

The present invention relates to new strontium salts of sulphonic acids, to a process for their preparation and to pharmaceutical compositions containing them.

A large number of mineral and organic salts of strontium are already known from the literature. Amongst the compounds of sulphonic acid, strontium bis(aminomethanesulphonate), and the use thereof in photographic papers, have already been described in
5 US patent 4,419,433. Strontium methanedisulphonate has been described in the publication *Recueil : Journal of the Royal Netherlands Chemical Society* **1981**, 100(12), 449-452. Strontium *m*-benzenedisulphonate has been described in the publication *J.Phys. Chem.* **1963**, 67, 337-339. Strontium 6-sulphonatohexanoate has been described in the publication
10 *Berichte* **1897**, 63, 1642-48. Strontium 1,5-naphthalenedisulphonate has been described in the publication *Acta Cryst.* **2001**, 57(4), 520-530. Strontium 1,6-naphthalenedisulphonate has been described in the publication *Helv. Chim. Acta* **1923**, 6(1), 1133-1146. Strontium bis(6-hydroxy-2-naphthalenesulphonate) has been described in the publication *Helv. Chim. Acta* **1925**, 8(1), 229-241. Strontium 2-oxo-1,3-propanedisulphonate has been described in
15 *Therm. Anal.* **1980**, 6th, Vol 2, 425-430. Strontium hydroxymethanesulphonate has been described in the patent specification JP 37006516. Strontium bis(4-aminobenzene-sulphonate) has been described in the publications *J. Applied Polymer Sc.* **2000**, 77(11), 2363-69 and *J. Prakt. Chem.* **1934**, 245-253. Strontium bis(2-aminobenzenesulphonate) and strontium bis(3-aminobenzenesulphonate) have been described in the publication
20 *J. Prakt. Chem.* **1935**, 6-10. Strontium 1,2-ethanedisulphonate has been described in the publication *Kristallogr. Kristallgeom. Kristallchem.* **1913**, 51, 502. Strontium 3-amino-3-carboxy-1-propanesulphonate chloride has been described in the publication *Inorg. Chem.* **2005**, 44(11), 3890-95.

The use of strontium salts for therapeutic purposes has already formed the subject of
25 publications and patents. For example, US patent 4,152,431 describes alkali metal salts that can be used in the treatment of inflammation. Patent application WO-94/09798 presents sulphate complexes of various metals which are active in the treatment of skin disorders. The works of Olle Svensson *et al* (*Acta Path. Microbiol. Immunol. Scand., Sect. A*, **1985**, 93, 115-120) demonstrate that strontium plays a part in some rickets cases.

Strontium ranelate and its use in the treatment of osteoporosis have been described in patent specification EP 0 415 850.

The present invention relates to new strontium salts derived from sulphonic acid, and to the use thereof in the treatment of osteoarthritis and osteoporosis.

Osteoporosis is a decrease in calcium mineralisation in the skeleton.

Like all living tissue, bone is subject to a continual destruction-reconstruction process : bone remodelling. It is characterised first of all by a phase of resorption of the old bone matrix by osteoclasts, followed by a phase of reparation by the formation of the protein matrix by osteoblasts, which will then be mineralised. In a young person, the bone equilibrium is balanced but, with age, an imbalance occurs between bone resorption and bone formation to the detriment of the latter.

Osteoarthritis is a degenerative pathology that affects articular cartilage in more than 50% of the population above the age of 65. It is characterised always by a degradation of the cartilaginous matrix surrounding the chondrocytes. In non-pathological conditions, those cells ensure the homeostasis of cartilage. On the other hand, under the effect of a certain number of factors (biomechanical and/or biochemical), chondrocytes are at the origin of the degradation of that surrounding tissue, because in such cases they secrete metalloproteases, which degrade type II collagen and proteoglycans, the matrix components characteristic of cartilage.

- 5 More especially, the present invention relates to strontium salts of the sulphonic acids of formula (I) :



wherein:

- A represents a group selected from OH, NH₂, SO₃H and CO₂H,

- B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom, by a nitrogen atom or by an SO₂ group,

5 with the exclusion of strontium bis(aminomethanesulphonate), strontium methane-
disulphonate, strontium 1,3-benzenedisulphonate, strontium 6-sulphonatohexanoate,
strontium 1,5-naphthalenedisulphonate, strontium 1,6-naphthalenedisulphonate,
strontium bis (6-hydroxy-2-naphthalenesulphonate), strontium 2-oxo-1,3-propane-
disulphonate, strontium hydroxymethanesulphonate, strontium bis(4-aminobenzene-
10 sulphonate), strontium bis(2-aminobenzenesulphonate), strontium bis(3-aminobenzene-
sulphonate), strontium 1,2-ethanedisulphonate and strontium 3-amino-3-carboxy-1-
propanesulphonate chloride.

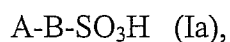
Arylene is understood to be phenylene, biphenylylene or naphthylene, each of those groups
being optionally substituted by one or more identical or different groups selected from
15 linear or branched C₁-C₆alkyl, OH, NH₂, SO₃H and CO₂H.

One embodiment of the present invention concerns strontium salts of the compounds of
formula (I) wherein A represents NH₂ or SO₃H.

Another embodiment of the present invention concerns strontium salts of the compounds
of formula (I) wherein B represents a substituted or unsubstituted linear C₁-C₆alkylene
20 chain.

Another embodiment of the present invention concerns strontium salts of the compounds
of formula (I) wherein B represents a substituted or unsubstituted linear C₃-C₆alkylene
chain.

25 Another embodiment of the present invention concerns strontium salts of the sulphonic
acids of formula (Ia), a particular case of the sulphonic acids of formula (I) :



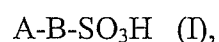
wherein :

- A represents a group selected from NH_2 and SO_3H ,
- B represents an unsubstituted linear or branched C_3 - C_6 alkylene chain.

Another embodiment of the present invention concerns the following strontium salts :

- strontium 1,3-propanedisulphonate;
- strontium bis(3-amino-1-propanesulphonate);
- strontium sulphonatoacetate;
- strontium bis(2-amino-1-ethanesulphonate);
- strontium 1,4-butanedisulphonate; and
- strontium 1,2-benzenedisulphonate.

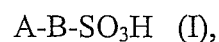
The invention relates also to a first process for the preparation of the strontium salts according to the invention by reaction of a sulphonic acid of formula (I) :



wherein A and B are as defined hereinbefore,

with strontium hydroxide, followed by isolation of the strontium salt so obtained.

The invention relates also to a second process for the preparation of the strontium salts according to the invention by reaction of the sodium or potassium salt of a sulphonic acid of formula (I) :



wherein A and B are as defined hereinbefore,

with strontium chloride, followed by isolation of the strontium salt so obtained.

The invention relates also to pharmaceutical compositions comprising as active ingredient a strontium salt according to the invention with one or more appropriate inert, non-toxic excipients, such as diluents, lubricants, binders, disintegrating agents, absorbers, colorants, sweetening agents etc..

By way of example and without implying any limitation there may be mentioned:

- *for the diluents* : lactose, dextrose, sucrose, mannitol, sorbitol, cellulose, glycerol,
- *for the lubricants* : silica, talc, stearic acid and magnesium and calcium salts thereof, polyethylene glycol,
- *for the binders* : aluminium silicate, magnesium silicate, starch, gelatin, tragacanth, methyl cellulose, sodium carboxymethylcellulose, carboxymethyl starch and polyvinylpyrrolidone,
- *for the disintegrating agents* : agar, alginic acid and its sodium salt, effervescent mixtures.

Among the pharmaceutical compositions according to the invention there may be mentioned, more especially, those which are suitable for oral, parenteral (intravenous or subcutaneous) and nasal administration, tablets or dragées, sublingual tablets, gelatin capsules, lozenges, suppositories, creams, ointments, dermal gels, injectable preparations, drinkable suspensions.

The useful dosage varies according to the sex, age and weight of the patient, the administration route, the nature of the disorder and of associated treatments, if any, and ranges from 5 mg to 3 g per 24 hours, for example from 100 mg to 2 g per 24 hours.

The following Examples illustrate the invention.

EXAMPLE 1 : Strontium 1,3-propanedisulphonate

A mixture of 222 g of 70% 1,3-propanedisulphonic acid in water (0.76 mol) and 200.4 g of strontium hydroxide octahydrate (0.75 mol) in 200 ml of water is heated at reflux for 3 hours. The reaction mixture is filtered hot and then cooled to 4°C. The precipitate formed is removed by filtration and 500 ml of 96% ethanol are added to the filtrate. The precipitate is filtered off, rinsed with 250 ml of a 70/30 ethanol/water mixture and dried to obtain 139 g of a white crystalline product of 1,3-propanedisulphonic acid strontium salt (yield 63%).

Melting point : >250°C

Elemental microanalysis:

	%C	%H	%S	%Sr
Calculated	12.43	2.09	22.13	30.23
Found	12.56	3.44	22.76	26.88

EXAMPLE 2 : Strontium bis(3-amino-1-propanesulphonate)

The expected product is obtained by reaction of 3-amino-1-propanesulphonic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

EXAMPLE 3 : Strontium sulphonatoacetate

The expected product is obtained by reaction of sulphoacetic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

Melting point : >270°C

Elemental microanalysis:

	%C	%H	%S
Calculated	10.64	0.89	14.21
Found	9.77	1.20	14.18

EXAMPLE 4 : Strontium bis(2-amino-1-ethanesulphonate)

The expected product is obtained by reaction of 2-amino-1-ethanesulphonic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

EXAMPLE 5 : Strontium 1,4-butanedisulphonate

- 5 0.75 mol of strontium chloride hexahydrate and 0.75 mol of disodium 1,4-butane-disulphonate are dissolved in 600 ml of water. After stirring for 1 hour, 1 litre of 96% ethanol is added. The precipitate formed is filtered off, rinsed with 500 ml of a 70/30 ethanol/water mixture and dried to yield the expected product.

EXAMPLE 6 : Strontium 1,2-benzenedisulphonate

- 10 The expected product is obtained by reaction of dipotassium 1,2-benzenedisulphonate with strontium chloride hexahydrate in accordance with the procedure of Example 6.

EXAMPLE 7 : Strontium bis(2-hydroxyethanesulphonate)

The expected product is obtained by reaction of sodium 2-hydroxyethanesulphonate with strontium chloride hexahydrate in accordance with the procedure of Example 6.

- 15 **EXAMPLE 8 : Distrontium 2,2-bis(sulphonatomethyl)-1,3-propanedisulphonate**

The expected product is obtained by reaction of 2,2-bis(sulphomethyl)-1,3-propanedisulphonic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

EXAMPLE 9 : Strontium 1,5-pentanedisulphonate

- 20 The expected product is obtained by reaction of disodium 1,5-pentanedisulphonate with strontium chloride hexahydrate in accordance with the procedure of Example 6.

EXAMPLE 10 : Strontium 1,6-hexanedisulphonate

The expected product is obtained by reaction of disodium 1,6-hexanedisulphonate with strontium chloride hexahydrate in accordance with the procedure of Example 6.

EXAMPLE 11 : Strontium bis(4-amino-1-butanedisulphonate)

5 The expected product is obtained by reaction of 4-amino-1-butanedisulphonic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

EXAMPLE 12 : Strontium bis(1-amino-2-benzenedisulphonate)

The expected product is obtained by reaction of 1-amino-2-benzenedisulphonic acid with strontium hydroxide octahydrate in accordance with the procedure of Example 1.

10

PHARMACOLOGICAL STUDY

EXAMPLE 13 : *In vitro* study of the inhibition of bovine cartilage catabolism by the compound of Example 1.

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Protocol

The study was carried out on fragments of bovine cartilage in culture medium (96-well plate), the degradation of which is stimulated by adding TNF α and oncostatin M (Schaller, S., Henriksen, K., Hoegh-Andersen, P., Sondergaard, B.C., Sumer, E.U., Tanko, L.B., Qvist, P., Karsdal, M.A. In vitro, ex vivo, and in vivo methodological approaches for
20 studying therapeutic targets of osteoporosis and degenerative joint diseases: how biomarkers can assist ? *Assay. Drug Dev. Technol.* 3, 553-580 (2005).

The duration of the cultivation period is 21 days (culture medium changed every 2 days).

A group not treated with TNF α and oncostatin M constitutes the control group.

Five lots of stimulated cartilage fragments were treated with the compound of Example 1,

each at a different dose : 0.01; 0.1; 1; 3 and 10 mM. 5 replications were carried out for each dose.

On D19, the concentration of CTX II (fragment of type II collagen resulting from the degradation of that collagen by metalloproteases) in the culture medium is measured using an ELISA technique. That parameter is expressed in ng/ml/mg of cartilage.

On D21, the following are measured in the cartilage remaining at the end of cultivation:

- the quantity of proteins, using the kit marketed by Biorad. For the groups treated with the compound of Example 1, the results of this parameter are expressed as the percentage inhibition of the degradation of the proteins in the cartilage of the untreated control group;
- and the quantity of glycosaminoglycans (GAGs), using the colorimetric technique with methylene blue (DMB). That parameter, too, is expressed as a percentage inhibition of the degradation of the GAGs evaluated in the control group after culturing for 21 days.

Results

The results of treatment with the compound of Example 1 are :

- a significant ($p < 0.001$) and dose-dependent inhibition of the salting out of CTX II in the culture medium ($IC_{50}=3.5$ mM);
- protection against degradation of the components of the cartilage starting from a dose of 1mM :

Components	Dose (mM)				
	0.01	0.1	1	3	10
proteins	/	/	22 %	41 %	55 % *
GAGs	/	/	4 %	8 %	26 % **

* : $p < 0.05$; ** : $p < 0.01$

The treatment is moreover well tolerated by the cells for the 21 days of cultivation (toxicity test employed : Alamar blue – negative whatever the dose).

Those results demonstrate that the compound of Example 1 provides significant protection against the degradation of the characteristic components of cartilage by way of inhibition of collagenolytic activity.

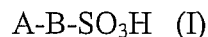
EXAMPLE 14 : Pharmaceutical composition

Preparation formula for a 1 g tablet containing a dose of 500 mg :

	Compound of Example 1	500 mg
5	Povidone K30	24 mg
	Cellulose Avicel PM102.....	417 mg
	Carboxymethyl starch Primojel	21 mg
	Magnesium stearate	6 mg
	Talc	32 mg

CLAIMS

1. Strontium salts of the sulphonic acids of formula (I) :



wherein :

- 5 - A represents a group selected from OH, NH₂, SO₃H and CO₂H,
 - B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom, by a nitrogen atom or by an SO₂ group,

10 with the exclusion of strontium bis(aminomethanesulphonate), strontium methane-disulphonate, strontium 1,3-benzenedisulphonate, strontium 6-sulphonatohexanoate, strontium 1,5-naphthalenedisulphonate, strontium 1,6-naphthalenedisulphonate, strontium bis(6-hydroxy-2-naphthalenesulphonate), strontium 2-oxo-1,3-propane-disulphonate, strontium hydroxymethanesulphonate, strontium bis(4-aminobenzene-
15 sulphonate), strontium bis(2-aminobenzenesulphonate), strontium bis(3-aminobenzene-sulphonate), strontium 1,2-ethanedisulphonate and strontium 3-amino-3-carboxy-1-propanesulphonate chloride,

20 arylene being understood to be phenylene, biphenylene or naphthylene, each of those groups being optionally substituted by one or more identical or different groups selected from linear or branched C₁-C₆alkyl, OH, NH₂, SO₃H and CO₂H.

2. Strontium salts according to claim 1, wherein A represents SO₃H or NH₂.

3. Strontium salts according to claim 1 or 2, wherein B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups

selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom or by an SO₂ group.

4. Strontium salts according to claim 3, wherein B represents a linear C₁-C₆alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom or by an SO₂ group.

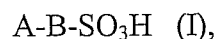
5. Strontium salts according to claim 4, wherein B represents a linear C₃-C₆alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom or by an SO₂ group.

6. Strontium salts according to claim 5, wherein A represents a group selected from NH₂ and SO₃H and B represents an unsubstituted linear or branched C₃-C₆alkylene chain.

7. Strontium salt according to claim 1, selected from:

- strontium 1,3-propanedisulphonate;
- strontium bis(3-amino-1-propanesulphonate);
- strontium sulphonatoacetate;
- strontium bis(2-amino-1-ethanesulphonate);
- strontium 1,4-butanedisulphonate; and
- strontium 1,2-benzenedisulphonate.

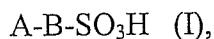
8. Process for the preparation of a strontium salt according to claim 1 by reaction of a sulphonic acid of formula (I) :



wherein A and B are as defined hereinbefore,

with strontium hydroxide, followed by isolation of the strontium salt so obtained.

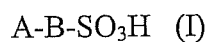
9. Process for the preparation of a strontium salt according to claim 1 by reaction of the sodium or potassium salt of a sulphonic acid of formula (I) :



wherein A and B are as defined hereinbefore,

5 with strontium chloride, followed by isolation of the strontium salt so obtained.

10. Pharmaceutical composition comprising as active ingredient the strontium salt of a sulphonic acid of formula (I) :



wherein :

- 10
- A represents a group selected from OH, NH₂, SO₃H and CO₂H,
 - B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom, by a nitrogen atom or by an SO₂ group,

15 in combination with one or more pharmaceutically acceptable, inert non-toxic carriers,

arylene being understood to be phenylene, biphenylene or naphthylene, each of those groups being optionally substituted by one or more identical or different groups selected from linear or branched C₁-C₆alkyl, OH, NH₂, SO₃H and CO₂H.

11. Use of the strontium salt of a sulphonic acid of formula (I) :



wherein :

- A represents a group selected from OH, NH₂, SO₃H and CO₂H,

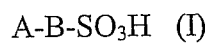
- B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom, by a nitrogen atom or by an SO₂ group,

5 in the manufacture of medicaments for use in the prevention or treatment of osteoarthritis,

arylene being understood to be phenylene, biphenylene or naphthylene, each of those groups being optionally substituted by one or more identical or different groups selected from linear or branched C₁-C₆alkyl, OH, NH₂, SO₃H and CO₂H.

10

12. Use of the strontium salt of a sulphonic acid of formula (I) :



wherein :

- A represents a group selected from OH, NH₂, SO₃H and CO₂H,
- 15 - B represents an arylene group or a linear or branched C₁-C₁₂alkylene chain optionally substituted by one or more groups selected from hydroxy, oxo, amino, SO₃H and CO₂H and in which one or more carbon atoms is optionally replaced by an oxygen atom, by a nitrogen atom or by an SO₂ group,

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in the manufacture of medicaments for use in the prevention or treatment of osteoporosis,

arylene being understood to be phenylene, biphenylene or naphthylene, each of those groups being optionally substituted by one or more identical or different groups selected from linear or branched C₁-C₆alkyl, OH, NH₂, SO₃H and CO₂H.