

Solvent-free alkane sulfonation

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The present invention relates to an alkane-sulfonation process using alkane and sulfur trioxide, especially pure sulfur trioxide (100%) under solvent-free conditions in the presence of an initiator. It further relates to the use of a precursor which forms "in-situ" an initiator for manufacturing of alkanesulfonic acids, especially methanesulfonic acids.

Alkanesulfonic acids are organic acids that can reach a similar acid strength as that of inorganic mineral acids, for example, sulfuric acid. However, in contrast to usual mineral acids such as sulfuric and nitric acids, the sulfonic acids are non-oxidizing and do not give off vapors that are harmful to health, as can be observed with hydrochloric and nitric acids. Further, many sulfonic acids, for example, methanesulfonic acid, are biologically degradable. The applications of sulfonic acids are many, for example, in cleaning agents, surfactants, galvanic and electronic industry, as catalysts, and in organic synthesis, pharmaceutical chemistry, for example, as protective groups. The salts of sulfonic acids are employed, for example, as surfactants, for example, sodium dodecylsulfonate, or in the electroplating industry, especially as tin, zinc, silver, lead and indium, but also other metal, alkylsulfonates. Furthermore, organic salts are employed in pharmaceutical chemistry. The very high solubility of alkyl sulfonates plays an important role, in particular. Further, no harmful gases are formed in electrolysis, and the use of toxic compounds, for example, cyanide, which is common in many cases, is dispensed with.

- 2 -

The structurally simplest representative of alkanesulfonic acids is methanesulfonic acid. US 2,493,038 describes the preparation of methanesulfonic acid from SO₃ and methane. US 2005/0070614 describes further methods for preparing methanesulfonic acid, and its application. The methods known in the prior art are in part complicated, cost-intensive, and lead to undesirable products because of the harsh reaction conditions.

The reaction conditions in conventional processes of alkanesulfonic acid production can result in undesirable side products, which even manifest themselves as disturbing inhibitors in the production of alkanesulfonic acids. This may lead to termination of the actual reaction for preparing the alkanesulfonic acid, but also to impurities, formation of side products and poor yields, based on sulfur trioxide and methane.

WO 2007/136425 A2 discloses the use of the compound di(methanesulfonyl) peroxide (DMSP), which must be prepared by a complex electrolysis and, in addition, is a crystallizable highly explosive solid, as an initiator in a reaction in which methanesulfonic acid is formed from sulfur trioxide and methane.

WO 2015/071365 A1 and WO 2015/071455 A1 both describe processes for the sulfonation of alkanes. The main steps are:

- 1) Synthesis of an initiator/initiator-solution.
- 2) Preparation of a sulfur trioxide-solution (oleum) by dissolving sulfur trioxide in an inert solvent (e.g. sulfuric acid)
- 3) Reaction of oleum with the corresponding alkane after or during addition of the initiator/ initiator- solution in a high-pressure-reactor.
- 4) Quenching of non-reacted starting material
- 5) Purification (e.g. distillation, crystallization etc.)
- 6) Recycling of the inert solvent (e.g. sulfuric acid).

It is the object of the examples disclosed herein to provide an improved process for manufacturing alkanesulfonic acid, especially methanesulfonic acid, allowing improved reaction control. Further, requirements for sulfur trioxide and alkanes should be not of relevance, meaning that not only absolute pure raw materials might be used, but that impurities do not affect negatively the reaction.

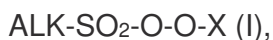
The object of the present disclosure is achieved, by use of a compound of the formula (I)



wherein ALK is a branched or unbranched alkyl group, especially a methyl, ethyl, propyl, butyl, isopropyl, isobutyl group, or a higher alkyl group, and X = hydrogen, zinc, aluminium, an alkali or alkaline earth metal, as an initiator-precursor for preparing alkanesulfonic acids, especially methanesulfonic acids from alkane, especially methane, and sulfur trioxide, especially pure sulfur trioxide.

In an aspect, there is provided a method of preparing methanesulfonic acid comprising:

mixing a compound of the formula (I)



wherein ALK is a methyl group and X is selected from the group consisting of hydrogen, zinc, aluminium, an alkali metal and an alkaline earth metal, with a first mixture comprising methane and sulfur trioxide, to form a second mixture comprising the methanesulfonic acid.

In another example, there is provided the use of the mixture as defined above as an initiator-precursor for preparing alkanesulfonic acids, especially methanesulfonic acid, from alkane, especially methane, and pure sulfur trioxide

In a further example, the object of the disclosure is achieved by a process for manufacturing the compound as defined above with $X = H$, comprising reacting an alkanesulfonic acid, especially methanesulfonic acid, with hydrogen peroxide. It might be followed by the isolation of the compound.

The object of the disclosure is achieved by a process for manufacturing alkanesulfonic acids, especially methanesulfonic acid, comprising the following steps:

- providing sulfur trioxide;
- reacting the sulfur trioxide with an alkane, especially methane, in a high-pressure autoclave or laboratory reactor;
- setting a pressure of from 1 to 200 bar;

- preparing the initiator-precursor according to formula (I), by reacting an alkanesulfonic acid or a solution containing the alkanesulfonic acid with a 30 % to 100 % (w/w) hydrogen peroxide solution;
- adding the initiator-precursor according to formula (I) or a solution thereof to the reactor;
- controlling the temperature of the reaction mixture at 0 °C to 100 °C;
- if necessary purifying the reaction product, for example, by distillation or extraction.

After the reaction has taken part, the reaction mixture contains essentially of the respective alkanesulfonic acid, especially methanesulfonic acid, as well as sulfuric acid. This mixture of alkanesulfonic acid, especially methanesulfonic acid (MSA), and H_2SO_4 might afterwards be used as the respective mixture. The combination of an alkanesulfonic acid, especially methanesulfonic acid, and sulfuric acid provides a strong acid in which even gold might be dissolved enabling different fields of technical applicability.

Alternatively, the alkanesulfonic acid, especially MSA, might be separated i.e. the method of the invention comprises the optional step of the purifying the reaction product, which might be done by distillation or extraction.

But also alkanesulfonic acids, and specially methanesulfonic acids, might be used in different technical fields, i.e. as cleaning agent (cleaning comprising the area of

cleaning and caring, home care as well as industrial and institutional cleaning of hard and soft surfaces, i.e. in dishwashing, commercial laundry, cleaning and sanitation, vehicle and transportation care, concrete cleaning, membrane cleaning, and others), for regeneration of ion exchange resins, in galvanic proceedings, in the area of oil, gas, mining, treatment of metals and/or their surfaces, in different areas of pharmaceutical, chemical and argro-chemical industry or in the production of biodiesel. MSA might also be used in galvanization process of plastics, the broad area of batteries, such as lead

- 5 -

battery recycling and recycling in general, such as metal recycling, as well as borane generation are further possible areas of application.

This invention enables major modifications leading to an improved process

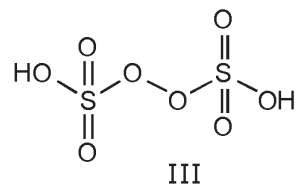
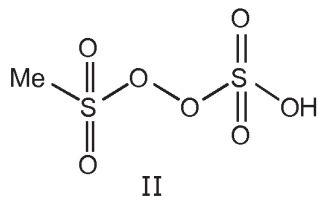
5 compared with the prior art by:

- Preparing the preferred initiator "in situ" using less or even no solvent.
- Easier purification of the product, due to higher product-concentrations
- No recycling of the inert solvent.

Where applicable:

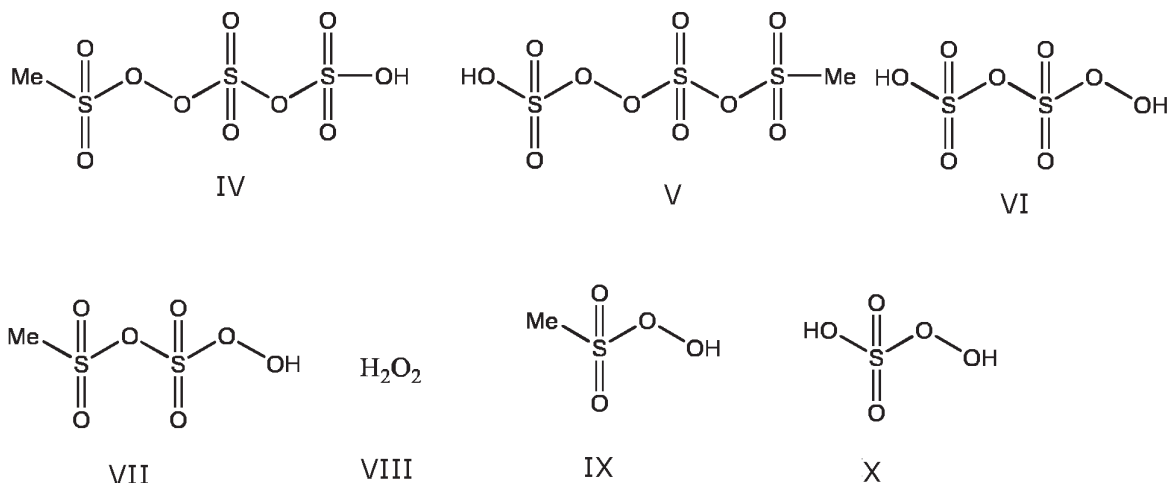
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- Avoiding the preparation of sulfur trioxide-solutions.
 - Reaction conditions without added solvent.
 - Evaporating non-reacted sulfur trioxide, instead of quenching.

In particular, the compound as defined above in formula (I) is present in a
 15 mixture of the invention which contains additionally at least one compound selected from the group consisting of formula II to XI, i. e. II, III, IV, V, VI, VII, VIII, IX, X, or XI:



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- 6 -



and combinations thereof.

In another embodiment the compound as defined above or the mixture of the
 5 invention is present in sulfuric acid or alkanesulfonic acid, especially
 methanesulfonic acid.

For example, the compound of formula (I) with $\text{X} = \text{H}$ can be manufactured by a
 process comprising reacting alkanesulfonic acids, especially methanesulfonic
 10 acid, with hydrogen peroxide. The thus obtained compound might be isolated
 but will preferably be used as initiator-precursor without any further isolation
 and/or cleaning step.

In particular, the isolation can be effected by extraction, chromatography,
 precipitation, recrystallization, freeze-drying or similar methods under mild
 15 conditions. In a particular embodiment of the process according to the invention,
 the isolation can be effected by means of precipitation or chromatography. Inert
 support materials and inert solvents, such as sulfuric or sulfonic acids, are
 employed therein. The use of organic solvents is also possible.

Inert support materials used for isolation are in particular those which do not
 20 negatively interfere with components being the actual reaction partners, e.g. by

- 7 -

reducing the yield of the compound of the invention. Furthermore, inert support materials can either chemisorb or physisorb - or both - a chemical compound, without destroying its functionality or structure in an irreversible way. Examples are materials based on e.g. silicon dioxide, aluminium oxide, zirconium oxide
5 and the like.

Surprisingly it has been found that instead of using oleum, as described in the prior art, also pure sulfur trioxide can be used according to the present invention. This avoids the preparation of sulfur trioxide solutions. The reaction
10 conditions are here without added solvents. Further, non-reacted sulfur trioxide can evaporate, avoiding the necessity quenching it.

In a further embodiment, sulfur trioxide is used in a form of oleum with a trioxide content of 50 % (w/w) or less, or 65 % (w/w) or more. Surprisingly it
15 has been found that contrary to the prior art for the processes of the present invention also oleum with a sulfur trioxide content of 65 % (w/w) or more, especially of 70 % w/w or more can be used without negatively affecting the inventive process. Even pure sulfur trioxide (100 % (w/w) sulfur trioxide) may be used.

20 Due to the advantages being connected with the use of pure sulfur trioxide mentioned above, the use of pure sulfur trioxide is preferred in the process for manufacturing alkanesulfonic acids according to the present invention. As contrary to the prior art, a circulation of solvent is not necessary, alkanes
25 comprising higher amounts of impurities compared to the prior art can be used. Impurities usually are enriched in the solvent leading to a reduced yield of MSA. By avoiding solvents and thus a circulation of them, impurities originating from the alkanes are not negatively influencing the production of MSA when pure sulfur trioxide is employed.

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The invention also relates to a process for manufacturing alkanesulfonic acids especially methanesulfonic acids, comprising the steps stated below:

5 Sulfur trioxide, especially pure sulfur trioxide is reacted with an alkane in a reactor. For alkanes with a low boiling point, the use of a high-pressure reactor is necessary. For pentane and higher alkanes, a common laboratory reactor is sufficient. In the case of gaseous alkanes, for example, methane, a pressure of 1 to 200 bar gas pressure is set. The initiator-precursor (e.g. alkanesulfonic hydroperoxide) that reacts "in situ" to a suitable initiator is added to this
10 solution. The initiator-precursor is prepared by reacting an alkanesulfonic acid or a solution of such alkanesulfonic acid with hydrogen peroxide to the alkanesulfonic hydroperoxide according to the reaction scheme 1 and can optionally be isolated:

Reaction scheme 1: $\text{ALK-SO}_2\text{-OH} + \text{H}_2\text{O}_2 \rightarrow \text{ALK-SO}_2\text{-O-O-H} + \text{H}_2\text{O}.$

15 The alkanesulfonic hydroperoxide (initiator-precursor) reacts "in situ" during the addition to the reactor to an alkanesulfonic sulfuric peroxyanhydride according to reaction scheme 2:

Reaction scheme 2: $\text{ALK-SO}_2\text{-O-OH} + \text{SO}_3 \rightarrow \text{ALK-SO}_2\text{-O-O-SO}_2\text{-OH}.$ ("in situ"-reaction)

20 Respective alkanesulfonic sulfuric peroxyanhydrides as initiators in the production of methanesulfonic acids are described in WO 2015/071455 A1. In said prior art document, the initiator is produced first in an additional reactor and afterwards added to the main reactor in which the process for the production of methanesulfonic acid or any other alkanesulfonic acid takes place. Contrary
25 thereto, in the present application an initiator precursor is formed which might be isolated but can be added without further purification. Said initiator precursor, being an alkanesulfonic hydroperoxide, reacts in-situ during the addition to the main reactor with the alkane and sulfur trioxide to form methanesulfonic acid.

The concentration of the hydrogen peroxide may be 20 to 100% (w/w). Subsequently, the reaction is completed at 0 to 100 °C. The raw product can be processed by extraction, crystallization, distillation or chromatography.

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This process can be applied in both batch- and continuous reactor systems.

The invention further relates to the use of an initiator precursor as defined above or a mixture as defined above in a device for performing the process for manufacturing an alkanesulfonic acid, especially methanesulfonic acid, wherein the device comprises a reactor (1) in which sulfur trioxide reacts with the compound of formula (I) as initiator-precursor to form an initiator; and reaction of said "in-situ"-built initiator with an alkane, especially methane; a distillation means (2) for distilling the product formed in the reactor (1); and a filling means (3); as well as connection means to connect the reactor (1) with the distillation means (2), and the filling means (3) with the distillation means (2). Fig 1 is a scheme of a process for the sulfonation using pure sulfur trioxide of an alkane (e.g. methane) including purification (e.g. distillation) as well as of a device for the production of methanesulfonic acid.

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The process according to the invention allows for alkanesulfonation, especially methanesulfonation, in a reactor system using sulfur trioxide, especially pure sulfur trioxide, with alkane, especially methane, with addition of an initiator precursor. The raw product might be purified by distillation, enabling the production of alkanesulfonic acid in high purity, especially methanesulfonic acid, as distillate.

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In the following the invention is further illustrated in an exemplary way taken the preparation of methanesulfonic acid as an example.

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Example 1:

Preparation of the initiator-precursor solution

To 100 ml of methanesulfonic acid, 78 ml of 60% (w/w) hydrogen peroxide was added dropwise with external cooling and intensive stirring.

5 Synthesis protocol:

In a 3.75 L autoclave, 2000 g of pure sulfur trioxide was charged, and the temperature controlled to 50°C. After a pressure of 100 bar of methane gas was set, intensive stirring is performed. Now, the initiator-precursor is metered dropwise to the solution. The pressure dropped down to 50 bar within 30
10 minutes. Afterwards the pressure was set to 100 bar again. The pressure dropped again down to 50 bar. The pressure was set again to 100 bar. Finally, the pressure dropped down to 30 bar. The yield is higher than 90%, based on sulfur trioxide. The reaction product contains 91% (w/w) methanesulfonic acid.

CLAIMS

1. A method of preparing methanesulfonic acid, comprising:

mixing a compound of the formula (I)

ALK-SO₂-O-O-X (I),

wherein ALK is a methyl group and X is selected from the group consisting of hydrogen, zinc, aluminium, an alkali metal and an alkaline earth metal, with a first mixture comprising methane and sulfur trioxide, to form a second mixture comprising the methanesulfonic acid.

2. The method of claim 1, further comprising:

before the mixing, reacting methanesulfonic acid with a 30 % to 100 % (w/w) hydrogen peroxide solution to form the compound of formula (I).

3. The method of claim 1, wherein X in formula (I) is H.

4. The method of claim 1, wherein during the mixing the compound of formula (I) reacts with SO₃ to form a compound of formula (II)

ALK-SO₂-O-O-SO₂-OX (II).

5. The method of claim 1, wherein the mixing includes combining an initiation solution comprising the compound of formula (I) and at least one selected from the group consisting of hydrogen peroxide and water, with the first mixture.

6. The method of claim 1, wherein the compound of formula (I) is formed in situ during the mixing.