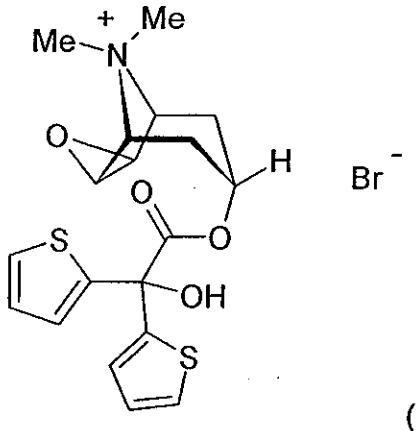
HFA suspension formulations of an anhydrate

The invention relates to propellant gas preparations for metered-dose aerosols with suspension formulations of the crystalline anhydrate of (1α,2β,4β,5α,7β)-7-[(hydroxydi-2-thienylacetyl)oxy]-9,9-dimethyl-3-oxa-9-azoniatricyclo[3.3.1.$0^{2,4}$]nonane-bromide.

Background to the invention

The compound (1α,2β,4β,5α,7β)-7-[(hydroxydi-2-thienylacetyl)oxy]-9,9-dimethyl-3-oxa-9-azoniatricyclo[3.3.1.$0^{2,4}$]nonane-bromide, is known from European Patent Application EP 418 716 A1 and has the following chemical structure:



(I)

The compound has valuable pharmacological properties and is known by the name tiotropium bromide (BA679). Tiotropium bromide is a highly effective anticholinergic and can therefore provide therapeutic benefit in the treatment of asthma or COPD (chronic obstructive pulmonary disease).

Tiotropium bromide is preferably administered by inhalation.

HFA-metered-dose aerosols containing tiotropium bromide as the sole active ingredient in suspended form may usefully be provided.

Detailed description of the invention

It has been found that, depending on the choice of conditions which can be used when purifying the crude product obtained after industrial manufacture, tiotropium bromide occurs in various crystalline modifications.

It has been found that these different modifications can be deliberately produced by selecting the solvents used for the crystallisation as well as by a suitable choice of

the process conditions used in the crystallisation process. One of these crystalline modifications is the crystalline monohydrate of tiotropium bromide.

It has now surprisingly been found that starting from this crystalline monohydrate of tiotropium bromide which is not yet known in the art it is possible to obtain an anhydrous crystal modification of tiotropium bromide (tiotropium anhydrate) which is exceptionally suitable for the preparation of suspensions in the propellant gases HFA 227 and/or HFA 134a for administration by inhalation.

Accordingly, the present invention relates to suspensions of this crystalline tiotropium bromide anhydrate in the propellant gases HFA 227 and/or HFA 134a, optionally in admixture with one or more other propellant gases, preferably selected from the group consisting of propane, butane, pentane, dimethylether, $CHClF_2$, CH_2F_2, CF_3CH_3, isobutane, isopentane and neopentane, wherein the crystalline tiotropium bromide anhydrate is chacterised by the elementary cell a = 10.4336(2)Å, b = 11.3297(3)Å, c = 17.6332(4) and $\alpha = 90°$, $\beta = 105.158(2)°$ and $\gamma = 90°$ with a cell volume = 2011.89(8)$Å^3$.

Where reference is made to crystalline tiotropium bromide anhydrate this should be taken as a reference to the anhydrous crystalline modification of tiotropium bromide which can be obtained by drying the crystalline tiotropium bromide monohydrate. This crystal modification is also optionally known as crystalline tiotropium bromide in anhydrous form.

Preferred suspensions are those which contain as propellant gas HFA 227 on its own, a mixture of HFA 227 and HFA 134a or HFA 134a on its own.
If a mixture of propellant gases HFA 227 and HFA 134a is used in the suspension formulations, the weight ratios in which these two propellant gas components are used may be freely selected.
If in the suspension formulations one or more other propellant gases are used in addition to the propellant gases HFA 227 and/or HFA 134a, selected from the group consisting of propane, butane, pentane,
dimethylether, $CHClF_2$, CH_2F_2, CF_3CH_3, isobutane, isopentane and neopentane, the proportion of this other propellant gas component is preferably less than 50 %, preferably less than 40%, more preferably less than 30%.

The suspensions preferably contain between 0.001 and 0.8% tiotropium.
Suspensions which contain 0.08 to 0.5%, more preferably 0.2 to 0.4% tiotropium are preferred.

By tiotropium is meant the free ammonium cation. The propellant gas suspensions are characterised in that they contain tiotropium in the form of the crystalline tiotropium bromide anhydrate which is exceptionally suitable for this application. Accordingly, the suspensions may contain between 0.0012 and 96% crystalline tiotropium bromide anhydrate. Of particular interest are suspensions which contain 0.096 to 0.6%, more preferably 0.24 to 0.48% crystalline tiotropium bromide anhydrate.

The percentages specified are always percent by mass. If parts by mass of tiotropium are given in percent by mass, the corresponding values for the crystalline tiotropium bromide anhydrate which is preferably used may be obtained by multiplying by a conversion factor of 1.2036.

In some cases the term suspension formulation may be used instead of the term suspension. The two terms are to be regarded as interchangeable.

The propellant-containing inhalation aerosols or suspension formulations may also contain other ingredients such as surface-active agents (surfactants), adjuvants, antioxidants or flavourings.

The surface-active agents (surfactants) which may be contained in the suspensions are preferably selected from among Polysorbate 20, Polysorbate 80, Myvacet 9-45, Myvacet 9-08, isopropylmyristate, oleic acid, propyleneglycol, polyethyleneglycol, Brij, ethyloleate, glyceryl trioleate, glyceryl monolaurate, glyceryl monooleate, glyceryl monosterate, glyceryl monoricinoleate, cetylalcohol, sterylalcohol, cetylpyridinium chloride, block polymers, natural oil, ethanol and isopropanol. Of the abovementioned suspension adjuvants Polysorbate 20, Polysorbate 80, Myvacet 9-45, Myvacet 9-08 or isopropylmyristate are preferably used. Myvacet 9-45 or isopropylmyristate are particularly preferred.

Where the suspensions contain surfactants, these are preferably present in an amount of 0.0005 – 1 %, more preferably 0.005 – 0.5%.

The adjuvants optionally contained in the suspensions are preferably selected from among alanine, albumin, ascorbic acid, aspartame, betaine, cysteine, phosphoric acid, nitric acid, hydrochloric acid, sulphuric acid and citric acid.

Of these, ascorbic acid, phosphoric acid, hydrochloric acid or citric acid are preferred, while hydrochloric acid or citric acid is more preferable.

Where the suspensions contain adjuvants, these are preferably present in an amount of 0.0001-1.0 %, preferably 0.0005-0.1 %, more preferably 0.001-0.01%, while an amount of from 0.001-0.005% is particularly preferred.

The antioxidants optionally contained in the suspensions are preferably selected from among ascorbic acid, citric acid, sodium edentate, editic acid, tocopherols, butylhydroxytoluene, butylhydroxyanisol and ascorbyl palmitate, of which tocopherols, butylhydroxytoluene, butylhydroxyanisol and ascorbyl palmitate are preferred.

The flavourings which may be contained in the suspensions are preferably selected from among peppermint, saccharine, Dentomint®, aspartame and ethereal oils (e.g. cinnamon, aniseed, menthol, camphor), of which peppermint or Dentomint® is particularly preferred.

For administration by inhalation it is necessary to prepare the active substance in finely divided form. The crystalline tiotropium bromide anhydrate which may be obtained as detailed in the experimental section is either ground (micronised or obtained in finely divided form by other technical methods known in principle in the art (such as precipitation and spray drying). Methods of micronising active substances are known in the art. Preferably, after micronisation, the active substance has an average particle size of 0.5 to 10 µm, preferably 1 to 6 µm, more preferably 1.5 to 5 µm. Preferably, at least 50%, more preferably at least 60%, most preferably at least 70% of the particles of active substance have a particle size which is within the ranges specified above. More preferably, at least 80%, most preferably at least 90% of the particles of active substance have a particle size within the ranges specified above.

Surprisingly, it has been found that it is also possible to prepare suspensions which contain, apart from the abovementioned propellant gases, only the active substance and no other additives. Accordingly, the suspensions may contain only the active substance and no other additives.

The suspensions may be prepared by methods known in the art. For this the ingredients of the formulation are mixed with the propellant gas or gases (optionally at low temperatures) and transferred into suitable containers.

The propellant gas-containing suspensions mentioned above may be administered using inhalers known in the art (pMDIs = pressurised metered dose inhalers). Accordingly, disclosed herein are pharmaceutical compositions in the form of suspensions as hereinbefore described combined with one or more inhalers suitable for administering these suspensions. In addition, disclosed herein are inhalers which are characterised in that they contain the propellant gas-containing suspensions described above. Also disclosed herein are containers (cartridges) which are fitted with a suitable valve and can be used in a suitable inhaler and which contain one of the above-mentioned propellant gas-containing suspensions. Suitable containers (cartridges) and methods of filling these cartridges with the propellant gas-containing suspensions are known from the prior art.

In view of the pharmaceutical activity of tiotropium the present invention further relates to the use of the suspensions according to the invention for preparing a drug for administration by inhalation or by nasal route, preferably for preparing a drug for the treatment by inhalation or by nasal route of diseases in which anticholinergics may provide a therapeutic benefit.

Most preferably, the suspensions may be used for preparing a pharmaceutical composition for the treatment by inhalation of respiratory complaints, preferably asthma or COPD.

The Examples that follow serve to illustrate the present invention more fully by way of example, without restricting it to their content.

Starting materials

Crystalline tiotropium bromide monohydrate:

The tiotropium obtained according to EP 418 716 A1may be used to prepare the crystalline tiotropium bromide monohydrate. This is then reacted as described below.

15.0 kg of tiotropium bromide are added to 25.7 kg of water in a suitable reaction vessel. The mixture is heated to 80-90°C and stirred at constant temperature until a clear solution is formed. Activated charcoal (0.8 kg), moistened with water, is

suspended in 4.4 kg of water, this mixture is added to the solution containing tiotropium bromide and rinsed with 4.3 kg of water. The mixture thus obtained is stirred for at least 15 min. at 80-90°C and then filtered through a heated filter into an apparatus which has been preheated to an outer temperature of 70°C. The filter is rinsed with 8.6 kg of water. The contents of the apparatus are cooled to a temperature of 20-25°C at a rate of 3-5°C every 20 minutes. Using cold water the apparatus is cooled further to 10-15°C and crystallisation is completed by stirring for at least another hour. The crystals are isolated using a suction filter drier, the crystal slurry isolated is washed with 9 L of cold water (10-15°C) and cold acetone (10-15°C). The crystals obtained are dried at 25°C for 2 hours in a nitrogen current. Yield: 13.4 kg of tiotropium bromide monohydrate (86 % of theory).

The tiotropium bromide monohydrate obtainable using the method described above was investigated by DSC (Differential Scanning Calorimetry). The DSC diagram shows two characteristic signals. The first, relatively broad, endothermic signal between 50-120°C can be attributed to the dehydration of the tiotropium bromide monohydrate into the anhydrous form. The second, relatively sharp, endothermic peak at 230 ± 5°C can be put down to the melting of the substance. This data was obtained using a Mettler DSC 821 and evaluated using the Mettler STAR software package. The data was recorded at a heating rate of 10 K/min.

The crystalline tiotropium bromide monohydrate was characterised by IR spectroscopy. The data was obtained using a Nicolet FTIR spectrometer and evaluated with the Nicolet OMNIC software package, version 3.1. The measurement was carried out with 2.5 µmol of tiotropium bromide monohydrate in 300 mg of KBr. The following Table shows some of the essential bands of the IR spectrum.

Wave number (cm^{-1})	Attribution	Type of oscillation
3570, 3410	O-H	elongated oscillation
3105	Aryl C–H	elongated oscillation
1730	C=O	elongated oscillation
1260	Epoxide C-O	elongated oscillation
1035	Ester C-OC	elongated oscillation
720	Thiophene	cyclic oscillation

The monocrystal X-ray structural analysis carried out showed that the crystalline tiotropium bromide hydrate obtainable by the above process has a simple monoclinic cell with the following dimensions:
a = 18.0774 Å, b = 11.9711 Å, c = 9.9321 Å, β = 102.691°, V = 2096.96 Å^3.
These data were obtained using an AFC7R 4-circuit diffractometer (Rigaku) using monochromatic copper K_α radiation. The structural resolution and refinement of the crystal structure were obtained by direct methods (SHELXS86 Program) and FMLQ-refinement (TeXsan Program).

Crystalline tiotropium bromide anhydrate:
The anhydrous form is produced from the crystalline tiotropium bromide monohydrate obtained as described above by careful drying at 80 –100 °C under reduced pressure, preferably under high vacuum over a period of at least 30 minutes. Alternatively to the drying step at 80 – 100 °C *in vacuo* the anhydrous form may also be prepared by storing over dried silica gel at ambient temperature over a period of at least 24 hours.

The crystalline structure of the anhydrous tiotropium bromide was determined from high-resolution X-ray powder data (synchrotron radiation) by a real space mixture using a so-called "simulating annealing" process. A final Rietveld analysis was carried out to refine the structural parameters. These investigations showed that the crystalline tiotropium bromide anhydrate which is used in the suspensions according to the invention is characterised by the elementary cell

a = 10.4336(2)Å,
b = 11.3297(3)Å,
c = 17.6332(4) Å and
α = 90°,
β = 105.158(2)° and
γ = 90° (cell volume = 2011.89(8) Å^3).

To prepare the suspensions according to the invention the crystalline tiotropium bromide anhydrate obtainable by the above process is micronised by methods known in the art, with the exclusion of moisture, to prepare the active substance in the form of the average particle size which corresponds to the specifications according to the invention.

Examples of formulations

Suspensions containing other ingredients in addition to active substance and propellant gas:

a) 0.02 % Tiotropium*
0.20 % Polysorbate 20
99.78 % HFA 227

b) 0.02 % Tiotropium*
1.00 % Isopropylmyristate
98.98 % HFA 227

c) 0.02 % Tiotropium*
0.3 % Myvacet 9-45
99.68 % HFA 227

d) 0.04 % Tiotropium*
1.00 % Myvacet 9-08
98.96 % HFA 227

e) 0.04 % Tiotropium*
0.04 % Polysorbate 80
99.92 % HFA 227

f) 0.04 % Tiotropium*
0.005 % Oleic acid
99.955 % HFA 227

g) 0.02 % Tiotropium*
0.1 % Myvacet 9-45
60.00 % HFA 227
39.88 % HFA 134a

h) 0.02 % Tiotropium*
0.30 % Isopropylmyristate
20.00 % HFA 227
79.68 % HFA 134a

i) 0.02 % Tiotropium*
0.01 % Oleic acid
60.00 % HFA 227
39.97 % HFA 134a

*used in the form of the tiotropium bromide anhydrate (conversion factor 1.2036)

Suspensions containing only active substance and propellant gas:

j) 0.02 % Tiotropium*
99.98 % HFA 227

k) 0.02 % Tiotropium*
99.98 % HFA 134a

l) 0.04 % Tiotropium*
99.96 % HFA 227

m) 0.04 % Tiotropium*
99.96 % HFA 134a

n) 0.02 % Tiotropium*
20.00 % HFA 227
79.98 % HFA 134a

o) 0.02 % Tiotropium*
60.00 % HFA 227
39.98 % HFA 134a

p) 0.04 % Tiotropium*
40.00 % HFA 227
59.96 % HFA 134a

q) 0.04 % Tiotropium*
80.00 % HFA 227
19.96 % HFA 134a

* used in the form of the tiotropium bromide anhydrate (conversion factor 1.2036)

Patent Claims

1) Suspensions of crystalline tiotropium bromide anhydrate in the propellant gases HFA 227 and/or HFA 134a, optionally in admixture with one or more other propellant gases selected from the group consisting of propane, butane, pentane, dimethylether, $CHClF_2$, CH_2F_2, CF_3CH_3, isobutane, isopentane and neopentane, wherein the crystalline tiotropium bromide anhydrate is chacterised by the elementary cell a = 10.4336(2)Å, b = 11.3297(3)Å, c = 17.6332(4) and α = 90°, β = 105.158(2)° and γ = 90° with a cell volume = 2011.89(8)Å^3.

2) Suspensions according to claim 1, characterised in that they contain between 0.001 and 0.8% tiotropium.

3) Suspensions according to claim 1 or 2, characterised in that they contain as other ingredients surface-active agents (surfactants), adjuvants, antioxidants and/or flavourings.

4) Suspensions according to claim 3, characterised in that they contain as surface-active agents (surfactants) one or more compounds selected from the group consisting of Polysorbate 20, Polysorbate 80, Myvacet 9-45, Myvacet 9-08, isopropylmyristate, oleic acid, propyleneglycol, polyethyleneglycol, Brij, ethyl oleate, glyceryl trioleate, glyceryl monolaurate, glyceryl monooleate, glyceryl monosterate, glyceryl monoricinoleate, cetylalcohol, sterylalcohol, cetylpyridinium chloride, block polymers, natural oil, ethanol and isopropanol .

5) Suspensions according to claim 3, characterised in that they contain as adjuvants one or more compounds selected from the group consisting of alanine, albumin, ascorbic acid, aspartame, betaine, cysteine, phosphoric acid, nitric acid, hydrochloric acid, sulphuric acid and citric acid.

6) Suspensions according to claim 3, characterised in that they contain as antioxidants one or more compounds selected from the group consisting of ascorbic acid, citric acid, sodium edetate, editic acid, tocopherols, butylhydroxytoluene, butylhydroxyanisol and ascorbyl palmitate.

7) Suspensions according to claim 1 or 2, characterised in that they contain no other ingredients apart from the active substance and the propellant gas or gases.

8) Use of a suspension according to one of claims 1 to 7 for preparing a pharmaceutical composition, preferably for preparing a pharmaceutical

composition for the treatment by inhalation or nasal route of diseases in which anticholinergics may confer a therapeutic benefit.

9) Use according to claim 8, characterised in that the diseases are respiratory complaints, preferably asthma or COPD.