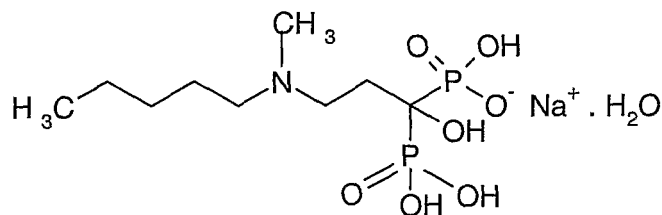


Ibandronate polymorph B

The present invention relates to a new polymorph crystal form of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt monohydrate (Ibandronate) of the following formula



Formula I

5 and a process for its preparation.

Ibandronate is one of the most potent anti-resorptive drugs that directly inhibit osteoclast activity and present an effective pharmacologic alternative for controlling hypercalcemia. Ibandronate binds to hydroxyapatite in calcified bone, rendering it  
 10 resistant to hydrolytic dissolution by phosphatases, thereby inhibiting both normal and abnormal bone resorption. This drug increases bone mass and decreases the risk of fractures and is therefore particularly well adapted to bone and calcium metabolic diseases such as for instance osteoporosis or Paget's disease (EP-A 0252504).

It has been found that Ibandronate may exist in various polymorphs.

15 One polymorph of Ibandronate hereinafter also designated as polymorph A was identified as being thermodynamically more stable, whereas a second polymorph of Ibandronate, hereinafter designated as polymorph B, is easier to separate within the production process.

20 The ability of a substance to exist in more than one crystal form is defined as polymorphism and these different crystal forms are known as "polymorph modifications" or "polymorphs". Polymorphism can influence many aspects of solid state properties of a drug. Different crystal modifications of a substance may differ considerably from one another in different physical properties which may influence directly their solubility for instance. Polymorphism is found in several organic compounds.

An exhaustive treatment of polymorphism in pharmaceutical and molecular crystals is given e.g. by H.G. Brittain in *Polymorphism in Pharmaceutical Solids*, H.G. Brittain or, Marcel Dekker Inc., New York, 1999 and in *Solid-State Chemistry of Drugs*, SSCI Inc., West Lafayette; Indiana, 1999

- 5           Object of the present invention is to specifically isolate and characterize Ibandronate polymorph B and to develop a process for the preparation of Ibandronate polymorph B.

The object has been achieved with the identification of crystalline polymorph B of Ibandronate and with a process for its preparation as claimed in the present invention.

- 10           Unless otherwise indicated, the following definitions are set forth to define the meaning and scope of the various terms used and described in the description.

The term "Ibandronate polymorph B" refers to the polymorph crystal form of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt monohydrate as defined in the claims and the description of the present invention.

- 15           The term "crystalline polymorph" refers to a crystal modification which can be characterized by analytical methods such as e.g. X-ray powder diffraction, IR spectroscopy and Raman spectroscopy.

The term IR means infrared.

Description of figures:

- 20           Figure 1: shows an X-ray diffraction pattern of crystalline Ibandronate polymorph B as obtained in example 1.

Figure 2: shows an IR-spectrum of crystalline Ibandronate polymorph B

Figure 3: shows a Raman spectrum of Ibandronate polymorph B

- 25           Figure 4: shows an X-ray diffraction pattern of crystalline Ibandronate polymorph A as obtained in Ref. example 2.

Figure 5: shows an IR-spectrum of crystalline Ibandronate polymorph A

Figure 6: shows a Raman spectrum of crystalline Ibandronate polymorph A

The crystalline Ibandronate polymorph B of the present invention can be characterized by an X-ray powder diffraction pattern having characteristic peaks expressed in angle 2-theta at approximately:

| Angle 2-theta | Intensity [%] |
|---------------|---------------|
| 9,7°          | 0.6           |
| 12,2°         | 1             |
| 14,4°         | 0.6           |
| 16,8°         | 1             |
| 25,8°         | 1.8           |

5

Angle 2-theta means an incertitude of  $\pm 0.2$  (expressed in degrees), 2-theta represents the reflexion angle according to the Bragg law. A reflection at a glancing angle  $\theta$  gives rise to a reflection at an angle  $2\theta$  to the direction of the incident beam.

The crystalline Ibandonate polymorph B as described above can further be  
10 characterized by the x-ray powder diffraction pattern as shown in Figure 1.

The crystalline Ibandronate polymorph B can furthermore be characterized by its IR absorption spectrum having characteristic peaks expressed in  $\text{cm}^{-1}$  at approximately:

|    |                            |
|----|----------------------------|
|    | Bands [ $\text{cm}^{-1}$ ] |
|    | 3679                       |
|    | 3164                       |
| 5  | 2955                       |
|    | 2854                       |
|    | 1377                       |
|    | 1290                       |
|    | 1157                       |
|    | 1093                       |
|    | 1068                       |
| 10 | 1035                       |
|    | 965                        |
|    | 951                        |
|    | 933                        |
|    | 905                        |
|    | 761                        |
|    | 723                        |

15        The term approximately means in this context that the  $\text{cm}^{-1}$  value can vary by  $\pm 4 \text{ cm}^{-1}$ .

      The crystalline Ibandronate polymorph B can further be characterized by the IR absorption spectrum shown in figure 2.

20        The crystalline Ibandronate polymorph B as described above can furthermore be described by Raman vibrational spectroscopy. The Raman spectrum has the following characteristic peaks expressed in  $\text{cm}^{-1}$  at approximately:

5

10

| Bands [ $\text{cm}^{-1}$ ] |
|----------------------------|
| 2968                       |
| 2951                       |
| 2928                       |
| 2887                       |
| 2849                       |
| 1441                       |
| 1308                       |
| 1136                       |
| 1056                       |
| 1023                       |
| 954                        |
| 907                        |
| 839                        |
| 762                        |
| 678                        |

The term approximately means in this context that the  $\text{cm}^{-1}$  value can vary by  $\pm 8 \text{ cm}^{-1}$ .

15 The crystalline Ibandronate polymorph B can further be characterized by the Raman spectrum shown in Figure 3.

The crystalline Ibandronate polymorph B described above is further characterized by a solubility in water of about 279 g/l at 25°C (partial conversion to crystalline Ibandronate polymorph A).

20 The process according to the present invention is characterized by the crystallization of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt or a monohydrate, a polymorph or a mixture of polymorphs thereof at a temperature of 10°C to 45°C in a polar solvent and by the addition of a polar aprotic solvent to initialize the crystallization.

As polar solvent preferably water is used.

Suitable polar aprotic solvents are aliphatic ketones such as acetone or methyl ethyl ketone or cyclic ethers like tetrahydrofuran or dioxane. Preferred polar aprotic solvents are acetone and tetrahydrofuran, whereas tetrahydrofuran is the most preferred.

5 Preferably the crystallization takes place at a temperature of about 35°C.

Expediently the crystallization temperature is maintained for 15 minutes to 120 minutes.

Starting product for the process of the present invention can either be the 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt  
10 e.g. obtained from a process as outlined in reference example 1, or crystalline Ibandronate polymorph A e.g. obtained according to reference example 2, or a mixture of crystalline Ibandronate polymorph A with crystalline Ibandronate polymorph B.

The starting product can either be dissolved in the polar solvent at about room temperature and then be warmed to the crystallization temperature or alternatively be  
15 dissolved at a higher temperature and then be cooled to the crystallization temperature as indicated above.

Ethanol residues which may be present from the manufacturing process (according to reference example 1) can easily be removed by known methods e.g. by distilling the ethanol off as azeotrope.

20 Crystallization as a rule occurs spontaneously but can also be initiated by addition of crystals of Ibandronate polymorph B.

The crystal suspension so obtained is as a rule be cooled under stirring until crystallization is complete before the filtration takes place.

The whole crystallization process may be controlled regarding temperature, heating  
25 and cooling periods with equipment common to the skilled practitioner.

Separation of the desired polymorph can be effected by common filtration techniques. As a rule the precipitate is washed with the polar solvent used for the crystallization, preferably with a mixture of water and acetone in a ratio of about 1:1 (V/V).

Drying of the crystalline Ibandronate polymorph B preferably happens at a temperature from 30°C to 60°C for about 24 hours to 72 hours either at normal or at reduced pressure.

The Ibandronate can be obtained with a content of the crystalline Ibandronate  
5 polymorph B of at least 80 %.

The crystalline Ibandronate polymorph B of the present invention can be used as a pharmaceutically active compound which acts as an efficient anti-resorptive drug that directly inhibits osteoclast activity and thus also increases bone mass. Accordingly this polymorph can be used for the treatment and/or prevention of diseases which are  
10 associated with bone and calcium metabolic disease such as for instance osteoporosis or Paget's disease.

The invention therefore also relates to pharmaceutical compositions comprising a crystalline Ibandronate polymorph B as defined above and a pharmaceutically acceptable carrier and/or adjuvant.

15 The invention also encompasses a crystalline Ibandronate polymorph B as described above for use as therapeutically active substances.

The following examples serve as illustration of the invention.

## Examples

### X-ray powder diffraction measurement method

The x-ray powder diffraction patterns of the individual crystalline Ibandronate polymorphs A and B were recorded with a Bruker D8 Advance AXS diffractometry (geometry: Bragg-Brentano; radiation:  $\text{CuK}\alpha$  in the angle range  $2\theta = 2^\circ$  to  $40^\circ$ ; Cu secondary monochromator; step scan with  $0.02^\circ$  and a measuring time of e.g. 4.0 s per step). The samples weighing approximately 500 mg were prepared into carrier wells and exposed to  $\text{CuK}\alpha$  radiation. Radiation diffracted at the lattice levels is converted into electronic signals by a scintillation counter and processed by the software package "Diffrac plus". The x-ray powder diffraction patterns of the individual crystalline Ibandronate polymorphs A and B are shown in Figure 1 and 4.

### IR measurement method

The IR spectra of the individual crystalline Ibandronate polymorphs A and B were recorded as film of Nujol suspension consisting of approx. 15 mg of sample in approx. 15 mg of Nujol between two sodium chloride plates. Measurements were carried out with an FT-IR spectrometer (IFS55 (Bruker) or equivalent instrument) in transmittance mode (resolution  $4\text{ cm}^{-1}$ , detector: DTGS). The IR spectra of the individual crystalline Ibandronate polymorphs A and B are shown in Figure 2 and 5.

### Raman measurement method

The Raman spectra of the individual crystalline Ibandronate polymorphs A and B were recorded as sample of about 20 mg of the powder and were filled into a glass tube (shortened NMR tube). The samples were measured with the FT-Raman of Nicolet coupled to a Magna 860 (Nicolet) in  $90^\circ$  scattering arrangement, detector: InGaAs. Measurement parameters resolution  $8\text{ cm}^{-1}$ ; laser power 0.95W, No of scan 300. The FT-Raman spectra of the individual crystalline Ibandronate polymorphs A and B are shown in Figure 3 and 6.

### Solubility measurement

The solubility of the individual crystalline Ibandronate polymorphs A and B was measured for various solutions. Approximately 10 g of the corresponding polymorph A or B were suspended in three different buffer solutions at pH 2, pH 4 (Titrisol-buffer, citrate/HCl), at pH 7 (methenamine buffer, HCl) or in water. The suspension was stirred for 24 hours at  $25^\circ\text{C}$  and was kept additionally 24 hours without stirring at the same temperature. Solubility was calculated by titration according to the following method.

The residue was filtered, 2 ml of the filtrate taken, 5 ml of Titriplex III solution were added and diluted with water to 100 ml. 2 ml of this solution were added to approximately 0.1 ml of xylenol orange indicator and the pH was adjusted to 6.5 by adding small portions of methenamine buffer solution or 0.1 M hydrochloric acid. The solution is titrated immediately with Th-DCTA-xylenol orange complex until the color changes from yellow to reddish-violet. The endpoint is determined photometrically.

Results are gathered in the following table.

|       | Polymorph A<br>solubility in [g/l] | Polymorph B<br>solubility in [g/l]* |
|-------|------------------------------------|-------------------------------------|
| pH 2  | 280                                | 274                                 |
| pH 4  | 276                                | 278                                 |
| pH 7  | 292                                | 299                                 |
| water | 278                                | 279                                 |

\* under at least partial conversion to polymorph A

10

#### Reference example 1

##### Preparation of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1, 1-diphosphonic acid monosodium salt

250 g (1.19 mol) *N*-methyl-*N*-pentyl- $\beta$ -alanine hydrochloride, 233 g (2.84 mol) phosphorous acid, 151 ml (1.65 mol) phosphorous oxychloride and 900 ml diethyl carbonate were heated stepwise to 80°C. After 2 hours reaction time under continued heating the mixture was cooled to 60°C and 1733 ml demineralized water were added, followed by azeotropic distillation of diethyl carbonate / water at 90 to 101°C. 358 ml demineralized water were added, the mixture was refluxed and water was distilled off. 316 ml demineralized water were added and water was distilled off twice. Finally 2040 ml demineralized water were added and the residue was cooled to 24°C. The pH was adjusted at 23°C with sodium hydroxide solution (50%) to 4.4. Thereafter, 1100 ml ethanol were added to start crystallization. The suspension was stirred for 8 hours at 21 to 22°C. Then the solid was separated, washed with 344 ml cold ethanol/demineralized water (7/5 V/V), subsequently with 344 ml acetone / demineralized water (5/2 V/V) and

dried at 60°C. 315.6 g (73.7 %) of the title product were obtained in the form of colorless crystals.

Assay (complexometric titration): 100.6 % (calculated on the anhydrous and solvent free basis)

Residual solvents: 2.3% ethanol (GC)  
3.9% water (KF)

### Reference example 2

### Preparation of crystalline Ibandronate polymorph A

10        150 g 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid  
monosodium salt (obtained according to reference example 1), were dissolved in 390 ml  
demineralized water at about 70-90°C. 205 ml water were distilled off. After filtration the  
filtrate was cooled to 60°C and stirred for 45 minutes. Crystallization was initiated by  
means of crystalline polymorph A. After crystallization a mixture of demineralized  
15    water/acetone (290 ml/518 ml) previously heated to 50°C was added under stirring.  
Thereafter, the suspension was cooled to about 20-25°C under stirring, until the  
crystallization was complete. The product was separated and washed with a mixture of 50  
ml acetone/demineralized water in a ratio of 1:1 (V/V). The product was dried for 48  
hours in a vacuum from 150 to 20 mbar at 60°C.

20                      Yield: 85 %

Identified with x-ray powder diffraction as crystalline Ibandronate polymorph A.  
(Figure 4)

Assay (complexometric titration): 101.0 % (calculated on the anhydrous and solvent free basis)

25 Example 1

### Preparation of crystalline Ibandronate polymorph B

55 g of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water were distilled off. After filtration, the remaining  
30 solution was brought to 35°C and 190 ml acetone were added in 20 minutes. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring, up to the complete crystallization.

The product was separated and washed with a mixture of acetone/demineralized water in a ratio of 1:1 (V/V). The product was dried in vacuum from 150 to 20 mbar for 12 hours at 40°C and 24 hours at 60°C.

Yield: 81 %

- 5 Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B. (Figure 1)

## Example 2

### Preparation of crystalline Ibandronate polymorph B

- 10 55 g of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water were distilled off. After filtration, the remaining solution was brought to 35°C, then 47 ml acetone were added and crystallization was initiated by means of 0.5 g crystalline Ibandronate polymorph B followed by addition of  
15 144 ml acetone. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring in order to obtain a complete crystallization. The product was separated and washed with a mixture of acetone/demineralized water in a ratio of 1:1 (V/V). The product was dried in vacuum of 150 to 20 mbar at 40°C for 12 hours and at 60°C for 24 hours.

Yield: 82 %

- 20 Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B. (Figure 1)

## Example 3

### Preparation of crystalline Ibandronate polymorph B

55 g of 3-(*N*-methyl-*N*-pentyl) amino-1-hydroxypropane-1,1-diphosphonic acid monosodium salt (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water were distilled off. After filtration, the remaining

solution was brought to 35°C and 382 ml acetone were added in 20 minutes and in parallel 0.5 g crystalline Ibandronate polymorph B were added. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring in order to obtain a complete crystallization. The product was separated and washed with a mixture of acetone/demineralized water in a ratio of 1:1 (V/V). The product was dried in vacuum of 150 to 20 mbar at 40°C for 12 hours and at 60°C for 24 hours.

Yield: 88 %

Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B. (Figure 1)

10

#### Example 4

##### Preparation of crystalline Ibandronate polymorph B

55 g Ibandronate monosodium salt, (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water was distilled off. After filtration, the remaining solution was brought to 35°C and 190 ml Tetrahydrofurane (THF) was added in 20 minutes. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring, up to the complete crystallization. The product was separated and washed with 20ml of THF. The product was dried in vacuum from 150 to 10 mbar for 12 hours at 40°C and 24 hours at 60°C.

20 Yield: 82%

Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B. (Figure 1)

#### Example 5

##### Preparation of crystalline Ibandronate polymorph B

55 g Ibandronate monosodium salt, (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water was distilled off. After filtration, the remaining solution was brought to 35°C, then 47 ml of Tetrahydrofurane (THF) were added and crystallization initiates by means of 0.5 g Ibandronate crystal modification B followed by addition of 143 ml THF. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring in order to obtain a complete crystallization. The product was separated

30

and washed with 20ml of THF. The product was dried in vacuum of 150 to 10 mbar at 40°C for 12 hours and at 60°C for 24 hours.

Yield: 79%

Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B.

5 (Figure 1)

### Example 6

Preparation of Ibandronate monosodium salt, monohydrate, polymorph B

10 55 g Ibandronate monosodium salt, (obtained according to reference example 1) were dissolved in 240 ml demineralized water. 75 ml water was distilled off. After filtration, the remaining solution was brought to 55°C and 190 ml of Tetrahydrofurane (THF) were added in 1 h. Thereafter, the mixture was cooled until  $\leq 25^{\circ}\text{C}$  under stirring in order to obtain a complete crystallization. The product was separated and washed with 20ml of THF. The product was dried in vacuum of 150 to 10 mbar at 40°C for 12 hours and at  
15 60°C for 24 hours.

Yield: 78,5%

Identified with x-ray powder diffraction as crystalline Ibandronate polymorph B.

(Figure 1)

Claims

1. A crystalline polymorph of 3-(N-methyl-N-pentyl) amino-1-hydroxypropane-1,  
1-diphosphonic acid monosodium salt monohydrate (Ibandronate) which is  
characterized by an X-ray powder diffraction pattern having characteristic peaks  
5 expressed in angle 2-theta at approximately

| Angle 2-theta |
|---------------|
| 9,7°          |
| 12,2°         |
| 14,4°         |
| 16,8°         |
| 25,8°         |

2. A crystalline polymorph of claim 1, characterized by the x-ray powder diffraction  
pattern shown in Figure 1.

3. A crystalline Ibandronate polymorph which is characterized by an IR absorption  
10 spectrum having characteristic peaks expressed in  $\text{cm}^{-1}$  at approximately  $3679 \text{ cm}^{-1}$ ,  $3164 \text{ cm}^{-1}$ ,  $2955 \text{ cm}^{-1}$ ,  $2854 \text{ cm}^{-1}$ ,  $1377 \text{ cm}^{-1}$ ,  $1290 \text{ cm}^{-1}$ ,  $1157 \text{ cm}^{-1}$ ,  $1093 \text{ cm}^{-1}$ ,  $1068 \text{ cm}^{-1}$ ,  $1035 \text{ cm}^{-1}$ ,  $965 \text{ cm}^{-1}$ ,  $951 \text{ cm}^{-1}$ ,  $933 \text{ cm}^{-1}$  and  $905 \text{ cm}^{-1}$ ,  $761 \text{ cm}^{-1}$  and  $723 \text{ cm}^{-1}$ .

4. A crystalline polymorph of claim 3, characterized by the IR absorption spectrum  
shown in Figure 2.

- 15 5. A crystalline Ibandronate polymorph which is characterized by a characteristic  
peak expressed in  $\text{cm}^{-1}$  at approximately  $2968 \text{ cm}^{-1}$  in a vibrational Raman spectrum.

6. A crystalline polymorph of claim 5 which is characterized by the characteristic  
peaks expressed in  $\text{cm}^{-1}$  at approximately  $2968 \text{ cm}^{-1}$ ,  $2951 \text{ cm}^{-1}$ ,  $2928 \text{ cm}^{-1}$ ,  $2887 \text{ cm}^{-1}$ ,  
 $2849 \text{ cm}^{-1}$ ,  $1441 \text{ cm}^{-1}$ ,  $1308 \text{ cm}^{-1}$ ,  $1136 \text{ cm}^{-1}$ ,  $1056 \text{ cm}^{-1}$ ,  $1023 \text{ cm}^{-1}$ ,  $954 \text{ cm}^{-1}$ ,  $907 \text{ cm}^{-1}$ ,  $839$   
20  $\text{cm}^{-1}$ ,  $762 \text{ cm}^{-1}$  and  $678 \text{ cm}^{-1}$  in vibrational Raman spectrum.

7. A crystalline polymorph of claim 5 and 6, characterized by the vibrational Raman  
spectrum shown in Figure 3.

8. Ibandronate containing at least 80% of a crystalline polymorph as characterized by claims 1 to 7.

9. A process for the preparation of a crystalline Ibandronate polymorph as characterized by the claims 1 to 8 comprising crystallizing 3-(*N*-methyl-*N*-pentyl) amino-  
5 1-hydroxypropane-1,1-diphosphonic acid monosodium salt or a monohydrate, a polymorph or a mixture of polymorphs thereof at a temperature of 10°C to 45°C in a polar solvent and by the addition of a polar aprotic solvent to initialize the crystallization.

10. Process according to claim 9, characterized in that the polar solvent is water and that the polar aprotic solvent is an aliphatic ketone or a cyclic ether.

10 11. Process according to claim 10, characterized in that as polar aprotic solvent tetrahydrofurane is used.

12. Pharmaceutical compositions comprising a crystalline polymorph according to any of claims 1 to 8 or obtained according to a process of claims 9 to 11 and a pharmaceutically acceptable carrier and/or adjuvant.

15 13. A crystalline polymorph according to any of claims 1 to 8 or obtained according to a process of claims 9 to 11 for use as therapeutic active substance.

14. The invention as herein before defined.

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