Supply and Demand in Changing Markets", 2003, Washington, D.C.) has also recently acquired importance. The culture of edible saltwater and freshwater animals, in particular fish and crustacea, likewise requires particular product forms for
30 supply with methionine.

The supply of fish and crustacea which are held commercially in aquacultures, requires a correspondingly protected product form, firstly in order that the product during feed administration remains sufficiently stable in
35 the aqueous environment and secondly in order that the

methionine product finally taken up by the animal can be optimally utilized in the animal organism.

Object of the invention

A general object was to provide a feed and a feed additive
5 in animal nutrition based on novel methionine substitutes.

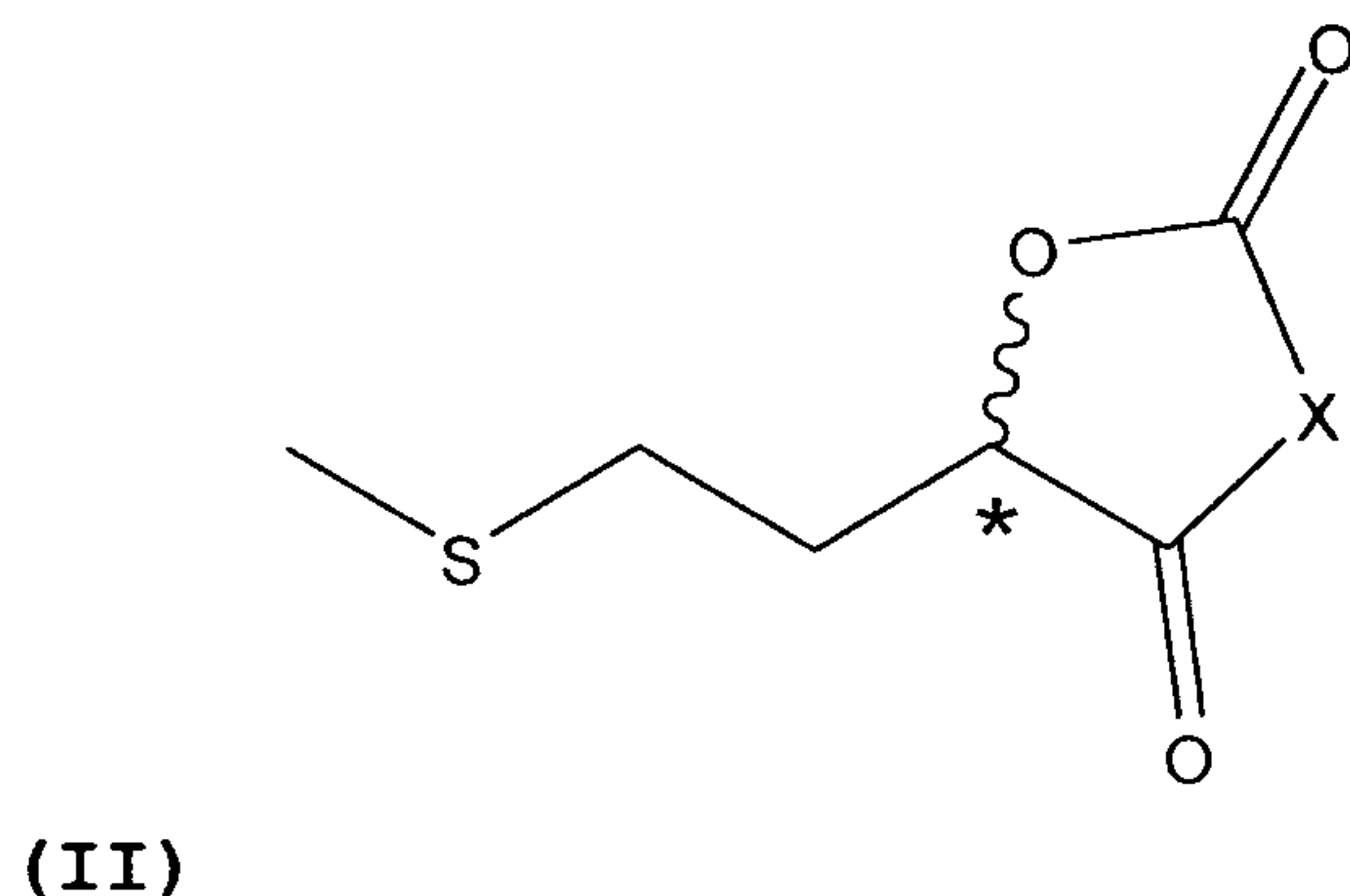
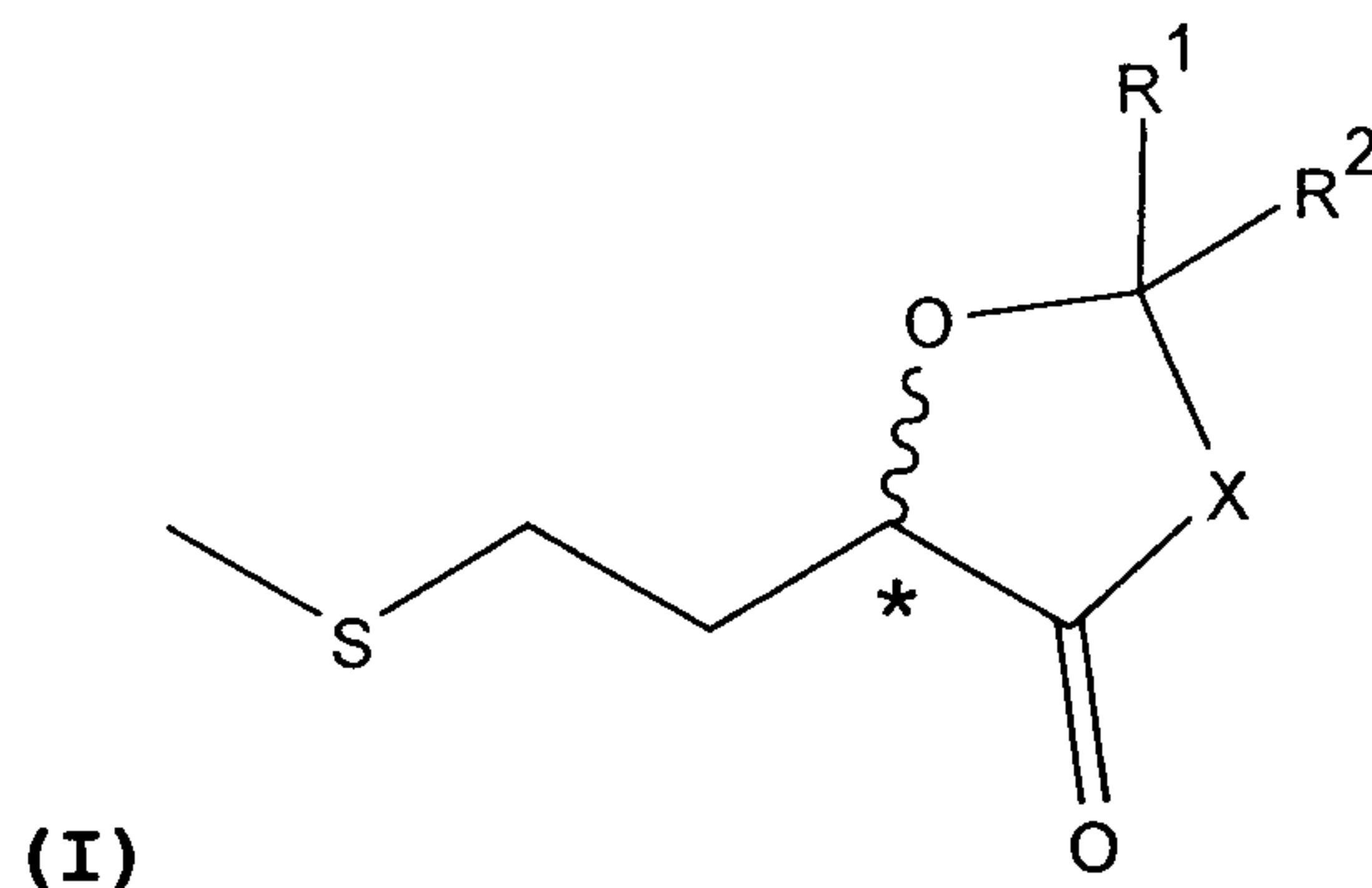
Against the background of the disadvantages of the prior art, it was especially an object to provide a chemically protected methionine product for farm animals. In a particular aspect, this product should be rumen-stable for use for ruminants,
10 especially for dairy cattle. In another aspect, the product should also be as suitable as possible for use in the nutrition of fish and crustacea in aquacultures. In this manner, in addition to D,L-methionine and MHA, a further efficient methionine source should be made available to the animals,
15 which as far as possible does not have the disadvantages of the known products, or has them only to a slight extent.

A further object was to find a feed and a feed additive having very high biological value and which should have good handleability and storability and also stability under
20 the conventional conditions of mixed-feed processing, in particular pelleting. In the case of ruminants, such a product would have the advantage of a significantly simpler and standardized mixed-feed processing/provision, so that the economic efficiency and also the quality, of milk
25 production would thereby be increased.

Description of the invention

These objects and also further objects which are not mentioned explicitly, but which can readily be derived or concluded from the context discussed herein may be achieved by
30 the heterocyclic compounds according to the invention and derivatives thereof according to formula **I** and formula **II**, in particular use thereof as feed, preferably for hens, pigs, ruminants, fish and crustacea.

The present invention therefore relates to a chemical compound of the general formula (I) or (II),



wherein X = O or NR, and R = H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, aryl, in particular phenyl, or aralkyl, in particular benzyl, and wherein R¹, R², are identical or different and in each case H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, allyl, aryl, in particular phenyl, or aralkyl, in particular benzyl, or R¹ and R² together are an optionally C₁-C₆-alkyl substituted C₂- to C₆-alkylene group.

The advantages of the compound I, are that, e.g., for R¹, R² = H or = low-alkyl residues such as methyl, ethyl, n-propyl, they are liquid, water-clear colorless components. Secondly, the components of the formula I are free from dimeric and oligomeric byproducts, quite in contrast to the commercially available 2-hydroxy-4-methylthioethylbutyric acid (MHA monomer). This is in equilibrium with its dimeric and higher oligomeric esters (condensation products) which have a significantly lower bioavailability than MHA monomer

or D,L-methionine itself. MHA is therefore, similarly to the analogous lactic acid, marketed as an 88 percent strength aqueous solution in order to influence the equilibrium in the direction of the desired monomer.

5 The components according to the invention, in contrast, do not need to be diluted with water, so that the pure active compound is available. Furthermore, they can readily be distilled, particularly in the case of $R^1, R^2 = H$, methyl, ethyl, *n*-propyl, so that a virtually 100% purity of these
10 novel substances can be achieved in a manner which is technically simple to carry out, which is an extraordinary processing advantage, and therefore also economic advantage.

The liquid compounds **I** and **II**, in each case where $X = O$,
15 can be used directly as liquid feed additive, which offers advantages for certain applications, in particular when in mixed feed operations, liquid metering systems for what are termed microcomponents are already available. Optionally, these components, however, can also be applied to solid
20 carriers which can be inorganic or organic in nature and should be suitable for feeds and thus a solid feed additive can be generated in a simple manner which can be handled as easily as, for example, D,L-methionine, as a classic solid feed additive, where only solid metering systems are
25 available.

Such inorganic carriers can be silicas, such as, for example, Sipernat from Evonik-Degussa, or silicates, and also aluminas or zeolites, e.g. calcium, sodium, or sodiumaluminum silicate, or metal carbonates such as
30 magnesium, calcium or sodium carbonate, individually or in a mixture of two or more such carriers.

Such organic carriers can be, for example, alginates, stearates, starches and gums. Preference is given to calcium, sodium or aluminum alginate, calcium or sodium

stearate, corn starch or gum Arabic, individually or in a mixture of two or more such carriers.

In this manner, a concentration lower than 100% of the component according to the invention can also be set in a
5 targeted manner, if this is wanted.

Preference is given to compounds of the formula **I** where $X = O$, since these are both acetals and esters and here in the hydrolysis in the organism, monomeric MHA is formed directly, which can subsequently be metabolized. In this
10 case the corresponding carbonyl compound $R^1R^2C=O$ is released simultaneously.

Preference is given here to compounds of the formula **I**, where R^1 and R^2 are each an optionally branched C_1 - C_6 -alkyl. For physiological reasons, the compound **4** having $R^1=R^2=CH_3$
15 is particularly preferred here, since in the MHA release, only acetone is formed, which is physiologically harmless. Owing to the low concentration of typically 0.1 to 0.5% by weight methionine equivalent in the mixed feed, however, other radicals R^1, R^2 and the carbonyl compounds
20 correspondingly released in the hydrolysis to give MHA are also justifiable.

Further preference is therefore given to the compound **2** (cf. examples), where $R^1 = R^2 = H$ and compound **6** where $R^1 = H$ and $R^2 = \text{tert-butyl}$. Compound **I** where $X = O$ and $R^1 = H$, R^2
25 = phenyl is also preferred here, since in its hydrolysis benzaldehyde is formed, which also occurs in plant products such as bitter almonds. In the hydrolysis of **2**, as carbonyl compound, formaldehyde is formed which is readily further oxidized to formate, which itself has importance as a feed
30 ingredient.

Likewise further preference is given to a compound **7** of the general formula **I** in which R^1 and R^2 together = $(CH_2)_5$, such that on its hydrolysis cyclohexanone is released.

10

Preferred compounds in the context of the present invention are also compounds of the formula **I** where $X = \text{NH}$. On its hydrolysis, in addition to the corresponding carbonyl compound $\text{R}^1\text{R}^2\text{C}=\text{O}$, ammonia is released at the same time.

5 This ammonia is exactly the molar NH_3 equivalent which is used in the organism for metabolizing the compound **II** according to the invention to give the amino acid methionine.

Preference is given in this case to compound **I** where $X = \text{NH}$
10 and $\text{R}^1 = \text{R}^2 = \text{H}$. On their hydrolysis, as carbonyl compound formaldehyde is formed which is readily further oxidized to formate which itself is of importance as a feed ingredient.

Preference is also given to compound **12** where $\text{R}^1 = \text{H}$ and R^2
= phenyl. On its hydrolysis, as carbonyl compound,
15 benzaldehyde is formed which is a natural component of bitter almonds.

Preference is also given to compounds of the formula **I** where $X = \text{NH}$, in which R^1 and R^2 are each an optionally branched $\text{C}_1\text{-C}_6\text{-alkyl}$.

20 In this case very particular preference is given to compound **10** where $\text{R}^1 = \text{R}^2 = \text{CH}_3$ and on its hydrolysis only NH_3 and acetone are released.

However, compound **13** where $\text{R}^1 = \text{CH}_3$ and $\text{R}^2 = \text{C}_2\text{H}_5$ and
compound **14** where R^1 and R^2 together = $(\text{CH}_2)_5$ are also novel
25 interesting feed ingredients.

In addition, compound **8** was found having the formula **II**, where $X = \text{O}$. This substance is liquid at room temperature. Hydrolysis leads directly to the monomer MHA and as byproduct gives only CO_2 , which in any case occurs in the
30 natural metabolism of living creatures and is therefore completely harmless. This is an extraordinary advantage for animal nutrition.

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The counterpart thereto which is interesting in the same manner is compound **15** having the formula **II** and X = NH, which is a colorless solid. Hydrolysis leads likewise directly to the MHA monomer (2-hydroxy-4-

5 methylthioethylbutyric acid) and, in addition to CO₂, as a further byproduct also gives NH₃, which likewise occurs in natural metabolism of living creatures and again is ready as NH₃ equivalent for the amino acid formation from the hydroxy acid MHA monomer and therefore can offer even

10 further advantages.

All compounds of the general formulae **I** and **II** according to the invention are suitable in principle for the use for nutrition of farm animals since all contain the parent substance of the methioninehydroxy analog which, on

15 physiological metabolism of the compounds is released as 2-hydroxy-4-methylthiobutyrate and is finally reacted to give methionine. Further advantages of such chemically protected methionine analogs have been described at the outset and hereinbefore. Such chemically protected product forms are,

20 firstly sufficiently stable during feeding and also in the aqueous environment, and secondly utilizable in the animal organism. Depending on animal species and feed matrix and feed conditions, a person skilled in the art will preferably consider one or other component.

25 Such compounds can be used in particular for the nutrition of poultry, of pigs, of ruminants, but also for nutrition of fish or crustacea. Feed mixtures for nutrition of farm animals containing at least one of the compounds of the general formulae **I** or **II** are also subject matter of the

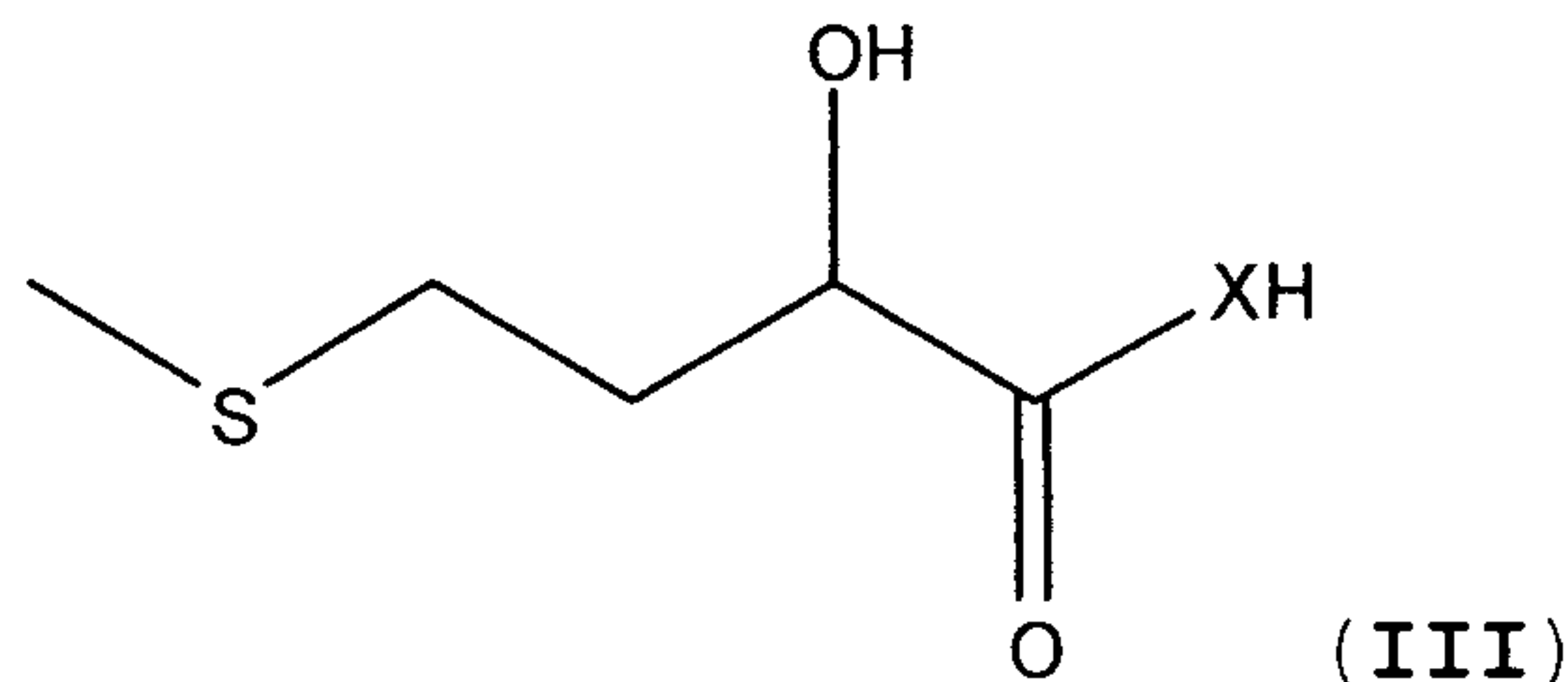
30 present invention, and also the corresponding use of these compounds for producing feed mixtures for the nutrition of farm animals.

A corresponding process for producing the compounds of the general formulae **I** or **II** is also subject matter of the

35 present invention.

12

Such a process proceeds from a compound of the general formula **III**,



wherein X, R¹ and R² each have the meaning given above. In the case of X = O, **III** is 2-hydroxy-4-methylthiobutyric acid (compound **3**, MHA monomer) which can also be generated in situ with acid from one of its salts, preferably the calcium salt (compound **1**, cf. Example 1). In the case of X=NH, **III** is 2-hydroxy-4-methylthiobutyramide (compound **9**, MHA-amide), which can be obtained from 2-hydroxy-4-methylthiobutyronitrile by known hydrolysis processes, e.g. using 55-70 percent strength sulfuric acid.

The invention therefore relates to a process for producing compounds of the formula **I**, which comprises reacting a compound of the general formula **III** with a carbonyl compound R¹R²C=O in free or acetalated form if appropriate in the presence of a solvent. Suitable solvents in this case are, for example, toluene or chloroform which can act at the same time as entrainers, and also tetrahydrofuran, dioxane, methylene chloride and dimethylformamide. However, it is particularly advantageous to employ the carbonyl compound used simultaneously as solvent, in particular when it is a ketone, such as, for example, in the case of acetone or methyl ethyl ketone. The excess carbonyl compound can readily be recovered in the conventional manner when the reaction is completed and reused directly, if appropriate also after further purification.

Such a process is preferably carried out under acid catalysis. The catalysts used are suitable Lewis acids or Brönstedt acids.

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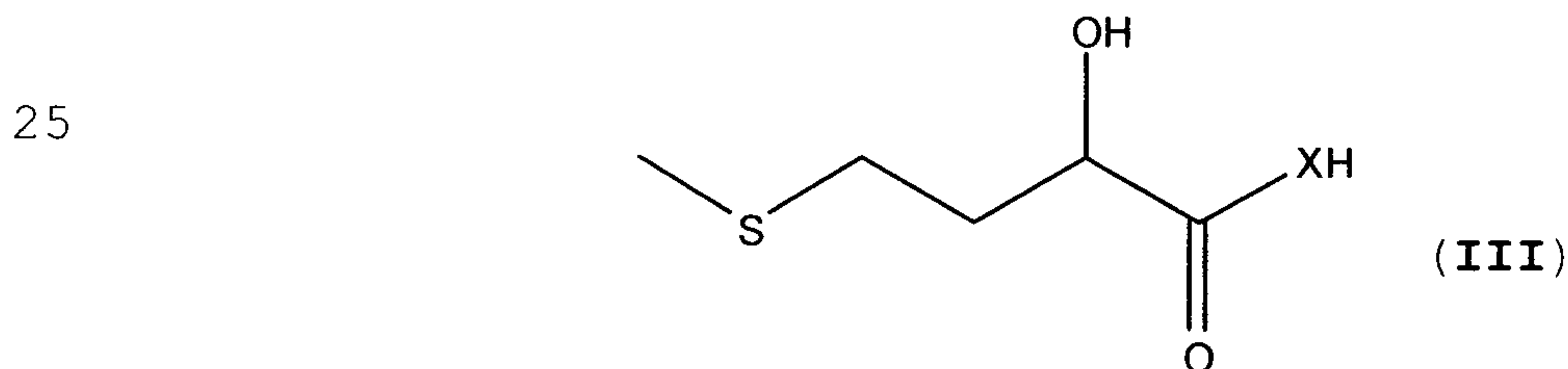
Preferred catalysts are HCl, H₂SO₄, *p*-toluenesulfonic acid, CF₃SO₃H as Brönstedt acids and ZnCl₂, CuSO₄, FeCl₃, AlCl₃, MgCl₂ and MgBr₂ as Lewis acids. The catalysts can be recovered in the conventional manner after completion of the reaction and reused directly, if appropriate after purification.

It is also possible that, instead of the carbonyl compound R¹R²C=O, that its dimethylacetal or diethylacetal is used. The resultant methanol or ethanol can be recovered from the reaction mixture, preferably by distillation.

It is also advantageous to remove from the reaction mixture the water which is formed during the condensation reaction on direct use of the carbonyl compound R¹R²C=O.

By removing water or alcohol formed from the reaction mixture, a higher conversion rate and greater selectivity for desired condensation products is achieved. For water/alcohol removal, in addition, also entrainers such as, for example, toluene, can also be used, so that water or alcohols can be removed by distillation in the form of azeotropes.

The invention also relates to a process for producing compounds of the formula **II**, which comprises reacting a compound of the general formula **III**



with a carbonic acid derivative X¹X²C=O, wherein X¹ and X² are identical or different and independently of one another can be chlorine or OCl₃, OCH₃, OCH₂CH₃, or imidazolyl or triazolyl bound via the nitrogen.

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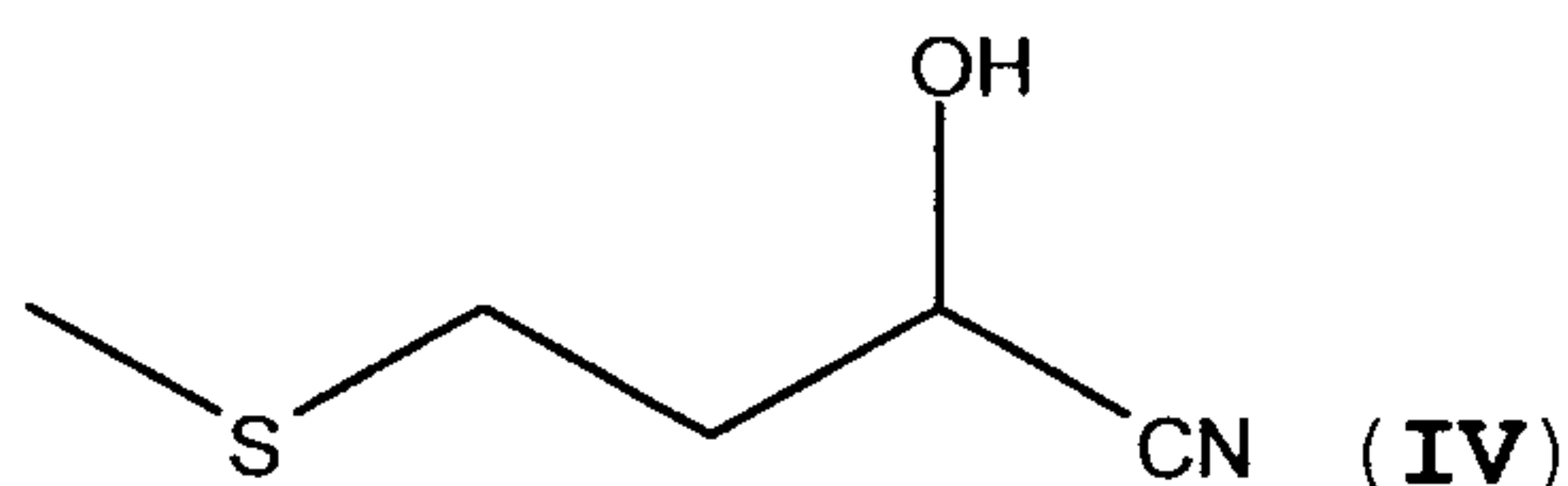
Since phosgene ($X^1, X^2 = \text{Cl}$) is problematic as a reagent, preferably the readily handleable diphosgene ($X^1 = \text{Cl}, X^2 = \text{OCCl}_3$) is used as reactive carbonic acid equivalent.

However, dimethyl carbonate or diethyl carbonate and the
5 indicated N-containing carbonic acid equivalents such as, for example, carbonyl diimidazole are also highly suitable and readily handleable.

Such a reaction can advantageously be carried out under not only acid, but also base catalysis. Acid catalysts which
10 can be used are the abovementioned Brönstedt or Lewis acids(?). Suitable compounds as basic catalysts are, in particular, alkali metal alkoxides of C_1 - C_4 -alcohols such as, for example, sodium methoxide or sodium ethoxide or else calcium *tert*-butylate.

15

A further suitable process variant for producing compounds of the formula **I** where $X = \text{NH}$, comprises reacting 2-hydroxy-4-methylthiobutyronitrile of the formula **IV**



20 with a carbonyl compound $\text{R}^1\text{R}^2\text{C}=\text{O}$ in the presence of acid and a carboxylic anhydride, wherein R^1 and R^2 have the meaning given above. This has the advantage that the precursor of 2-hydroxy-4-methylthiobutyramide (MHA-amide) is dispensed with.

25 In such a process variant, the acid used is preferably sulfuric acid and/or acetic acid, and the carboxylic anhydride is preferably acetic anhydride.

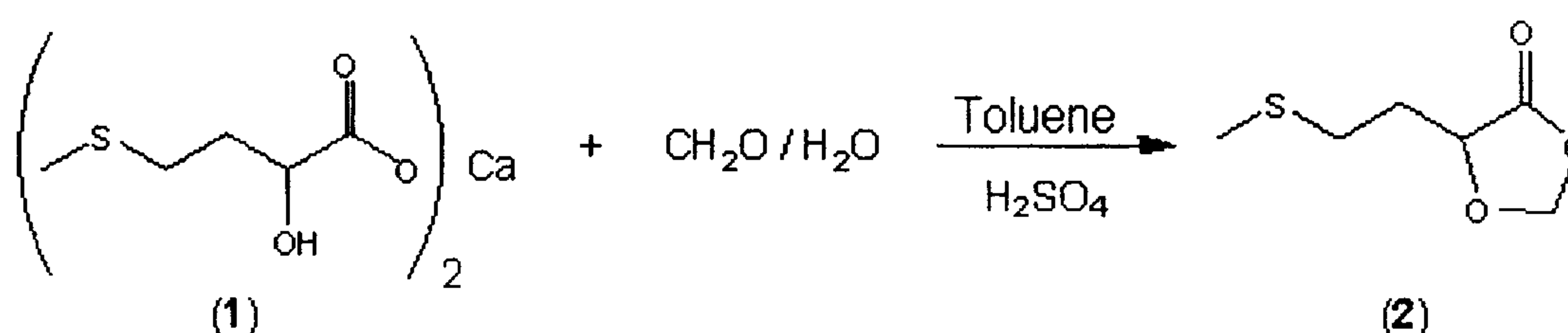
All process variants have the advantage that they can be carried out in a simple manner and with in part good to
30 very good yields.

The examples hereinafter serve for more detailed illustration of the invention without being restrictive.

Examples:

Example 1:

Synthesis of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) from 2-hydroxy-4-(methylthio)butanoic acid calcium salt (**1**) and formalin solution by Brönstedt acid catalysis in a two-phase mixture:



10.0 g (29.5 mmol) of 2-hydroxy-4-(methylthio)butanoic acid calcium salt (**1**) were placed in a 500 mL three-neck round bottom flask in 150 mL of water and 150 mL of toluene and admixed with 3.5 g (34.6 mmol) of 97% strength sulfuric acid. After addition of 50 g (0.58 mol, 19.6 eq.) of 37% strength formalin solution, the mixture was heated to boiling temperature and stirred for 16 h at this temperature. After it was cooled, the phases were separated and the aqueous phase was washed twice, each time with 50 mL of toluene. The combined organic phases were washed once with 50 mL of NaCl solution, dried over MgSO_4 and concentrated on a rotary evaporator. The resultant crude product was subsequently distilled (boiling point = 125°C/1.5 mbar). This produced 7.7 g (47.6 mmol, yield = 81%) of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) as a colorless liquid.

^1H -NMR of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) (500 MHz, CDCl_3): δ = 2.02-2.21 (m, 2H, CH_2); 2.12 (s, 3H, SCH_3); 2.62-2.72 (m, 2H, SCH_2); 4.39-4.41 (m, 1H, CH); 5.44 (s, 1H, CH); 5.55 (s, 1H, CH)

^{13}C -NMR of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) (125.8 MHz, CDCl_3): δ = 15.29 (SCH_3); 29.38 (SCH_2); 29.74

17

(CH₂); 71.49 (CH); 94.26 (OCH₂O); 172.80 (C=O)

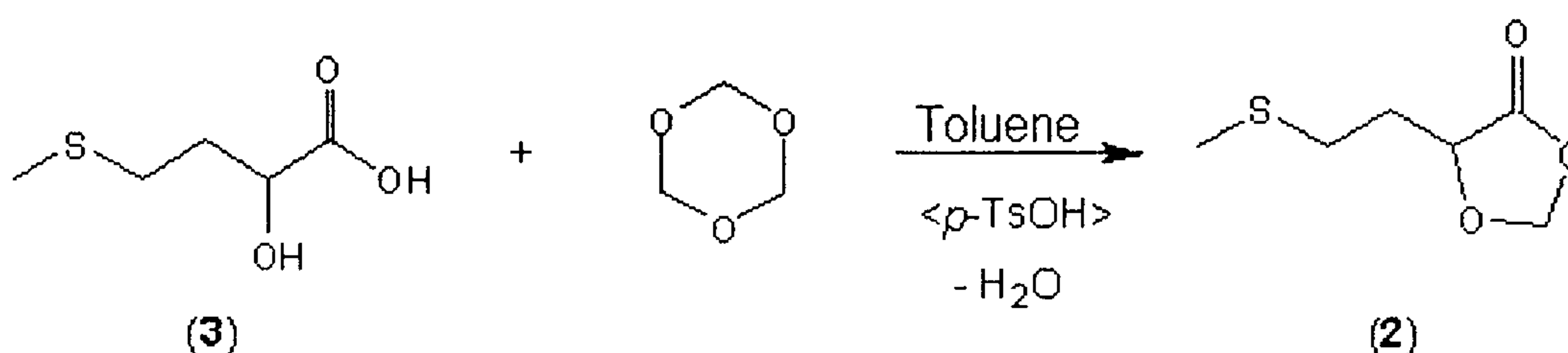
Elemental analysis for C₆H₁₀O₃S (M = 162.21 g/mol):

Calculated: C 44.43; H 6.21; S 19.77

Found: C 44.22; H 6.36; S 19.69

5 Example 2:

Synthesis of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and trioxane or paraformaldehyde by Brönstedt acid catalysis:

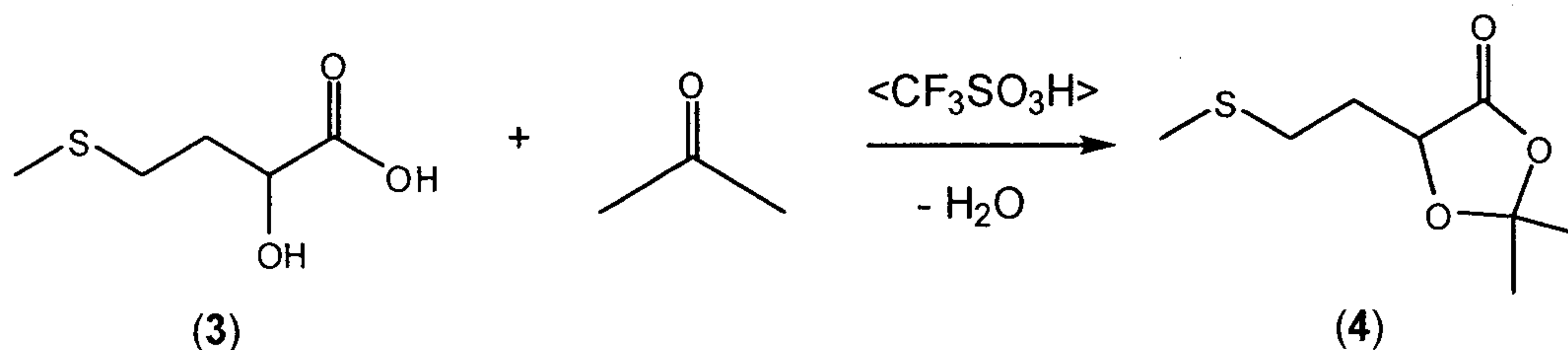


- 10 5.0 g (33.3 mmol) of 2-hydroxy-4-(methylthio)butanoic acid (**3**) and 5.0 g (55.5 mmol, 1.67 eq.) of 1,3,5-trioxane (alternatively 5.0 g of paraformaldehyde) were placed in a 100 mL three-neck round bottom flask in 50 mL of toluene, admixed with a spatula tip of *p*-toluenesulfonic acid and
- 15 heated to boiling. After 12 h, the solvent was distilled off on a rotary evaporator and the resultant crude product was distilled in vacuum. This produced 4.6 g (28.5 mmol, yield = 86%) of 5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**2**) as colorless liquid. The NMR data agreed with those
- 20 from Example 1.

Example 3:

Synthesis of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**4**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and acetone by Brönstedt acid catalysis:

18



5.0 g (33.3 mmol) of 2-hydroxy-4-(methylthio)butanoic acid (3) were placed in a 250 mL three-neck round bottom flask in 100 mL of acetone, admixed with a few drops of trifluoromethanesulfonic acid or sulfuric acid and stirred at RT for 16 h. Subsequently the reaction mixture was concentrated on a rotary evaporator, taken up into 100 mL of diethyl ether and extracted twice, each time with 25 mL of saturated NaCl solution. The ether phase was dried over MgSO₄, concentrated on a rotary evaporator and the resultant crude product subsequently distilled in vacuum via a Vigreux column (boiling point = 122°C/1 mbar). This produced 5.2 g (27.4 mmol, yield = 82%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (4) as colorless oil.

¹H-NMR of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (4) (500 MHz, CDCl₃): δ = 1.55 (s, 3H, CH₃); 1.61 (s, 3H, CH₃); 1.95-2.20 (m, 2H, CH₂); 2.11 (s, 3H, SCH₃); 2.62-2.66 (m, 2H, SCH₂); 4.55 (dd, ³J = 7.5 Hz, ²J = 4.4 Hz, 1H, CH)

¹³C-NMR of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (4) (125.8 MHz, CDCl₃): δ = 14.96 (SCH₃); 25.46 (CH₃); 26.92 (CH₃); 29.04 (CH₂); 30.73 (CH₂); 72.18 (CH); 110.37 (C); 172.68 (C=O)

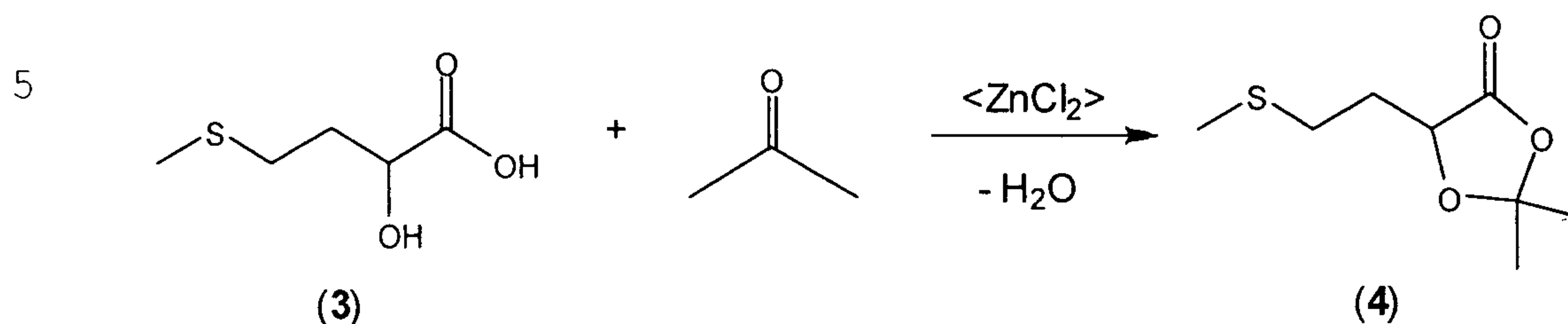
Elemental analysis for C₈H₁₄O₃S (M = 190.26 g/mol):

Calculated: C 50.50; H 7.42; S 16.85

Found: C 50.28; H 7.63; S 16.88

Example 4:

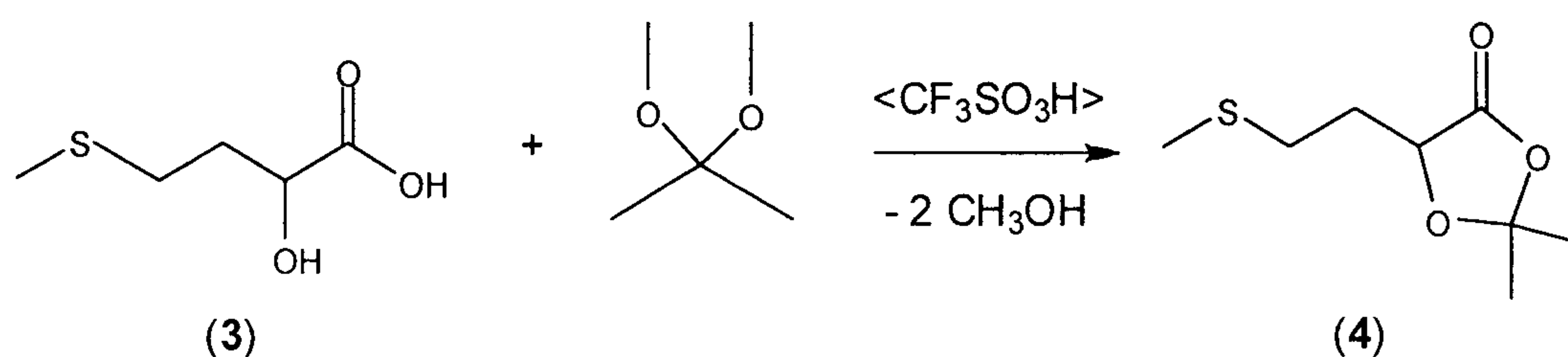
Synthesis of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**4**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and acetone by Lewis acid catalysis:



1.0 g (6.7 mmol) of 2-hydroxy-4-(methylthio)butanoic acid (**3**) were placed in a 100 mL three-neck round bottom flask in 20 mL of acetone, admixed with 1.0 eq. of Lewis acid (893 mg of ZnCl_2 , alternatively 1.69 g of $\text{MgBr}_2 \cdot 2 \text{Et}_2\text{O}$ or 1.38 g of $\text{BF}_3 \cdot 2 \text{H}_2\text{O}$) and stirred at RT for 16 h. Subsequently the reaction mixture was concentrated on a rotary evaporator, taken up into 100 mL of diethyl ether, washed with 50 mL of water and twice with 25 mL each time of saturated NaCl solution. The ether phase was then dried over MgSO_4 , concentrated on a rotary evaporator and the resultant crude product subsequently distilled in vacuum on a Kugelrohr ball-tube apparatus. This produced 1.1 g (5.8 mmol, yield = 87%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**4**) as colorless oil. The NMR data agreed with those from Example 3.

Example 5:

Synthesis of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**4**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and acetone by transketalization:

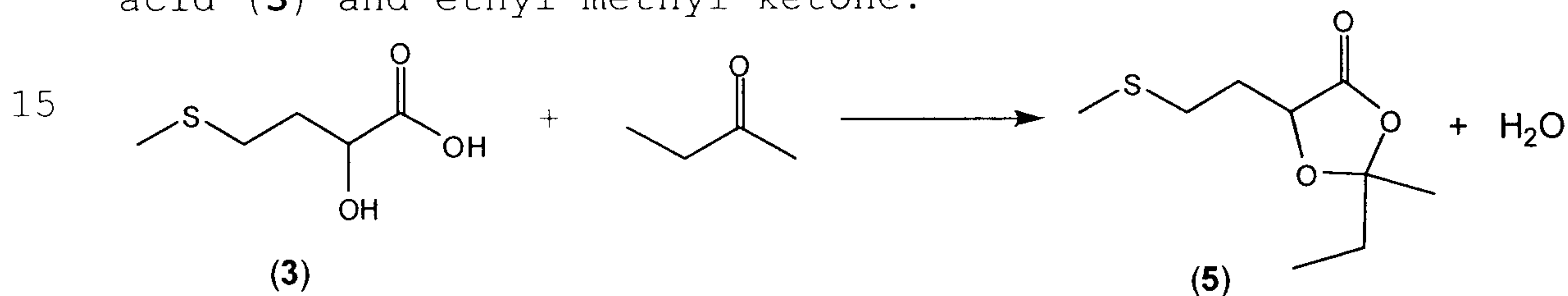


20

5.0 g (33.3 mmol) of 2-hydroxy-4-(methylthio)butanoic acid (**3**) and 5.0 g (48.0 mmol, 1.44 eq.) of 2,2-dimethoxypropane were placed in a 100 mL three-neck round bottom flask in 50 mL of tetrahydrofuran and heated to boiling. After 3 h, the solvent was distilled off on a rotary evaporator and the resultant crude product was subsequently distilled in vacuum. This produced 5.6 g (29.7 mmol, yield = 89%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**4**) as colorless oil. The NMR data agreed with those from Example 3.

Example 6:

Synthesis of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**5**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and ethyl methyl ketone:



35.0 g (205 mmol) of 88% strength 2-hydroxy-4-(methylthio)butanoic acid (**3**) were added to 350 mL of ethyl methyl ketone and held under reflux for 5 h. After the mixture was cooled the solvent was taken off together with the resultant water on a rotary evaporator and the residue was distilled in vacuum (boiling point = 103°C, 0.4 mbar). This produced 26.5 g (mmol, yield = 56%) of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**5**) as colorless liquid. The ethyl methyl ketone taken off was dried over MgSO₄ and could subsequently be used again for the next reaction.

¹H-NMR of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**5**) (diastereomer mixture, ratio 63:37) (500 MHz, CDCl₃): δ = 0.96-1.00 (m, 3H, CH₃); 1.52, 1.56 (s, 3H, CH₃); 1.80-1.88 (m, 2H, CH₂); 1.97-2.18 (m, 2H,

21

CH₂); 2.11 (s, 3H, SCH₃); 2.63-2.67 (m, 2H, CH₂); 4.54-4.58 (m, 1H, CH)

¹³C-NMR of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**5**) (diastereomer mixture, ratio 63:37)

5 (125.8 MHz, CDCl₃): δ = 7.23, 7.87 (CH₃); 15.24 (SCH₃); 23.86, 25.09 (CH₂); 29.34, 29.51, 30.97, 31.54, 32.42, 32.60 (CH₃, 2 x CH₂); 72.25, 73.00 (CH); 112.29, 112.83 (C); 173.04, 173.09 (C=O)

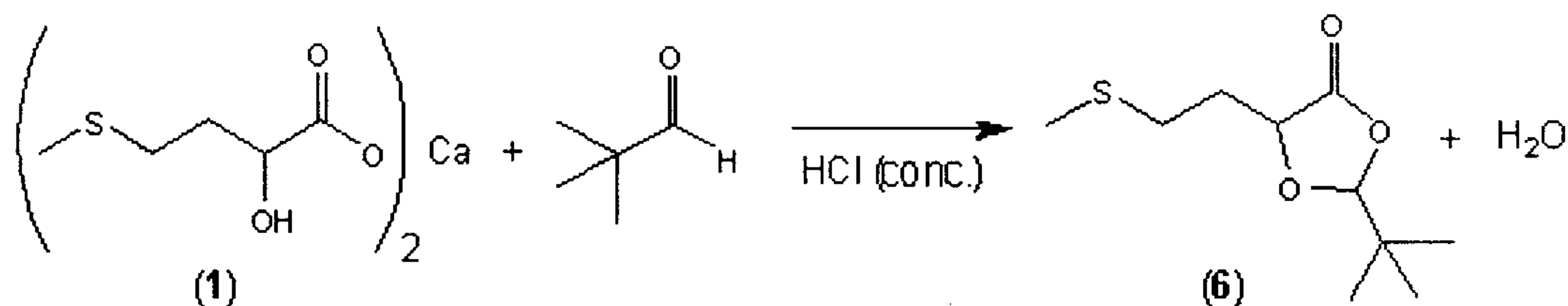
Elemental analysis for C₉H₁₆O₃S (M = 204.29 g/mol):

10 Calculated: C 52.91; H 7.89; S 15.70

Found: C 53.04; H 8.02; S 15.46

Example 7:

Synthesis of 2-*tert*-butyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**6**) 2-hydroxy-4-(methylthio)butanoic acid calcium salt (**1**) and pivalaldehyde under Brönstedt acid catalysis:



6.77 g (20 mmol) of 2-hydroxy-4-(methylthio)butanoic acid calcium salt (**1**) were slowly admixed with 13.8 g of conc. hydrochloric acid under stirring and ice cooling. A clear solution formed. Subsequently, under a protective gas atmosphere, 15 mL of toluene and 3.45 g (40 mmol) of freshly distilled pivalaldehyde were added, heated to 75°C, wherein the two-phase mixture became clear. Then, the mixture was stirred at this temperature for 7 h. After it had cooled, two phases formed. The organic toluene phases were separated off and the aqueous phase was washed twice,

each time with 10 mL of toluene. The combined organic phases were washed three times, each time with 15 mL of water, dried over Na₂SO₄ and, after filtration, concentrated on a rotary evaporator. The resultant crude product was subsequently freed from the last solvent residues in high vacuum. This produced 2.62 g (12.0 mmol, yield = 30%) of 2-*tert*-butyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**6**) as slightly yellowish oil.

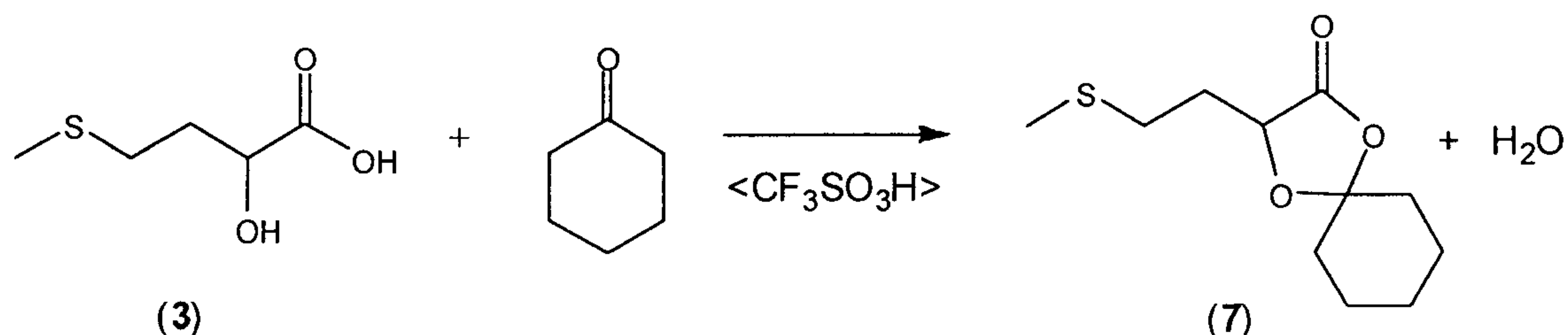
¹H-NMR of 2-*tert*-butyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**6**) (diastereomer mixture) (500 MHz, CDCl₃): δ = 0.96, 0.98 (s, 9H, CH₃); 1.99-2.22 (m, 2H, CH₂); 2.09 (s, 3H, SCH₃); 2.64-2.69 (m, 2H, CH₂); 4.43-4.46, 4.51-4.54 (m, 1H, CH); 5.15, 5.28 (s, 1H, CH)

¹³C-NMR of 2-*tert*-butyl-5-(2-(methylthio)ethyl)-1,3-dioxolan-4-one (**6**) (diastereomer mixture) (125.8 MHz, CDCl₃): δ = 15.21, 15.25 (SCH₃); 23.24, 23.44 (CH₃); 29.37, 29.39, 30.22, 30.33, 34.24, 35.74 (C, 2 x CH₂); 73.15, 73.42 (CH); 109.43, 110.46 (CH); 173.17, 173.27 (C=O)

Elemental analysis for C₁₀H₁₈O₃S (M = 218.31 g/mol):
 Calculated: C 55.01; H 8.33; S 14.69
 Found: C 55.36; H 8.52; S 14.23

Example 8:

Synthesis of 3-(2-(methylthio)ethyl)-1,4-dioxaspiro[4.5]decan-2-one (**7**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and cyclohexanone:



10.0 g (66.6 mmol) of 2-hydroxy-4-(methylthio)butanoic acid

23

(**3**) and 13.1 g (133.2 mmol, 2.0 eq.) of cyclohexanone were placed in a 250 mL three-neck round bottom flask in 100 mL of THF, admixed with a few drops of trifluoromethanesulfonic acid and stirred at RT for 16 h. Subsequently the reaction mixture was concentrated on a rotary evaporator. The resultant residue was dissolved with 100 mL of a mixture of 10 mL of dichloromethane and 90 mL of *n*-hexane and washed twice with 50 mL each time of water and once with 50 mL of saturated NaCl solution. The organic phase was subsequently dried over MgSO₄ and concentrated on a rotary evaporator. The resultant crude product was then chromatographed through a silica gel column using *n*-hexane/ethyl acetate=15:1. After concentration on a rotary evaporator, the last solvent residues were removed in high vacuum. This produced 11.2 g (48.6 mmol, yield = 73%) of 3-(2-(methylthio)ethyl)-1,4-dioxaspiro[4.5]decan-2-one (**7**) as colorless liquid.

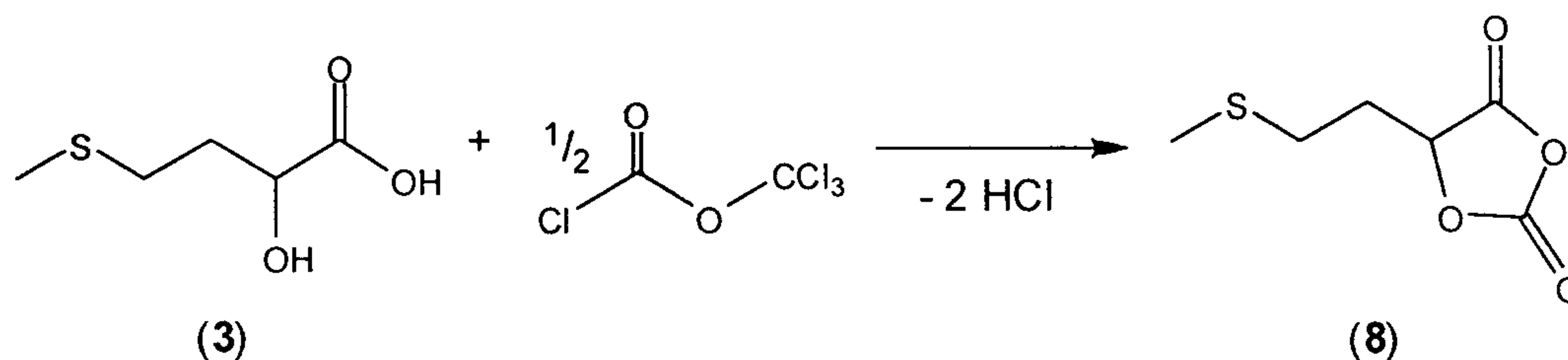
¹H-NMR of 3-(2-(methylthio)ethyl)-1,4-dioxaspiro[4.5]decan-2-one (**7**) (500 MHz, CDCl₃): δ = 1.38-1.88 (m, 10H, 5 x CH₂); 1.96-2.20 (m, 2H, CH₂); 2.11 (s, 3H, SCH₃); 2.65 (t, ³J = 7.4 Hz, 2H, SCH₂); 4.55 (dd, ³J = 7.6, ²J = 4.5 Hz, 1H, CH)

¹³C-NMR of 3-(2-(methylthio)ethyl)-1,4-dioxaspiro[4.5]decan-2-one (**7**) (125.8 MHz, CDCl₃): δ = 22.86 (SCH₃); 23.00 (CH₂); 24.50 (CH₂); 29.38 (SCH₂); 31.13 (CH₂); 35.24 (CH₂); 36.77 (CH₂); 72.25 (CH); 111.49 (C); 173.07 (C=O)

Example 9:

Synthesis of 5-(2-(methylthio)ethyl)-1,3-dioxolan-2,4-dione (**8**) from 2-hydroxy-4-(methylthio)butanoic acid (**3**) and diphosgene:

24

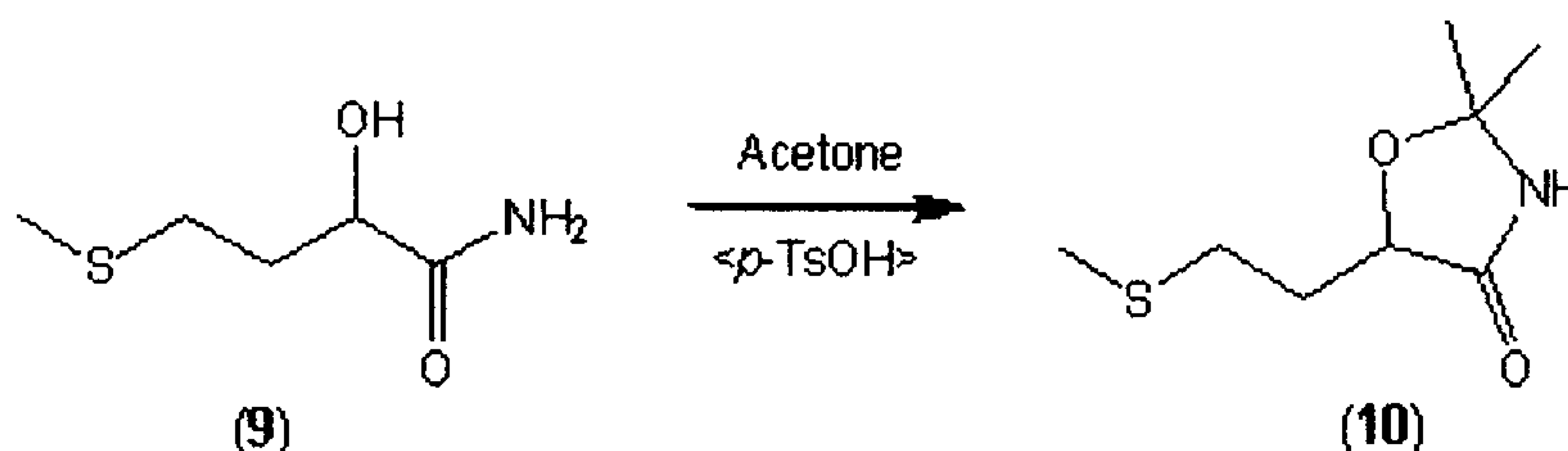


5 1.5 g (10.0 mmol) of 2-hydroxy-4-(methylthio)butanoic acid
 (3) were placed in a 50 mL Schlenk flask in 10 mL of dry
 THF and under an argon atmosphere, 1.5 mL (12.0 mmol) of
 diphosgene were added over a period of 15 min. After
 addition of 30 mg of activated carbon, the reaction mixture
 10 was stirred at RT for 12 h. Subsequently the reaction
 solution was filtered through a Celite bed, concentrated at
 room temperature on a rotary evaporator and dried for 4 h
 in high vacuum. This produced 1.1 g (9.7 mmol, yield = 97%)
 of 5-(2-(methylthio)ethyl)-1,3-dioxolan-2,4-dione (8) as
 15 yellowish oil.

^1H -NMR of 5-(2-(methylthio)ethyl)-1,3-dioxolan-2,4-dione
 (8) (500 MHz, CDCl_3): δ = 2.10 (s, 3H, SCH_3); 2.20-2.40 (m,
 2H, CH_2); 2.60-2.80 (m, 2H, SCH_2); 5.20-5.30 (m, 1H, CH)

Example 10:

20 Synthesis of 2,2-dimethyl-5-(2-(
 (methylthio)ethyl)oxazolidin-4-one (10) from 2-hydroxy-4-(
 (methylthio)butanamide (9) and acetone by Brönstedt acid
 catalysis:



25 14.9 g (0.1 mol) of 2-hydroxy-4-(methylthio)butanamide (9)
 in 150 mL of toluene were placed in a 250 mL three-neck
 flask having a water separator and reflux condenser,

25

admixed with 11.6 g of acetone (0.2 mol) and 0.8 g of *p*-toluenesulfonic acid and slowly heated to boiling temperature with stirring. The turbid suspension clarified at 90°C. The entire solution was boiled under reflux for 14 h. During this, in total the toluene phase which distilled over was drained off twice and subsequently supplemented twice each time with 11.6 g of acetone. After the mixture had cooled, the turbid reaction solution was filtered and the filtrate was washed once with 100 mL of dilute NaHCO₃ solution, twice with 100 mL each time of H₂O and subsequently once with 100 mL of saturated sodium chloride solution. Thereafter the toluene phase was dried over Na₂SO₄. After the filtration the solvent was taken off on a rotary evaporator in vacuum. This produced 13.2 g of an orange-brown oil which slowly crystallized. For recrystallization, 30 mL of *n*-hexane were added, the mixture was briefly heated to boiling temperature, subsequently cooled to RT, and allowed to stand overnight. On the next day the solid which had crystallized out was filtered off and dried in high vacuum. This produced 11.5 g (0.06 mol, M = 189.28 g/mol, yield = 60%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**8**) as a slightly yellowish solid (melting point = 84°C).

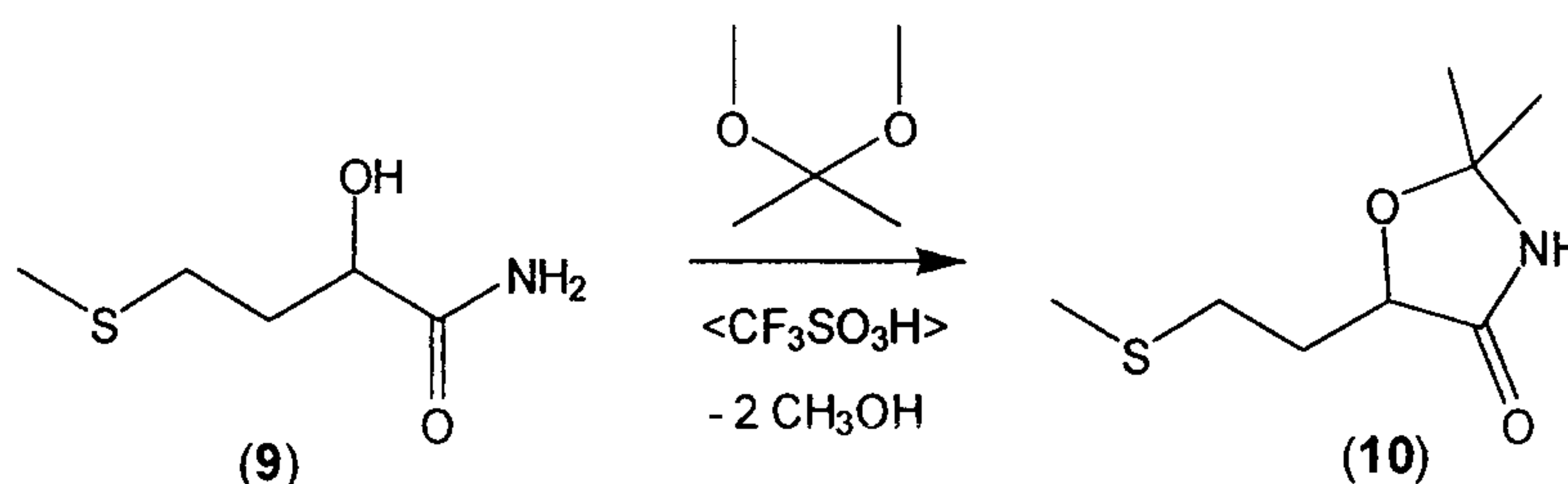
¹H-NMR of 2,2-dimethyl-5-(2-(methylthio)ethyl)-4-oxazolidinone (**10**) (500 MHz, DMSO-d₆): δ = 1.34 (s, 3H, CH₃); 1.36 (s, 3H, CH₃); 1.73-1.78 (m, 1H, CH); 1.87-1.92 (m, 1H, CH); 2.04 (s, 3H, SCH₃); 2.48-2.56 (m, 2H, CH₂); 4.23-4.28 (m, 1H, CH); 8.83 (bs, 1H, NH).

¹³C-NMR of 2,2-dimethyl-5-(2-(methylthio)ethyl)-4-oxazolidinone (**10**) (125.8 MHz, DMSO-d₆): δ = 14.50 (SCH₃); 28.07, 28.70, 29.10, 31.66 (2 x CH₂, 2 x CH₃); 74.53 (CH); 89.60 (C); 171.94 (C=O).

Elemental analysis for C₈H₁₅NO₂S (M = 189.28 g/mol):
Calculated: C 50.76; H 7.99; N 7.40; S 16.94
Found: C 50.90; H 8.11; N 7.31; S 16.90

Example 11:

Synthesis of 2,2-dimethyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**10**) from 2-hydroxy-4-(methylthio)butanamide (**9**) by transketalization:



10.0 g (67.0 mmol) of 2-hydroxy-4-(methylthio)butanamide (**9**) were suspended in 70 mL of dry tetrahydrofuran in a 250 mL three-neck flask and admixed with 13.96 g (134.0 mmol, 2.0 eq.) of dimethoxypropane. After addition of a few drops of trifluoromethanesulfonic acid, the reaction mixture was stirred for 16 h at room temperature. Subsequently the solvent was removed on a rotary evaporator at 100 mbar/30°C. The oily residue was dissolved in 100 mL of diethyl ether and washed twice with 50 mL of water each time. The ether phase was dried over MgSO_4 and concentrated on a rotary evaporator. The resultant solid was subsequently recrystallized from 100 mL of *n*-hexane, filtered off and the last solvent remains were removed in high vacuum. This produced 11.8 g (62 mmol, yield = 93%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**10**) as colorless solid. The NMR data agreed with those of Example 10.

Elemental analysis for $\text{C}_8\text{H}_{15}\text{NO}_2\text{S}$ ($M = 189.28 \text{ g/mol}$):

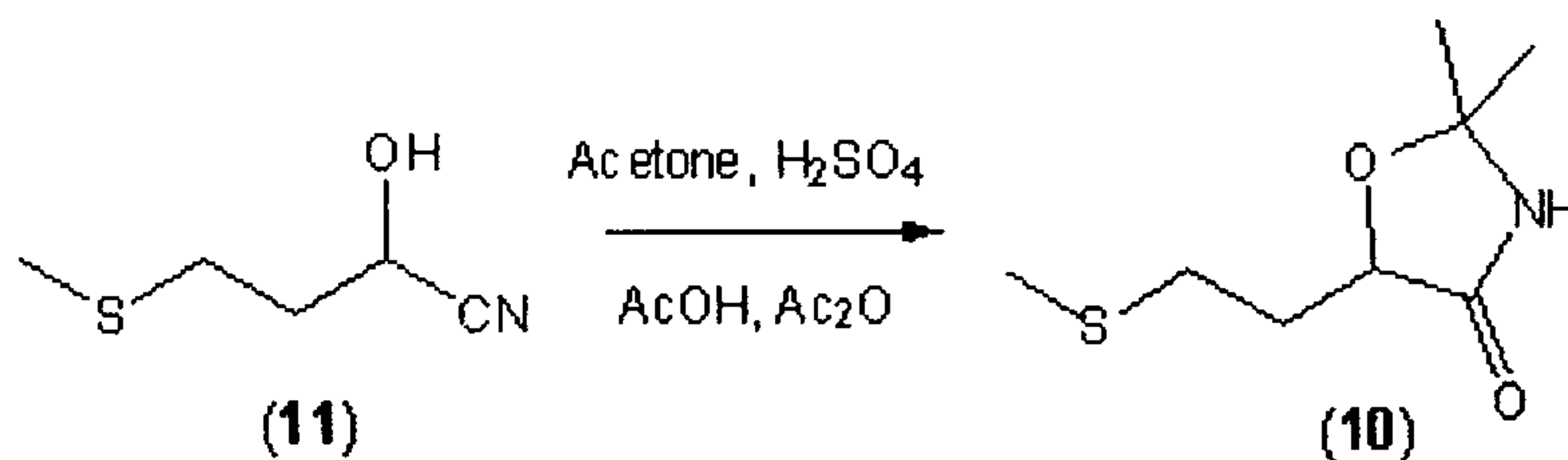
Calculated: C 50.76; H 7.99; N 7.40; S 16.94

Found: C 50.96; H 8.14; N 7.31; S 16.88

27

Example 12:

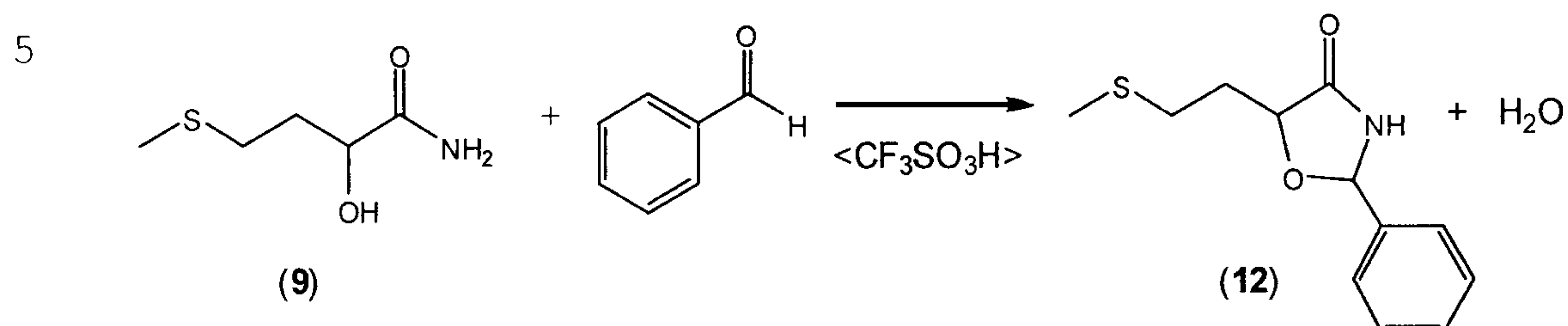
Synthesis of 2,2-dimethyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**10**) from 1-hydroxy-3-(methylthio)propanecarbonitrile (**11**):



In a 100 mL three-neck flask, 13.1 g of 96% strength 1-hydroxy-3-(methylthio)propanecarbonitrile (**11**) (0.1 mol) and 7.0 g of acetone (0.12 mol) were dissolved in 30 mL of glacial acetic acid at 10°C. Then, 5 mL of acetic anhydride (0.05 mol) were slowly added dropwise. Subsequently, a mixture of 10 mL of conc. sulfuric acid and 10 mL of glacial acetic acid was added slowly at 0°C. During this it must be ensured that the entire reaction solution does not become warmer than 0°C. This produced a viscous, yellowish, scarcely stirrable suspension. After addition was complete, the mixture was stirred for 1 h at 10°C and subsequently 15 min at RT. The reaction solution was poured onto ice (approximately 150 g) and thereafter extracted three times with 100 mL of diethyl ether each time. The ether phase was washed once with saturated sodium hydrogencarbonate solution and subsequently with saturated sodium chloride solution and dried over sodium sulfate. The Na₂SO₄ was filtered off and the ether was taken off in vacuum. This produced 4.5 g of an orange-brown oil which was recrystallized from *n*-hexane. After filtration and removal of final solvent residues in high vacuum, 2.8 g (14.8 mmol, M = 189.28 g/mol, yield = 15%) of 2,2-dimethyl-5-(2-(methylthio)ethyl)-4-oxazolidinone (**10**) were isolated as a slightly yellowish solid. The NMR data agreed with those of Example 10.

Example 13:

Synthesis of 5-(2-(methylthio)ethyl)-2-phenyloxazolidin-4-one (**12**) from 2-hydroxy-4-(methylthio)butanamide (**9**) by Brönstedt acid catalysis:



5.0 g (33.5 mmol) of 2-hydroxy-4-(methylthio)butanamide (**9**) were suspended in 35 mL of dry tetrahydrofuran in a 100 mL three-neck flask and admixed with 7.1 g (67 mmol, 2.0 eq.) of freshly distilled benzaldehyde. After addition of a few drops of trifluoromethanesulfonic acid, the reaction mixture was stirred at room temperature for 16 h. The clear reaction solution was concentrated on a rotary evaporator and the resultant residue taken up in 100 mL of diethyl ether. Subsequently, the mixture was washed thrice each time with 30 mL of water and once with 30 mL of saturated NaCl solution. The ether phase was dried over MgSO₄ and concentrated on a rotary evaporator. The resultant product mixture was then separated via fractional crystallization. From 100 mL of dichloromethane/diethyl ether=1:1, in total 2.8 g of a solid was isolated which was subsequently recrystallized from diethyl ether. This produced 2.1 g (8.8 mmol, yield = 26%) of 5-(2-(methylthio)ethyl)-2-phenyloxazolidin-4-one (**12**) as colorless solid (melting point = 130°C).

¹H-NMR of 5-(2-(methylthio)ethyl)-2-phenyloxazolidin-4-one (**12**) (500 MHz, CDCl₃): δ = 2.00-2.30 (m, 2H, CH₂); 2.11 (s, 3H, SCH₃); 2.63-2.75 (m, 2H, SCH₂); 4.49-4.53 (m, 1H, CH); 6.03-6.05 (m, 1H, CH); 6.24 (bs, 1H, NH); 7.40-7.50 (m, 5H, H_{Phenyl})

¹³C-NMR of 5-(2-(methylthio)ethyl)-2-phenyloxazolidin-4-one

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(**12**) (125.8 MHz, CDCl₃): δ = 19.67 (SCH₃); 29.93 (SCH₂); 31.74 (CH₂); 76.68 (CH); 87.33 (CH); 127.23, 129.28, 130.49, 138.12 (C_{Phenyl}); 175.25 (C=O)

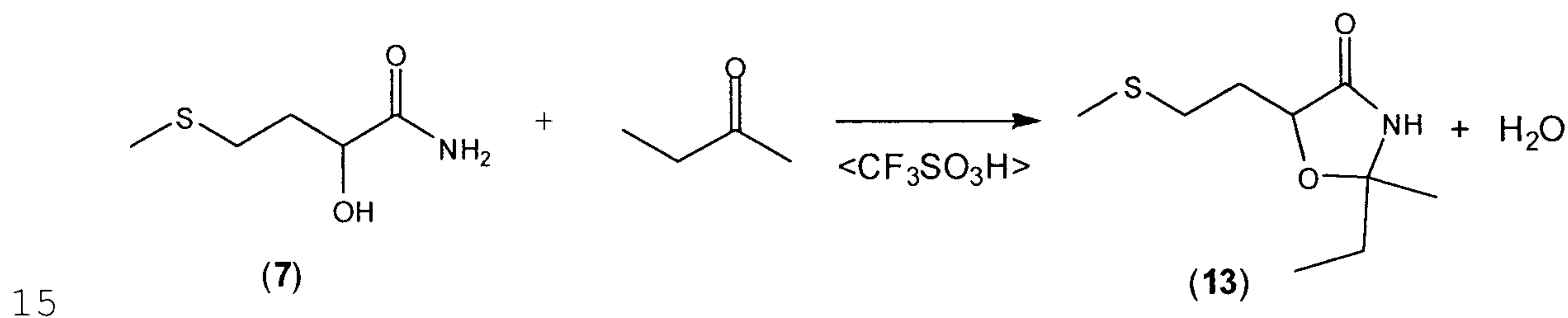
Elemental analysis for C₁₂H₁₅NO₂S (M = 237.32 g/mol):

5 Calculated: C 60.73; H 6.37; N 5.90; S 13.51

Found: C 60.61; H 6.27; N 5.66; S 13.49

Example 14:

Synthesis of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**13**) from 2-hydroxy-4-(methylthio)butanamide (**9**) by Brönstedt acid catalysis:



5.0 g (33.5 mmol) of 2-hydroxy-4-(methylthio)butanamide (**9**) were suspended in 35 mL of dry tetrahydrofuran in a 100 mL three-neck flask and admixed with 4.8 g (67 mmol, 2.0 eq.) of ethyl methyl ketone. After addition of a few drops of trifluoromethanesulfonic acid, the reaction mixture was stirred at room temperature for 5 days. The clear reaction solution was concentrated on a rotary evaporator, the resultant residue taken up in 100 mL of diethyl ether and washed three times with 30 mL of water each time and once with 30 mL of saturated NaCl solution. The combined ether phases were dried over MgSO₄, concentrated on a rotary evaporator and the residue was recrystallized twice from a diethyl ether/*n*-hexane mixture. This produced 5.1 g (24.9 mmol, yield = 74%) of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**13**) as a colorless solid (m.p. = 62°C).

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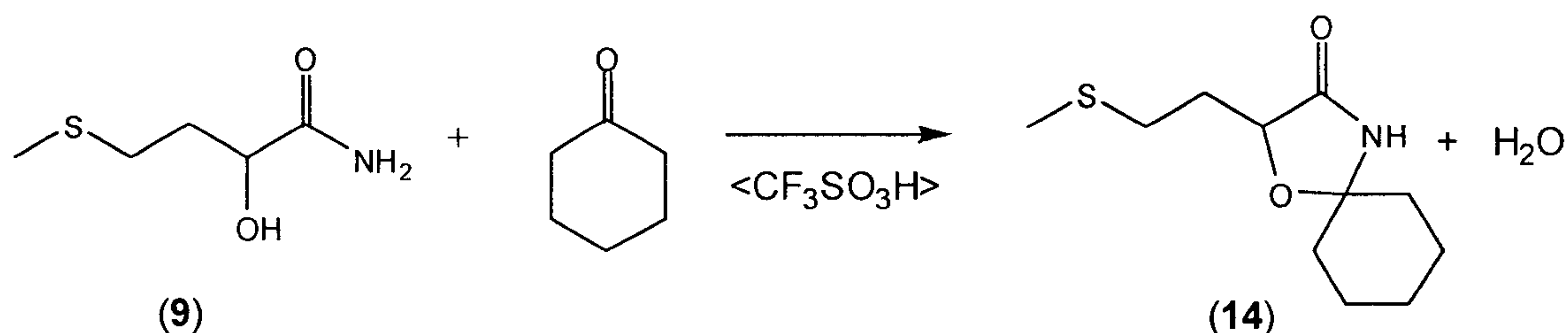
¹H-NMR of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**13**) (diastereomer mixture) (500 MHz, CDCl₃): δ = 0.95 (t, ³J = 7.4 Hz, 3H, CH₃); 1.44-1.46 (pd, 3H, CH₃); 1.62-1.80 (m, 2H, CH₂); 1.90-2.16 (m, 2H, CH₂); 2.12 (s, 3H, SCH₃); 2.60-2.70 (m, 2H, SCH₂); 4.42-4.48 (m, 1H, CH); 6.60-6.80 (bd, 1H, NH)

¹³C-NMR of 2-ethyl-2-methyl-5-(2-(methylthio)ethyl)oxazolidin-4-one (**13**) (diastereomer mixture) (125.8 MHz, CDCl₃): δ = 7.82, 7.97 (CH₃); 15.36, 15.37 (SCH₃); 26.55, 27.62, 29.55, 29.78, 31.79, 32.42, 34.09, 34.51 (3 x CH₂, 1 x CH₃); 75.18, 76.27 (CH); 92.56, 92.81 (C); 174.13, 174.19 (C=O)

Elemental analysis for C₉H₁₇NO₂S (M = 203.30 g/mol):
Calculated: C 53.17; H 8.43; N 6.89; S 15.77
Found: C 52.46; H 8.27; N 6.49; S 15.71

Example 15:

Synthesis of 2-(2-(methylthio)ethyl)-1-oxa-4-azaspiro[4.5]decan-3-one (**14**) from 2-hydroxy-4-(methylthio)butanamide (**9**) by Brönstedt acid catalysis:



10.0 g (67.0 mmol) of 1-hydroxy-3-(methylmercapto)butanamide (**9**) were suspended in 150 mL of dry toluene in a 250 mL three-neck flask and admixed with 32.9 g (336 mmol, 5.0 eq.) of cyclohexanone. After addition of a few drops of trifluoromethanesulfonic acid, the reaction mixture was heated to boiling and stirred at this

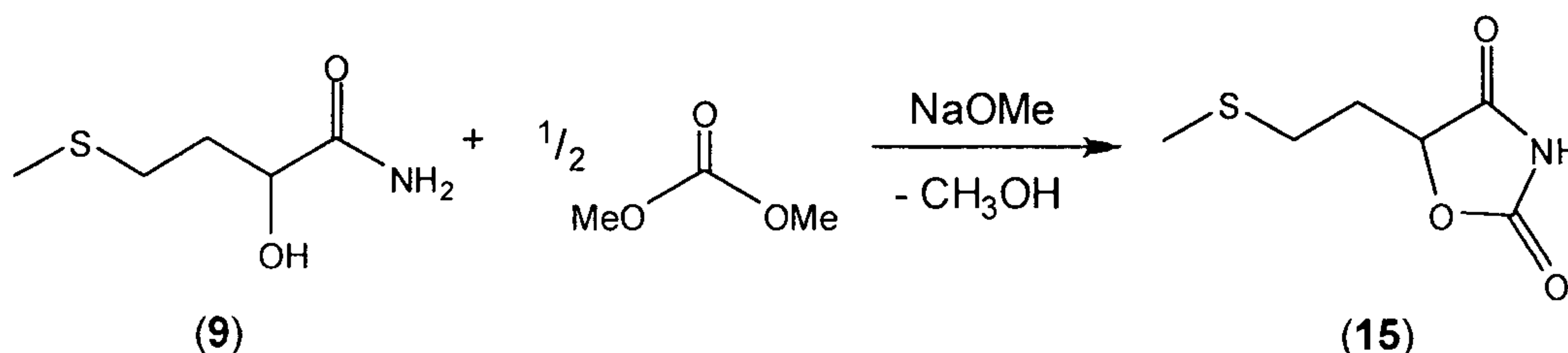
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temperature for 1 h. The reaction solution was subsequently cooled and extracted twice, each time with 50 mL of water. The organic phase was dried over MgSO_4 and removed on a rotary evaporator at 70 mbar/40°C. The resultant solid was recrystallized from *n*-hexane/EtOAc, filtered off, dried and the last solvent residues were removed in high vacuum. This produced 12.4 g (54 mmol, yield = 80%) of 2-(2-(methylthio)ethyl)-1-oxa-4-azaspiro[4.5]decan-3-one (**14**) as colorless solid (m.p. = 109°C).

- ¹H-NMR of 2-(2-(methylthio)ethyl)-1-oxa-4-azaspiro[4.5]decan-3-one (**14**) (500 MHz, CDCl_3): δ = 1.38-1.80 (m, 10H, 5 x CH_2); 1.90-2.18 (m, 2H, CH_2); 2.12 (s, 3H, SCH_3); 2.64 (t, 3J = 7.6 Hz, 2H, CH_2); 4.44 (dd, 3J = 7.6 Hz, 2J = 2.1 Hz, 1H, CH); 8.41 (bs, 1H, NH)
- ¹³C-NMR of 2-(2-(methylthio)ethyl)-1-oxa-4-azaspiro[4.5]decan-3-one (**14**) (125.8 MHz, CDCl_3): δ = 15.42 (SCH_3); 23.02, 23.12, 24.68 (3 x CH_2); 29.52 (SCH_2); 32.30 (CH_2); 37.85, 38.93 (2 x CH_2); 75.33 (CH); 91.98 (C); 174.54 (C=O)
- Elemental analysis for $\text{C}_{11}\text{H}_{19}\text{NO}_2\text{S}$ (M = 229.34 g/mol):
 Calculated: C 57.61; H 8.35; N 6.11; S 13.98
 Found: C 57.72; H 8.46; N 5.98; S 13.99

Example 16:

- Synthesis of 5-(2-(methylthio)ethyl)oxazolidin-2,4-dione (**15**) from 2-hydroxy-4-(methylthio)butanamide (**9**):



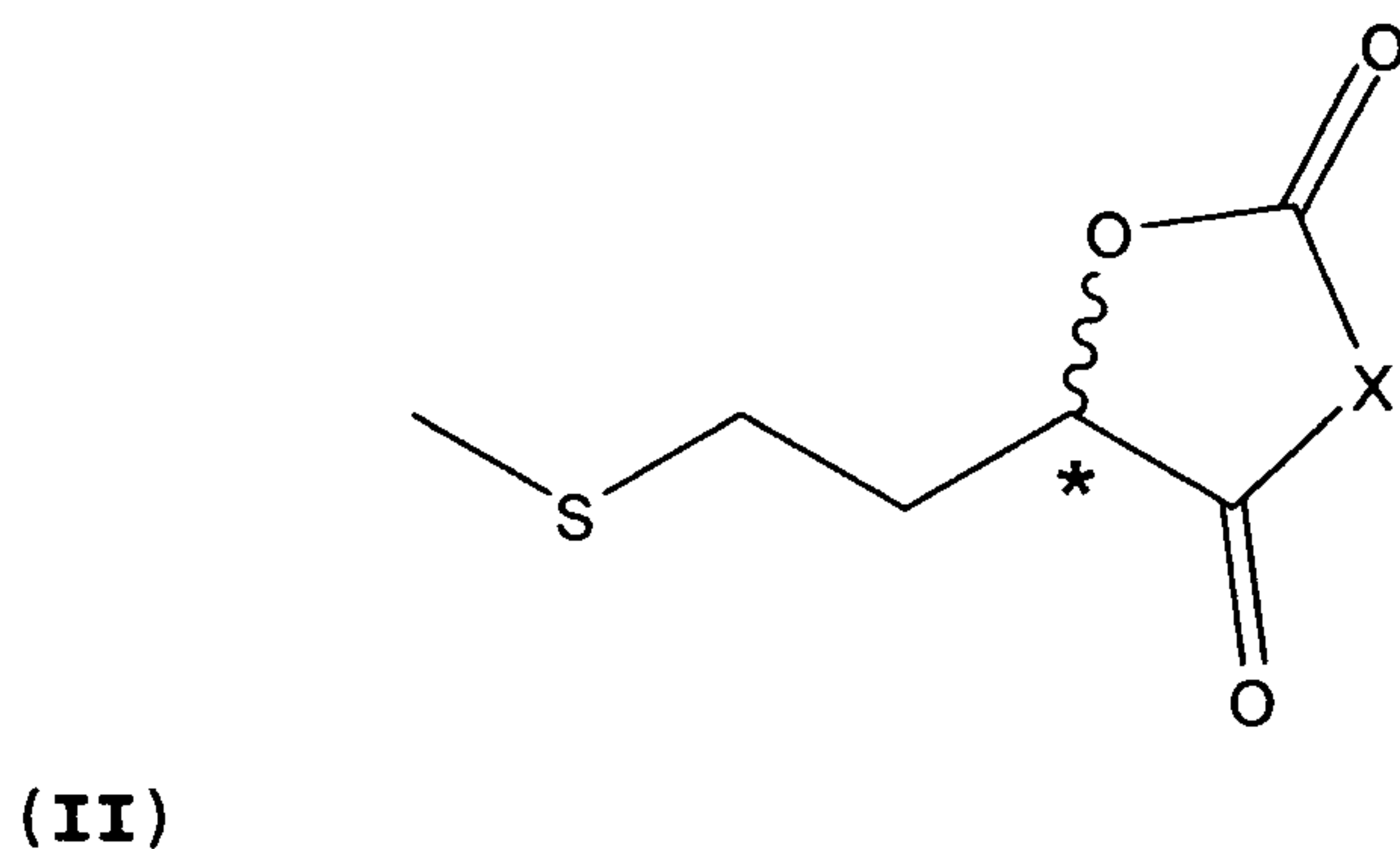
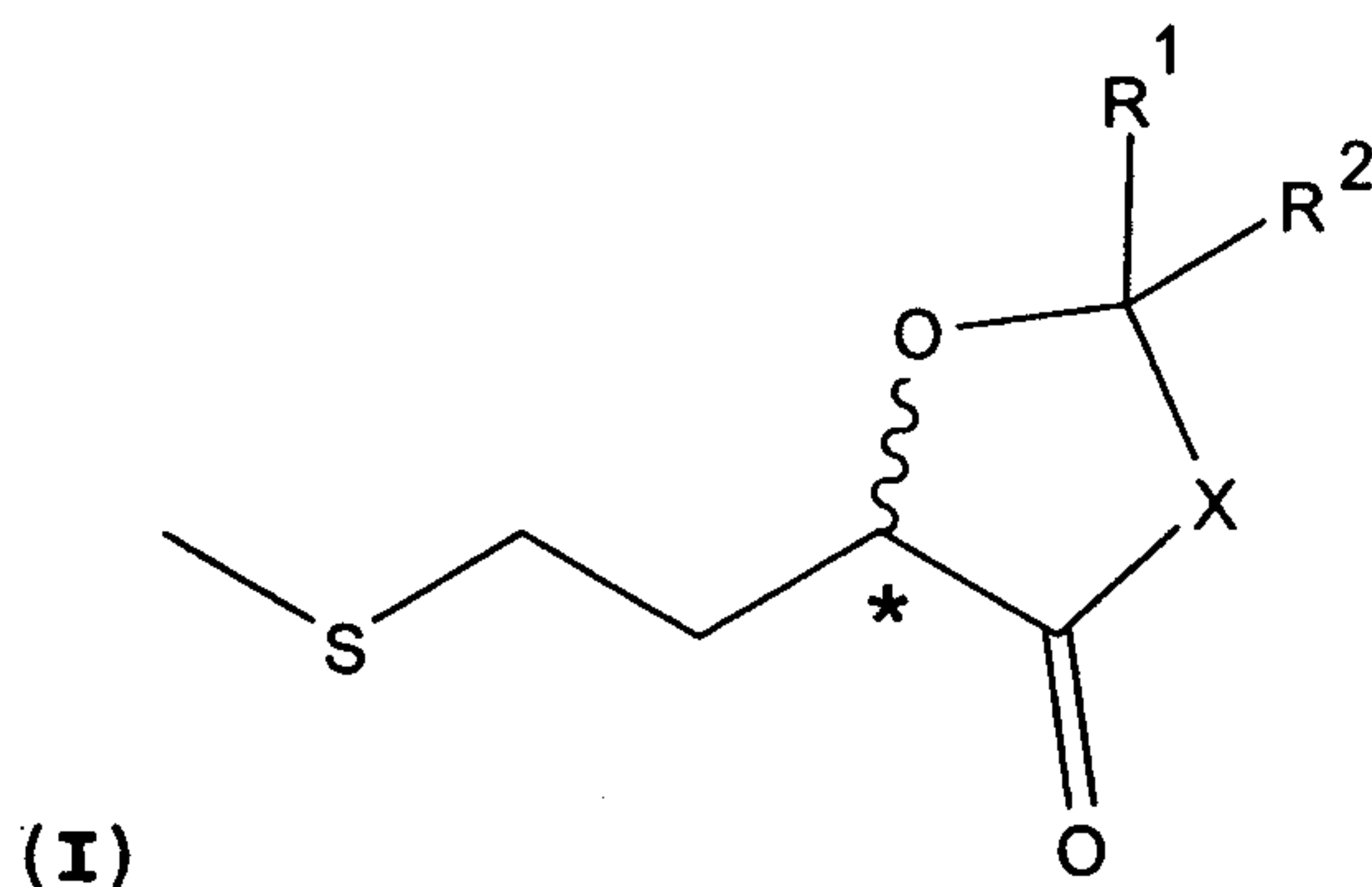
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5.0 g (33.5 mmol) of 1-hydroxy-3-(methylmercapto)butanamide (**9**) were suspended in 50 mL of methanol in a 250 mL three-neck flask, 10 mL of dimethyl carbonate were added and subsequently the mixture was admixed with 9.05 g (168 mmol, 5.0 eq.) of sodium methoxide. The reaction mixture was heated to boiling and stirred at this temperature for 24 h under reflux. The reaction solution was cooled and admixed twice with 100 mL of cold water and extracted three times, each time using 50 mL of *tert*-butyl methyl ether. The combined organic phase was dried over MgSO₄ and concentrated on a rotary evaporator at 15 mbar/40°C and stored overnight in a refrigerator. The crystallized solid was recrystallized repeatedly from a mixture of *n*-hexane/EtOAc. After the filtration and drying, the last solvent residues were removed in high vacuum. This produced 2.8 g (12.2 mmol, yield = 36.4%) of 5-(2-(methylthio)ethyl)oxazolidin-2,4-dione (**15**) as colorless solid.

¹H-NMR of 5-(2-(methylthio)ethyl)oxazolidin-2,4-dione (**15**) (500 MHz, CDCl₃): δ = 2.10 (s, 3H, SCH₃); 2.20-2.40 (m, 2H, CH₂); 2.60-2.80 (m, 2H, SCH₂); 5.0-5.2 (m, 1H, CH); 9.1 (bs, 1H, NH)

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A chemical compound of the general formula I or II,



wherein X is O or NR, wherein R is H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, aryl, or aralkyl, and wherein R¹, R², are identical or different and are each H, an optionally branched C₁-C₆-alkyl, C₃-C₆-cycloalkyl, allyl, aryl, or aralkyl;

or R¹ and R² together are an optionally C₁-C₆-alkyl substituted C₂- to C₆-alkylene group.

2. A chemical compound as claimed in claim 1, wherein aryl is phenyl.
3. A chemical compound as claimed in claim 1 or 2, wherein aralkyl is benzyl.
4. The compound of the formula I as claimed in claim 1, 2 or 3, wherein X is O.

5. The compound as claimed in any one of claims 1 to 4, wherein R^1 and R^2 are H.
6. The compound as claimed in any one of claims 1 to 4, wherein R^1 is H and R^2 is *tert*-butyl.
7. The compound as claimed in any one of claims 1 to 4, wherein R^1 is H and R^2 is phenyl.
8. The compound as claimed in any one of claims 1 to 4, wherein R^1 and R^2 are each an optionally branched C_1 - C_6 -alkyl.
9. The compound as claimed in claim 8, wherein R^1 and R^2 are CH_3 .
10. The compound as claimed in any one of claims 1 to 4, wherein R^1 and R^2 together are $(CH_2)_5$.
11. The compound of the formula I as claimed in claim 1, wherein X is NH.
12. The compound as claimed in claim 11, wherein R^1 and R^2 are H.
13. The compound as claimed in claim 11, wherein R^1 is H and R^2 is phenyl.
14. The compound as claimed in claim 11, wherein R^1 and R^2 are each an optionally branched C_1 - C_6 -alkyl.
15. The compound as claimed in claim 14, wherein R^1 and R^2 is CH_3 .

16. The compound as claimed in claim 14, wherein R^1 is CH_3 and R^2 is C_2H_5 .

17. The compound as claimed in claim 11, wherein R^1 and R^2 together are $(CH_2)_5$.

18. The compound of the formula **II** as claimed in claim 1, wherein X is O.

19. The compound of the formula **II** as claimed in claim 1, wherein X is NH.

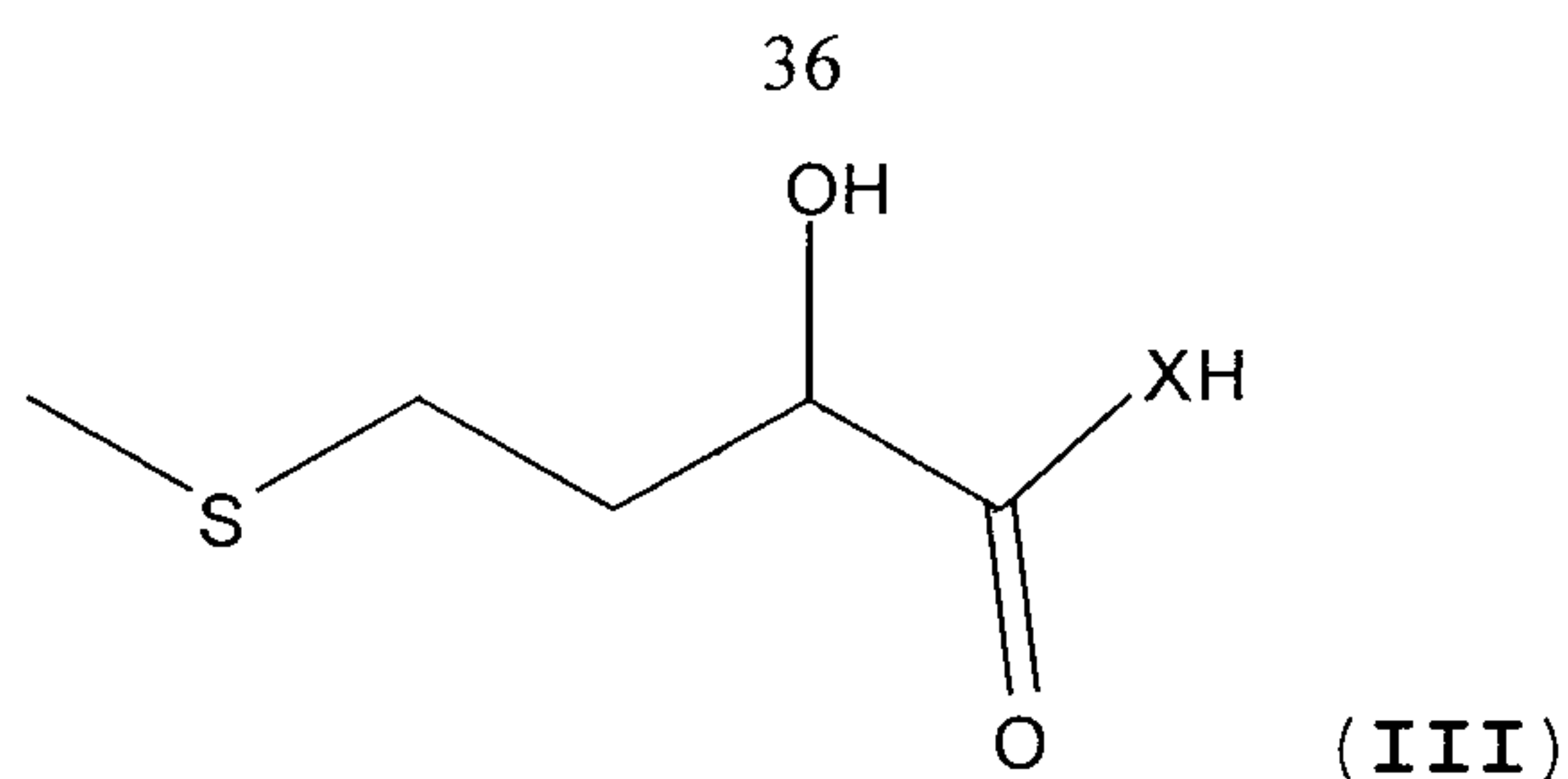
20. The use of a compound as defined in any one of claims 1 to 19 for the nutrition of farm animals.

21. The use as claimed in claim 20, for the nutrition of poultry, pigs, ruminants, fish or crustacea.

22. A feed mixture for the nutrition of farm animals which comprises at least one compound as defined in any one of claims 1 to 19.

23. The use of a compound as defined in any one of claims 1 to 19 for production of a feed mixture for the nutrition of farm animals.

24. A process for producing a compound of formula **I** as defined in claim 1, wherein a compound of the general formula **III**



is reacted with a carbonyl compound $R^1R^2C=O$ in free or acetalated form in the presence of a solvent, wherein X, R^1 and R^2 are as defined in claim 1.

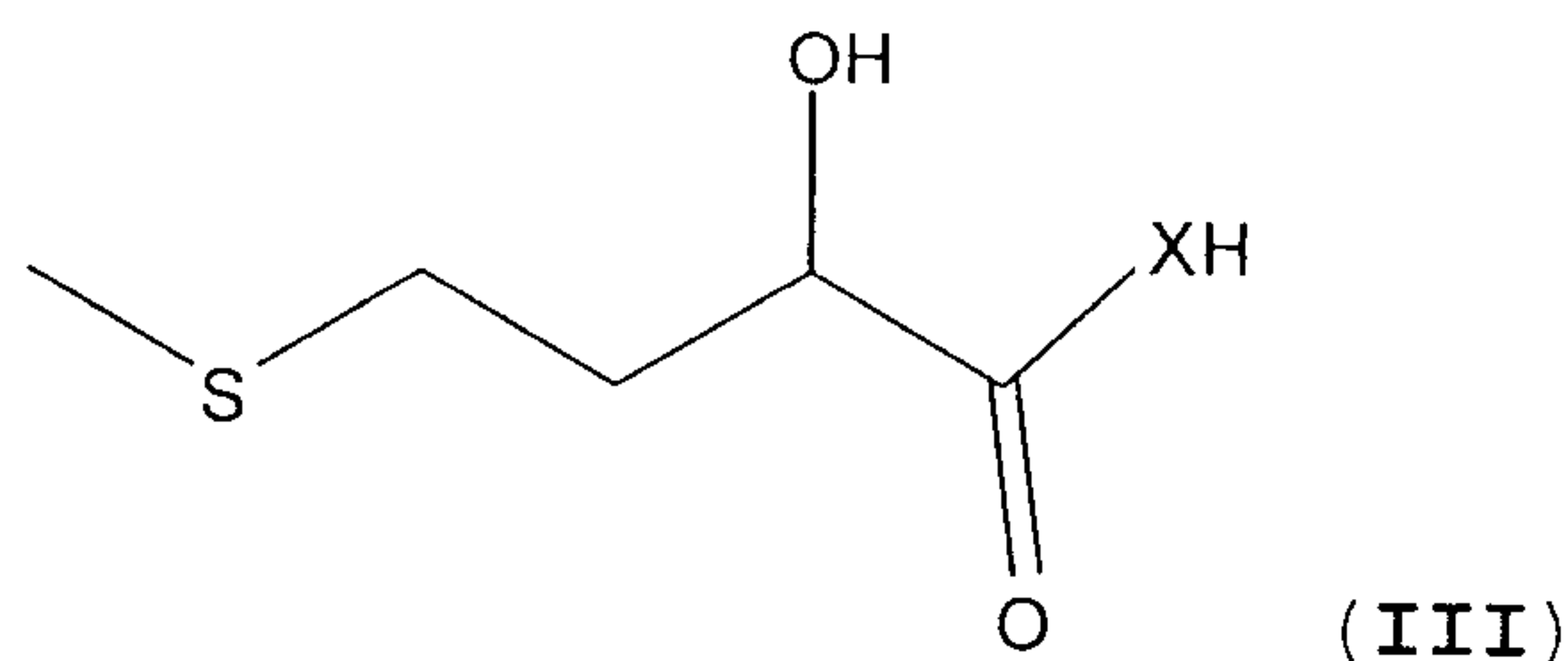
25. The process as claimed in claim 24, wherein a Lewis acid or a Brönstedt acid is used as a catalyst.

26. The process as claimed in claim 25, wherein the catalyst is HCl, H_2SO_4 , *p*-toluenesulfonic acid, CF_3SO_3H , $ZnCl_2$, $CuSO_4$, $FeCl_3$, $AlCl_3$, $MgCl_2$, or $MgBr_2$.

27. The process as claimed in any one of claims 24 to 26, wherein the carbonyl compound is the dimethylacetal or diethylacetal of the compound $R^1R^2C=O$.

28. The process as claimed in any one of claims 24 to 27, wherein water or alcohol which is formed during the reaction is removed.

29. A process for producing a compound of formula **II** as defined in claim 1, wherein a compound of the general formula **III**



is reacted with a carbonic acid derivative $X^1X^2C=O$, wherein X^1 and X^2 are identical or different and independently of

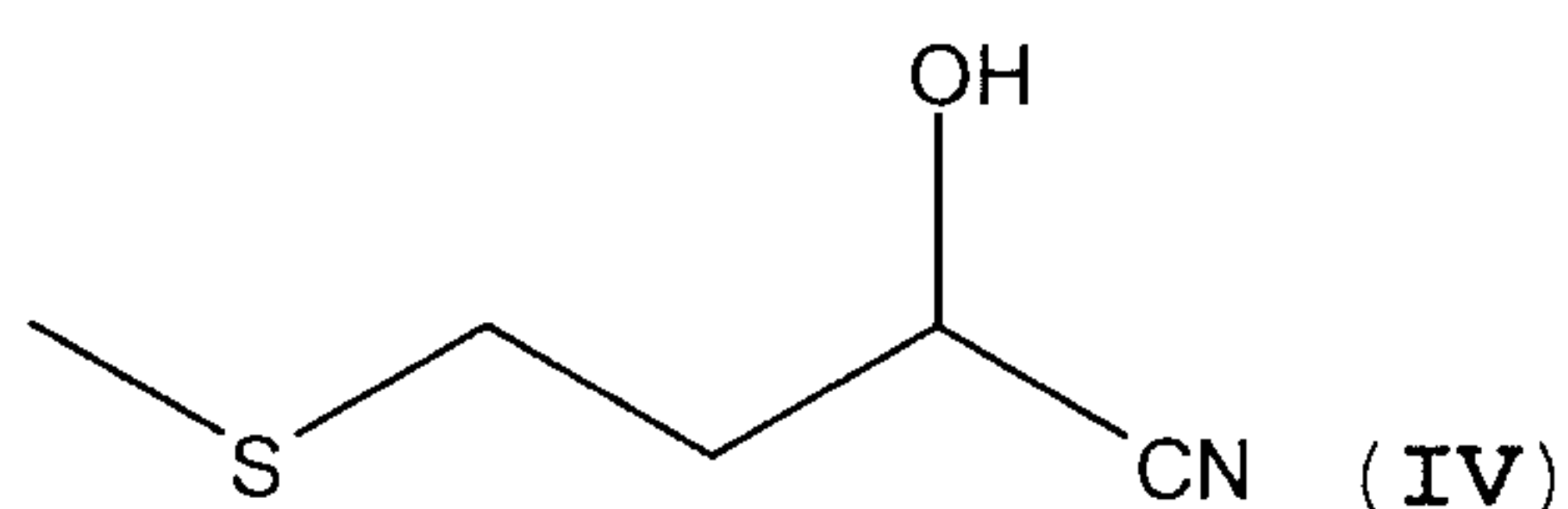
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one another are each chlorine, OCCl_3 , OCH_3 , OCH_2CH_3 , or imidazolyl or triazolyl bound via the nitrogen.

30. The process as claimed in claim 29, wherein X^1 is Cl and X^2 is OCCl_3 .

31. The process as claimed in claim 29 or 30, wherein the reaction is carried out under acid or base catalysis.

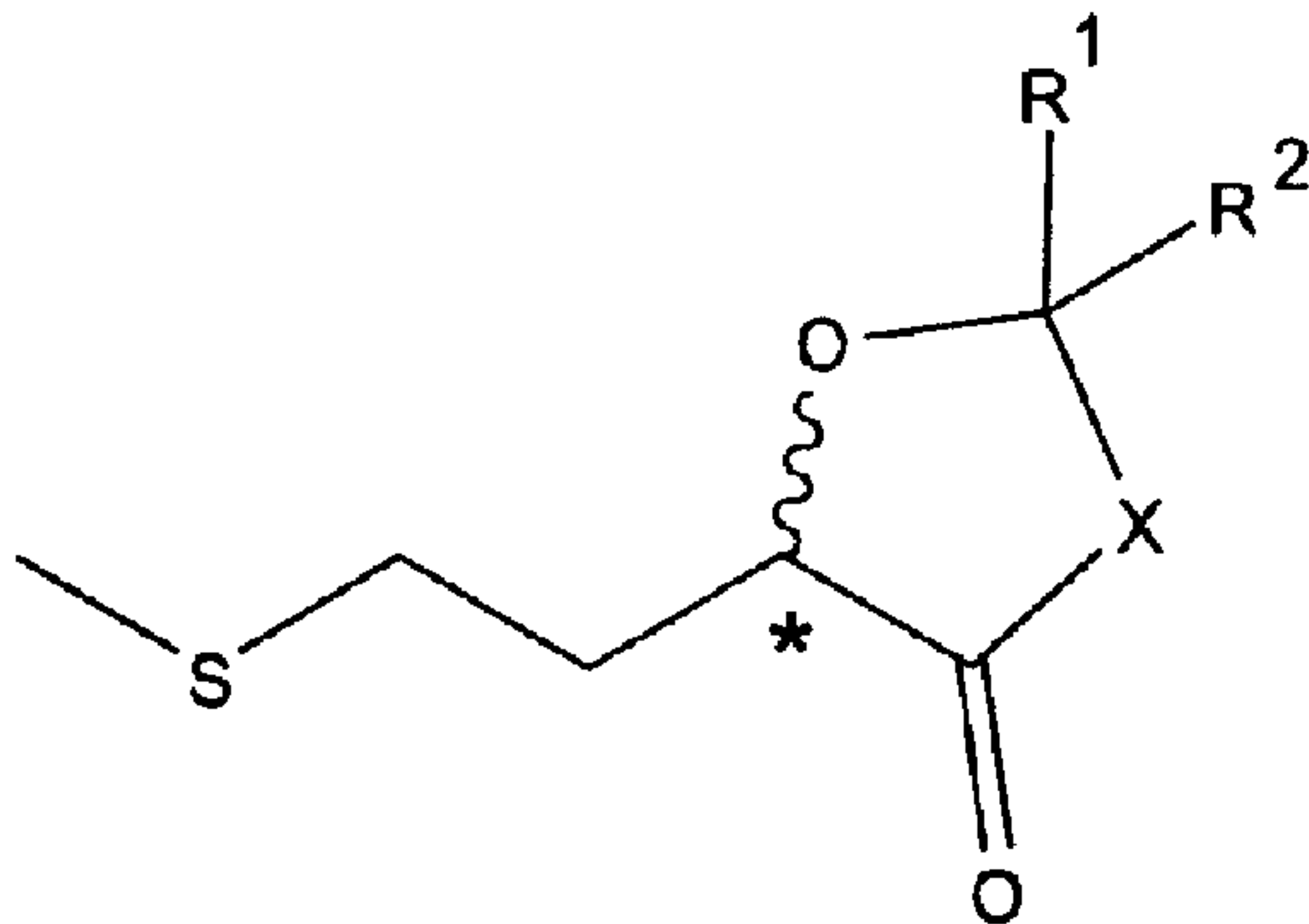
32. A process for producing a compound of formula I as defined in claim 1, wherein X is NH, and wherein the hydroxynitrile of the formula **IV**



is reacted with a carbonyl compound $\text{R}^1\text{R}^2\text{C}=\text{O}$ in the presence of acid and a carboxylic anhydride, wherein R^1 and R^2 are as defined in claim 1.

33. The process as claimed in claim 32, wherein the acid is sulfuric acid and/or acetic acid and the carboxylic anhydride is acetic anhydride.

(I)



(II)

