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(54) Titre : NOUVELLES FORMES DE [R-(R*,R*)]-2-(4-FLUOROPHENYL)β,Δ-DIHYDROXY-5-(ISOPROPYL)-3-PHENYL-4-[(PHENYLAMINO)CARBONYL]-1H-PYRROLE-1-HEPTANOATEDE CALCIUM (2:1)

(54) Title: NOVEL FORMS OF [R-(R*,R*)]-2-(4-FLUOROPHENYL)-β,Δ-DIHYDROXY-5-(1-METHYLETHYL)-3-PHENYL-4-[(PHENYLAMINO)CARBONYL]-1H-PYRROLE-1-HEPTANOIC ACID CALCIUM SALT (2:1)

(57) Abrégé/Abstract:
Novel forms of [R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]-1H-pyrrole-1-heptanoic acid hemi calcium salt designated Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, and Form XXX, characterized by their X-ray powder diffraction, solid-state NMR, and/or Raman spectroscopy are described, as well as methods for the preparation and pharmaceutical composition of the same, which are useful as agents for treating hyperlipidemia, hypercholesterolemia, osteoporosis, benign prostatic hyperplasia (BPH) and Alzheimer's disease.

ABSTRACT

Novel forms of [R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]-1 H-pyrrole-1 -heptanoic acid hemi calcium salt designated Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, and Form XXX, characterized by their X-ray powder diffraction, solid-state NMR, and/or Raman spectroscopy are described, as well as methods for the preparation and pharmaceutical composition of the same, which are useful as agents for treating hyperlipidemia, hypercholesterolemia, osteoporosis, benign prostatic hyperplasia (BPH) and Alzheimer's disease.

NOVEL FORMS OF [R-(R*,R*)]-2-(4-FLUOROPHENYL)-β,δ-DIHYDROXY-5-(1-METHYLETHYL)-3-PHENYL-4-[(PHENYLAMINO)CARBONYL]-1H-PYRROLE-1-HEPTANOIC ACID CALCIUM SALT (2:1)

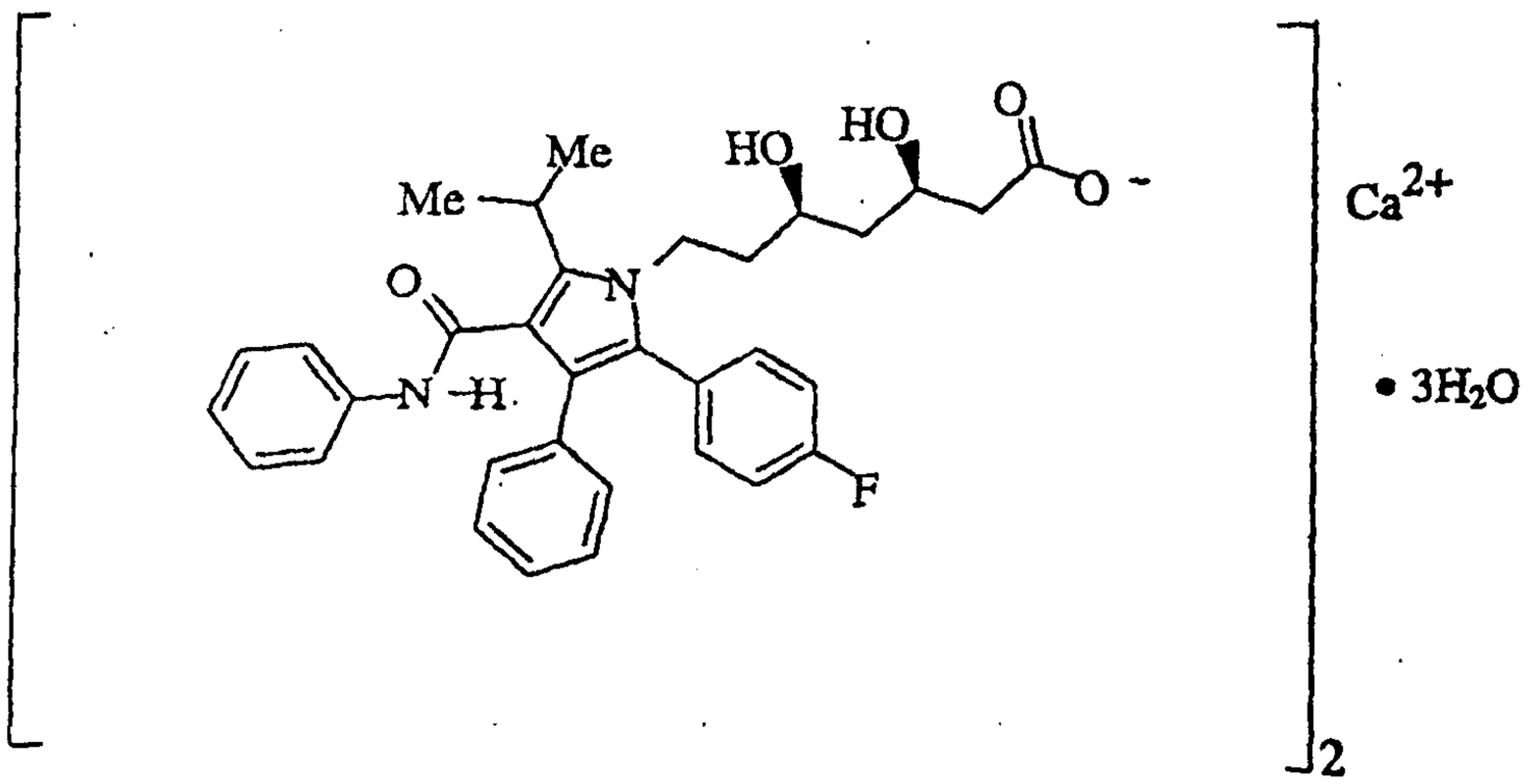
FIELD OF THE INVENTION

The present invention relates to novel forms of atorvastatin calcium which is known by the chemical name [R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]-1H-pyrrole-1-heptanoic acid hemi calcium salt useful as pharmaceutical agents, to methods for their production and isolation, to pharmaceutical compositions which include these compounds and a pharmaceutically acceptable carrier, as well as methods of using such compositions to treat subjects, including human subjects, suffering from hyperlipidemia, hypercholesterolemia, osteoporosis, benign prostatic hyperplasia, and Alzheimer's disease.

BACKGROUND OF THE INVENTION

The conversion of 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) to mevalonate is an early and rate-limiting step in the cholesterol biosynthetic pathway. This step is catalyzed by the enzyme HMG-CoA reductase. Statins inhibit HMG-CoA reductase from catalyzing this conversion. As such, statins are collectively potent lipid lowering agents.

Atorvastatin calcium, disclosed in United States Patent No. 5,273,995, is currently sold as Lipitor® having the chemical name [R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino) carbonyl]-1H-pyrrole-1-heptanoic acid calcium salt (2:1) trihydrate and the formula



Atorvastatin calcium is a selective, competitive inhibitor of HMG-CoA reductase. As such, atorvastatin calcium is a potent lipid lowering compound and is thus useful as a hypolipidemic and/or hypocholesterolemic agent.

A number of patents have issued disclosing atorvastatin, formulations of atorvastatin, as well as processes and key intermediates for preparing atorvastatin. These include: United States Patent

Numbers 4,681,893; 5,273,995; 5,003,080; 5,097,045; 5,103,024; 5,124,482; 5,149,837; 5,155,251; 5,216,174; 5,245,047; 5,248,793; 5,280,126; 5,397,792; 5,342,952; 5,298,627; 5,446,054; 5,470,981; 5,489,690; 5,489,691; 5,510,488; 5,686,104; 5,998,633; 6,087,511; 6,126,971; 6,433,213; and 6,476,235 .

Additionally, a number of published International Patent Applications and patents have disclosed crystalline forms of atorvastatin, as well as processes for preparing amorphous atorvastatin. These include: US Patent 5,969,156; US 6,121,461;US 6,605,729; WO 00/71116; WO 01/28999; WO 01/36384;WO 01/42209; WO 02/41834; WO 02/43667; WO 02/43732; WO 02/051804; WO 02/057228; WO 02/057229; WO 02/057274; WO 02/059087; WO 02/072073; WO 02/083637; WO 02/083638; WO 03/050085; WO 03/070702; and WO 04/022053.

Atorvastatin is prepared as its calcium salt, i.e., [R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)-carbonyl]-1H-pyrrole-1-heptanoic acid calcium salt (2:1). The calcium salt is desirable, since it enables atorvastatin to be conveniently formulated in, for example, tablets, capsules, lozenges, powders, and the like for oral administration.

The process by which atorvastatin calcium is produced needs to be one which is amenable to large-scale production. Additionally, it is desirable that the product should be in a form that is readily filterable and easily dried. Finally, it is economically desirable that the product be stable for extended periods of time without the need for specialized storage conditions.

Furthermore, it has been disclosed that the amorphous forms in a number of drugs exhibit different dissolution characteristics, and in some cases different bioavailability patterns compared to the crystalline forms (Konno T., Chem. Pharm. Bull., 1990; 38; 2003-2007). For some therapeutic indications, one bioavailability pattern may be favored over another.

In the course of drug development, it is generally assumed to be important to discover the most stable crystalline form of the drug. This most stable crystalline form is the form which is likely to have the best chemical stability, and thus the longest shelf-life in a formulation. However, it is also advantageous to have multiple forms of a drug, e.g. salts, hydrates, polymorphs, crystalline, and noncrystalline forms. There is no one ideal physical form of a drug because different physical forms provide different advantages. The search for the most stable form and for such other forms is arduous and the outcome is unpredictable.

The successful development of a drug requires that it meet certain requirements to be a therapeutically effective treatment for patients. These requirements fall into two categories: (1) requirements for successful manufacture of dosage forms, and (2) requirements for successful drug delivery and disposition after the drug formulation has been administered to the patient.

There are many kinds of drug formulations for administration by various routes, and the optimum drug form for different formulations is likely to be different. As mentioned above, a drug formulation must have sufficient shelf-life to allow successful distribution to patients in need of treatment. In addition, a drug formulation must provide the drug in a form which will dissolve in the patient's gastrointestinal tract when orally dosed. For oral dosing in an immediate release dosage form, such as an immediate release tablet, capsule, suspension, or sachet, it is generally desirable to have a drug salt or drug form which has high solubility, in order to assure complete dissolution of the dose and optimal bioavailability. For some drugs,

particularly low solubility drugs or poorly wetting drugs, it may be advantageous to utilize a noncrystalline drug form, which will generally have a higher initial solubility than a crystaliine form when administered into the gastrointestinal tract. A noncrystalline form of a drug is frequently less chemically stable than a crystalline form. Thus, it is advantageous to identify noncrystalline drug forms which are sufficiently chemically stable to provide a practical product which is stable enough to maintain its potency for enough time to permit dosage form manufacture, packaging, storage, and distribution to patients around the world.

On the other hand, there are dosage forms which operate better if the drug form is less soluble. For example, a chewable tablet or a suspension or a sachet dosage form exposes the tongue to the drug directly. For such dosage forms, it is desirable to minimize the solubility of the drug in the mouth, in order to keep a portion of the drug in the solid state, minimizing bad taste. For such dosage forms, it is often desirable to use a low solubility salt or crystalline form.

For controlled release oral or injectable, e.g. subcutaneous or intramuscular, dosage forms, the desired drug solubility is a complex function of delivery route, dose, dosage form design, and desired duration of release. For a drug which has high solubility, it may be desirable to utilize a lower solubility crystalline salt or polymorph for a controlled release dosage form, to aid in achievement of slow release through slow dissolution. For a drug which has low solubility, it may be necessary to utilize a higher solubility crystalline salt or polymorph, or a noncrystalline form, in order to achieve a sufficient dissolution rate to support the desired drug release rate from the controlled release dosage form.

In soft gelatin capsule dosage forms ("soft-gels"), the drug is dissolved in a small quantity of a solvent or vehicle such as a triglyceride oil or polyethylene glycol, and encapsulated in a gelatin capsule. An optimal drug form for this dosage form is one which has a high solubility in an appropriate soft-gel vehicle. In general, a drug form which is more soluble in a triglyceride oil will be less soluble in water. Identification of an appropriate drug form for a soft-gel dosage form requires study of various salts, polymorphs, crystalline, and noncrystalline forms.

Thus, it can be seen that the desired solubility of a drug form depends on the intended use, and not all drug forms are equivalent.

For a drug form to be practically useful for human or animal therapy, it is desirable that the drug form exhibit minimal hygroscopicity. Dosage forms containing highly hygroscopic drugs require protective packaging, and may exhibit altered dissolution if stored in a humid environment. Thus, it is desirable to identify nonhygroscopic crystalline salts and polymorphs of a drug. If a drug is noncrystalline, or if a noncrystalline form is desired to improve solubility and dissolution rate, then it is desirable to identify a noncrystalline salt or form which has a low hygroscopicity relative to other noncrystalline salts or forms.

A drug, crystalline or noncrystalline, may exist in an anhydrous form, or as a hydrate or solvate or hydrate/solvate. The hydration state and solvation state of a drug affects its solubility and dissolution behavior.

The melting point of a drug may vary for different salts, polymorphs, crystalline, and noncrystalline forms. In order to permit manufacture of tablets on commercial tablet presses, it is desirable that the drug melting point be greater than around 60°C, preferably greater than 100°C to prevent drug melting during tablet manufacture. A preferred drug form in this instance is one that has the highest melting point. In

addition, it is desirable to have a high melting point to assure chemical stability of a solid drug in a solid dosage form at high environmental storage temperatures which occur in direct sunlight and in geographic areas such as near the equator. If a soft-gel dosage form is desired, it is preferred to have a drug form which has a low melting point, to minimize crystallization of the drug in the dosage form. Thus, it can be seen that the desired melting point of a drug form depends on the intended use, and not all drug forms are equivalent.

When a drug's dose is high, or if a small dosage form is desired, the selection of a salt, hydrate, or solvate affects the potency per unit weight. For example, a drug salt with a higher molecular weight counterion will have a lower drug potency per gram than will a drug salt with a lower molecular weight counterion. It is desirable to choose a drug form which has the highest potency per unit weight.

The method of preparation of different crystalline polymorphs and noncrystalline forms varies widely from drug to drug. It is desirable that minimally toxic solvents be used in these methods, particularly for the last synthetic step, and particularly if the drug has a tendency to exist as a solvate with the solvent utilized in the last step of synthesis. Preferred drug forms are those which utilize less toxic solvents in their synthesis.

The ability of a drug to form good tablets at commercial scale depends upon a variety of drug physical properties, such as the Tableting Indices described in Hiestand H, Smith D. Indices of tableting performance. Powder Technology, 1984;38:145-159. These indices may be used to identify forms of a drug, e.g. of atorvastatin calcium, which have superior tableting performance. One such index is the Brittle Fracture Index (BFI), which reflects brittleness, and ranges from 0 (good - low brittleness) to 1 (poor - high brittleness). Other useful indices or measures of mechanical properties, flow properties, and tableting performance include compression stress, absolute density, solid fraction, dynamic indentation hardness, ductility, elastic modulus, reduced elastic modulus, quasistatic indentation hardness, shear modulus, tensile strength, compromised tensile strength, best case bonding index, worst case bonding index, brittle/viscoelastic bonding index, strain index, viscoelastic number, effective angle of internal friction (from a shear cell test), cohesivity (from a powder avalanche test), and flow variability. A number of these measures are obtained on drug compacts, preferably prepared using a triaxial hydraulic press. Many of these measures are further described in Hancock B, Carlson G, Ladipo D, Langdon B, and Mullarney M. Comparison of the Mechanical Properties of the Crystalline and Amorphous Forms of a Drug Substance. International Journal of Pharmaceutics, 2002;241:73-85.

Drug form properties which affect flow are important not just for tablet dosage form manufacture, but also for manufacture of capsules, suspensions, and sachets.

The particle size distribution of a drug powder can also have large effects on manufacturing processes, particularly through effects on powder flow. Different drug forms have different characteristic particle size distributions.

From the above discussion, it is apparent that there is no one drug form which is ideal for all therapeutic applications. Thus it is important to seek a variety of unique drug forms, e.g. salts, polymorphs, noncrystalline forms, which may be used in various formulations. The selection of a drug form for a specific formulation or therapeutic application requires consideration of a variety of properties,

as described above, and the best form for a particular application may be one which has one specific important good property while other properties may be acceptable or marginally acceptable.

We have now surprisingly and unexpectedly found novel forms of atorvastatin calcium. Thus the present invention provides new forms of atorvastatin calcium designated Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, XXX. The new forms of atorvastatin are purer, more stable, or have advantageous manufacturing and/or physical properties compared to forms of atorvastatin previously described.

In general, the new forms of atorvastatin calcium disclosed in the present application have high water solubility and high dissolution rates. This is an advantage for immediate release dosage forms since such forms need to be fully dissolved in the stomach before passing into the digestive tract. Additionally, some of the new forms can be prepared using solvents which are nontoxic. This avoids any residual solvents and their toxicity. Furthermore, some of the new forms have low hygroscopicity which, as explained above, is desirable from a packaging or handling aspect. Also, some of the new forms have advantageous tableting properties and can be conveniently made into a tablet. Additionally, some of the new forms can be easily and directly prepared, which provide a cost advantage. Also, some of the new forms are physically stable and not easily converted into other forms.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to Form XX atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
7.5 – 9.0	m	vb
17.5-26.0	s	vb

[a] s = strong; m = medium
[b] vb = very broad (>1 degrees 2θ peak width)

In a second aspect, the present invention is directed to Form XXI atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	w	b
4.1	w	b
5.0	w	b
6.3	w	b
7.6	s	b
8.6	m	b, sh

9.2	w	b, sh
10.1	w	b
12.2	w	b
16.7	m	vb
18.2	m	vb
19.2	m	vb
20.1	m	vb
20.5	w	vb
23.1	m	vb, sh
29.6	w	vb

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a third aspect, the present invention is directed to Form XXII atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
4.0	m	b
4.9	w	b
8.0	m	b
10.0	s	b
11.1	w	b
11.7	w	b
12.2	w	b
13.1	w	b, sh
13.5	m	b
14.0	w	b
14.8	w	b, sh
16.1	m	b
16.4	m	b, sh
17.0	m	b
17.4	m	b, sh
17.7	m	b, sh
19.2	w	b
20.0	m	b
20.3	m	b
21.3	w	b
22.6	w	b
24.5	w	vb
27.0	w	b
28.1	w	b
28.9	w	vb
29.4	w	vb

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a fourth aspect, the present invention is directed to Form XXIII atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.2	w	b
4.1	w	b
5.0	w	b
6.3	w	b
7.2	w	b, sh
7.7	s	b
8.1	m	b
8.5	m	b
9.1	w	b
10.1	w	b
10.5	w	b
12.1	w	b
12.8	w	b
13.3	w	b
16.7	m	vb
18.4	m	vb
19.1	m	b
20.2	m	vb
21.0	w	b
21.4	m	b
23.2	m	vb
24.3	w	b
25.2	w	b
29.3	w	b

[a] s = strong; m = medium; w = weak

[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a fifth aspect, the present invention is directed to Form XXIV atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_a radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
2.9	m	b
4.6	w	b
5.2	w	b
7.4	m	b, sh
7.8	s	b
8.7	m	b
9.5	s	b
10.0	w	b
12.2	w	vb
12.5	w	b
13.4	w	b
13.9	w	b
17.3	w	vb
18.0	m	b
18.6	m	b
19.0	m	b
20.6	w	b
21.2	w	vb
22.3	w	vb
22.7	s	b
23.2	m	b, sh
24.2	w	b

24.5	w	vb
25.0	w	vb
26.4	w	vb
28.8	w	vb
31.8	w	b

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a sixth aspect, the present invention is directed to Form XXV atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	w	b
5.2	w	vb
6.4	w	sh, b
7.4	s	vb
7.9	w	sh, vb
8.7	m	vb
10.4	w	vb
12.0	w	vb
12.7	w	vb
16.6	m	vb
18.1	m	vb
19.2	m	vb
20.0	m	b
20.7	m	b
22.8	m	vb
23.2	m	vb
24.4	m	vb
25.6	w	vb
26.5	w	vb
29.3	w	vb

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a seventh aspect, the present invention is directed to Form XXVI atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_α radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.7	w	b
7.3	w	b, sh
8.4	s	b
9.0	s	b
12.2	w	b
16.0	w	vb
17.1	m	vb
17.7	m	vb
18.7	m	b
20.1	s	b

20.7	m	b, sh
22.3	m	vb
23.0	m	vb
25.2	m	vb
28.7	w	vb

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In an eighth aspect, the present invention is directed to Form XXVII atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_a radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.5	w	b, sh
3.9	m	b
4.6	w	b
7.1	w	vb, sh
7.5	s	b
7.9	m	vb, sh
9.6	m	b
9.9	m	b
10.6	w	b
11.8	w	b
13.0	w	vb
15.3	w	b
16.6	w	vb
17.2	w	vb
18.7	s	b
22.6	w	vb
23.8	w	b
25.1	w	b

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In an ninth aspect, the present invention is directed to Form XXVIII atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Bruker diffractometer with CuK_a radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
7.6	s	b
9.5	m	b
12.2	w	b
16.5	m	b
17.0	m	b
18.0	w	b
19.2	w	b
19.5	w	b, sh
20.5	m	b
20.9	w	b

21.5	w	b
21.8	w	b, sh
22.3	m	vb
23.3	w	b
23.8	w	b

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In a tenth aspect, the present invention is directed to Form XXIX atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Bruker diffractometer with CuK_a radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
8.0	m	b
10.2	w	b
11.5	m	b
14.5	w	b
15.3	w	b
16.2	m	vb
18.0	m	b
19.6	m	b
20.2	m	b
20.6	w	b
21.4	w	b
22.3	m	b
23.0	m	b
23.9	w	b
24.2	m	b
24.9	s	b
25.9	w	vb
26.9	w	b
28.6	w	b
29.1	w	b
30.4	w	b
30.9	w	b

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

In an eleventh aspect, the present invention is directed to Form XXX atorvastatin calcium characterized by the following x-ray powder diffraction (XRPD) pattern expressed in terms of degree 2θ and relative intensities with a relative intensity of >10% and relative peak width measured on a Shimadzu diffractometer with CuK_a radiation:

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	s	b
9.0	m	b
9.7	w	b
10.5	w	b
12.0	w	b
16.5	w	b
17.0	m	b
19.0	m	b

19.3	w	b, sh
19.9	w	b
20.9	m	b
21.1	w	b
21.6	s	b
22.5	m	vb
24.3	m	b
26.7	w	b
27.0	w	b
27.6	w	b
29.6	w	b
31.8	w	b

[a] s = strong; m = medium; w = weak
[b] b = broad, sh = shoulder, vb = very broad (>1 degrees 2θ peak width)

As inhibitors of HMG-CoA reductase, the novel forms of atorvastatin calcium are useful as hypolipidemic and hypocholesterolemic agents as well as agents in the treatment of osteoporosis, benign prostatic hyperplasia (BPH), and Alzheimer's disease.

A still further embodiment of the present invention is a pharmaceutical composition for administering an effective amount of Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, or Form XXX atorvastatin calcium in unit dosage form in the treatment methods mentioned above. Finally, the present invention is directed to methods for production of Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, or Form XXX atorvastatin calcium.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described by the following nonlimiting examples which refer to the accompanying Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX, short particulars of which are given below.

Figure 1

Diffractogram of Form XX atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 2

Diffractogram of Form XXI atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 3

Diffractogram of Form XXII atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 4

Diffractogram of Form XXIII atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 5

Diffractogram of Form XXIV atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 6

Diffractogram of Form XXV atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 7

Diffractogram of Form XXVI atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 8

Diffractogram of Form XXVII atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 9

Diffractogram of Form XXVIII atorvastatin calcium carried out on a Bruker diffractometer.

Figure 10

Diffractogram of Form XXIX atorvastatin calcium carried out on a Bruker diffractometer.

Figure 11

Diffractogram of Form XXX atorvastatin calcium carried out on a Shimadzu XRD-6000 diffractometer.

Figure 12

Small angle diffractogram of Form XX atorvastatin calcium.

Figure 13

Small angle diffractogram of Form XXII atorvastatin calcium.

Figure 14

Small angle diffractogram of Form XXIV atorvastatin calcium.

Figure 15

Small angle diffractogram of Form XXV atorvastatin calcium.

Figure 16

Small angle diffractogram of Form XXVII atorvastatin calcium.

Figure 17

Small angle diffractogram of Form XXX atorvastatin calcium.

Figure 18

Raman spectrum of Form XX atorvastatin calcium.

Figure 19

Raman spectrum of Form XXII atorvastatin calcium.

Figure 20

Raman spectrum of Form XXIV atorvastatin calcium .

Figure 21

Raman spectrum of Form XXV atorvastatin calcium.

Figure 22

Raman spectrum of Form XXVII atorvastatin calcium.

Figure 23

Raman spectrum of Form XXVIII atorvastatin calcium.

Figure 24

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XX atorvastatin calcium.

Figure 25

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXII atorvastatin calcium.

Figure 26

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXIV atorvastatin calcium.

Figure 27

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXV atorvastatin calcium.

Figure 28

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXVII atorvastatin calcium.

Figure 29

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXVIII atorvastatin calcium.

Figure 30

Solid state ^{13}C nuclear magnetic resonance spectrum of Form XXX atorvastatin calcium.

Figure 31

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XX atorvastatin calcium.

Figure 32

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXII atorvastatin calcium.

Figure 33

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXIV atorvastatin calcium.

Figure 34

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXV atorvastatin calcium.

Figure 35

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXVII atorvastatin calcium.

Figure 36

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXVIII atorvastatin calcium.

Figure 37

Solid state ^{19}F nuclear magnetic resonance spectrum of Form XXX atorvastatin calcium.

DETAILED DESCRIPTION OF THE INVENTION

Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, or Form XXX atorvastatin calcium may be characterized by x-ray powder diffraction patterns, by their solid state nuclear magnetic resonance spectra (NMR), and/ or their Raman spectra.

The "forms" of atorvastatin calcium disclosed in the present invention may exist as disordered crystals, liquid crystals, plastic crystals, mesophases, and the like. Forms that are related through disorder will have essentially the same major peak positions but the disordering process will cause broadening of these peaks. For many of the weaker peaks, the broadening may be so severe that they are no longer visible above the background. The peak broadening caused by disorder may in addition cause errors in the location of the exact peak position.

X-RAY POWDER DIFFRACTION

Form XX, Form XXI, Form XXII, Form XXIII, Form XXIV, Form XXV, Form XXVI, Form XXVII, Form XXVIII, Form XXIX, and Form XXX atorvastatin calcium were characterized by their X-ray powder diffraction pattern. Thus, the X-ray powder diffraction patterns of Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, and XXX were carried out on a Shimadzu XRD-6000 X-ray diffractometer using Cu K_α radiation. This instrument is equipped with a fine focus X-ray tube. The tube voltage and amperage were set to 40kV and 40 mA, respectively. The divergence and scattering slits were set at 1°, and the receiving slit was set at 0.15mm. Diffraction radiation was detected by a NaI scintillation detector. A theta-two theta continuous scan at 3°C/min (0.4 sec/0.02° step) from 2.5 to 40 °2θ was used. A silicon standard was analyzed each day to check the instrument alignment. Data were collected and analyzed using XRD-6000 V. 4.1. Samples were prepared for analysis by placing them in an aluminum holder.

The X-ray powder diffraction patterns of Forms XXVIII and XXIX were carried out on a Bruker D5000 diffractometer using Cu K_α radiation. The instrument was equipped with a fine focus X-ray tube. The tube voltage and amperage were set to 40 kV and 40 mA, respectively. The divergence and scattering slits were set at 1 mm, and the receiving slit was set at 0.6 mm. Diffracted radiation was detected by a Kevex PSI detector. A theta two theta continuous scan at 2.4 °/min (1 sec/0.04° step) from 3.0 to 40 °2θ was used. An alumina standard was analyzed to check the instrument alignment. Data were collected and analyzed using Bruker axs software Version 7.0. Samples were prepared for analysis by placing them in a quartz holder. It should be noted that Bruker Instruments purchased Siemans; thus,. a Bruker D5000 instrument is essentially the same as a Siemans D5000.

To perform an X-ray diffraction measurement on a Bragg-Brentano instrument like the Shimadzu system or the Bruker system used for measurements reported herein, the sample is typically placed into a holder which has a cavity. The sample powder is pressed by a glass slide or equivalent to ensure a random surface and proper sample height. The sample holder is then placed into the Shimadzu instrument. The incident X-ray beam is directed at the sample, initially at a small angle relative to the plane of the holder, and then moved through an arc that continuously increases the angle between the incident beam and the plane of the holder. Measurement differences associated with such X-ray powder analyses result from a variety of factors including: (a) errors in sample preparation (e.g., sample height), (b) instrument errors (e.g. flat sample errors), (c) calibration errors, (d) operator errors (including those errors present when determining the peak locations), and (e) the nature of the material (e.g. preferred orientation and transparency errors). Calibration errors and sample height errors often result in a shift of all the peaks in the same direction. Small differences in sample height when using a flat holder will lead to large displacements in XRPD peak positions. A systematic study showed that, using a Shimadzu XRD-6000 in the typical Bragg-Brentano configuration, sample height difference of 1 mm lead to peak shifts as high as 1 °2θ (Chen et al.; J Pharmaceutical and Biomedical Analysis, 2001; 26,63). These shifts can be identified from the X-ray Diffractogram and can be eliminated by compensating for the shift (applying a systematic correction factor to all peak position values) or recalibrating the instrument. As mentioned above, it is possible to rectify measurements from the various machines by applying a systematic correction factor to bring the peak positions into agreement. In general, this correction factor will bring the

measured peak positions from the Shimadzu or the Bruker into agreement with the expected peak positions and may be in the range of 0 to 0.2 ° 2θ.

Tables 1-11 list peak positions in degrees 2θ, relative intensities, and relative peak widths for X-ray powder diffraction patterns of each form of atorvastatin calcium disclosed in the present application. The relatively narrow peak positions were picked by the Shimadzu software using default settings. X-ray powder diffraction patterns were processed by the Shimadzu XRD-6000 version 2.6 software to automatically find peak positions. The "peak position" means the maximum intensity of a peaked intensity profile. To maximize accuracy and precision, the entire intensity profile is considered when selecting peak positions. Intensity spikes from large crystals and the expected intensity fluctuations from noise were considered in picking the position of a peak.

The following processes were used with the Shimadzu XRD-6000 "Basic Process" version 2.6 algorithm:

1. Smoothing was done on all patterns.
2. The background was subtracted to find the net, relative intensity of the peaks.
3. A peak from CuK_a alpha2 (1.5444 Å) wavelength was subtracted from the peak generated by CuK_a alpha1 (1.5406Å) peak at 50% intensity for all patterns.

Default values of the software were used in picking the peaks and all peak positions were rounded to $1/10^{th}$. Some of the XRPD patterns displayed very diffuse and very noisy patterns and the peak positions were determined manually, and expressed as a range of degree 2 theta (from the beginning of the broad peak to the end of the broad peak). All peak positions were rounded to 0.1 °2θ. The following abbreviations are used to describe the peak intensity (s = strong; m = medium; w = weak) and the peak width (b = broad (where broad refers to peak widths of between 0.2 and 1.0 degrees 2θ, sh = shoulder, vb = very broad (where very broad refers to peaks with >1 degrees 2θ peak width)).

Table 1. XPRD Peak List for Form XX

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
7.5 – 9.0	m	vb
17.5-26.0	s	vb

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 2. XPRD Peak List for Form XXI

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	w	b
4.1	w	b
5.0	w	b
6.3	w	b
7.6	s	b
8.6	m	b, sh

9.2	w	b, sh
10.1	w	b
12.2	w	b
16.7	m	vb
18.2	m	vb
19.2	m	vb
20.1	m	vb
20.5	w	vb
23.1	m	vb, sh
29.6	w	vb

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 3. XPRD Peak List for Form XXII

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
4.0	m	b
4.9	w	b
8.0	m	b
10.0	s	b
11.1	w	b
11.7	w	b
12.2	w	b
13.1	w	b, sh
13.5	m	b
14.0	w	b
14.8	w	b, sh
16.1	m	b
16.4	m	b, sh
17.0	m	b
17.4	m	b, sh
17.7	m	b, sh
19.2	w	b
20.0	m	b
20.3	m	b
21.3	w	b
22.6	w	b
24.5	w	vb
27.0	w	b
28.1	w	b
28.9	w	vb
29.4	w	vb

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 4. XPRD Peak List for Form XXIII

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.2	w	b
4.1	w	b
5.0	w	b
6.3	w	b
7.2	w	b, sh
7.7	s	b
8.1	m	b
8.5	m	b
9.1	w	b
10.1	w	b
10.5	w	b
12.1	w	b
12.8	w	b
13.3	w	b
16.7	m	vb
18.4	m	vb
19.1	m	b
20.2	m	vb
21.0	w	b
21.4	m	b
23.2	m	vb
24.3	w	b
25.2	w	b
29.3	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 5. XPRD Peak List for Form XXIV

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
2.9	m	b
4.6	w	b
5.2	w	b
7.4	m	b, sh
7.8	s	b
8.7	m	b
9.5	s	b
10.0	w	b
12.2	w	vb
12.5	w	b
13.4	w	b
13.9	w	b
17.3	w	vb
18.0	m	b
18.6	m	b
19.0	m	vb
20.6	w	b
21.2	w	vb
22.3	w	vb
22.7	s	b
23.2	m	b, sh

24.2	w	b
24.5	w	vb
25.0	w	vb
26.4	w	vb
28.8	w	vb
31.8	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 6. XPRD Peak List for Form XXV

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	w	b
5.2	w	vb
6.4	w	sh, b
7.4	s	vb
7.9	w	sh, vb
8.7	m	vb
10.4	w	vb
12.0	w	vb
12.7	w	vb
16.6	m	vb
18.1	m	vb
19.2	m	vb
20.0	m	b
20.7	m	b
22.8	m	vb
23.2	m	vb
24.4	m	vb
25.6	w	vb
26.5	w	vb
29.3	w	vb

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 7. XPRD Peak List for Form XXVI

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.7	w	b
7.3	w	b, sh
8.4	s	b
9.0	s	b
12.2	w	b
16.0	w	vb
17.1	m	vb
17.7	m	vb
18.7	m	b
20.1	s	b
20.7	m	b, sh
22.3	m	vb
23.0	m	vb
25.2	m	vb
28.7	w	vb

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 8. XPRD Peak List for Form XXVII

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.5	w	b, sh
3.9	m	b
4.6	w	b
7.1	w	vb, sh
7.5	s	b
7.9	m	vb, sh
9.6	m	b
9.9	m	b
10.6	w	b
11.8	w	b
13.0	w	vb
15.3	w	b
16.6	w	vb
17.2	w	b
18.7	s	b
22.6	w	vb
23.8	w	b
25.1	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 9. XPRD Peak List for Form XXVIII

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
7.6	s	b
9.5	m	b
12.2	w	b
16.5	m	b
17.0	m	b
18.0	w	b
19.2	w	b
19.5	w	b, sh
20.5	m	b
20.9	w	b
21.5	w	b
21.8	w	b, sh
22.3	m	vb
23.3	w	b
23.8	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 10. XPRD Peak List for Form XXIX

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
8.0	m	b
10.2	w	b
11.5	m	b
14.5	w	b
15.3	w	b
16.2	m	vb
18.0	m	b
19.6	m	b
20.2	m	b
20.6	w	b
21.4	w	b
22.3	m	b
23.0	m	b
23.9	w	b
24.2	m	b
24.9	s	b
25.9	w	vb
26.9	w	b
28.6	w	b
29.1	w	b
30.4	w	b
30.9	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 11. XPRD Peak List for Form XXX

degree 2θ	Relative Intensity[a]	Relative Peak Width[b]
3.1	s	b
9.0	m	b
9.7	w	b
10.5	w	b
12.0	w	b
16.5	w	b
17.0	m	b
19.0	m	b
19.3	w	b, sh
19.9	w	b
20.9	m	b
21.1	w	b
21.6	s	b
22.5	m	vb
24.3	m	b
26.7	w	b
27.0	w	b
27.6	w	b
29.6	w	b
31.8	w	b

[a]s=strong; m=medium; w=weak
[b]b=broad; sh=shoulder; vb=very broad (> 1 degrees 2θ peak width)

Table 12 lists combinations of 2θ peaks for Forms XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium, i.e., a set of x-ray diffraction lines that are unique to each form.

Table 12. Forms XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX.

Form	degree 2θ
XXI	3.1 4.1 5.0 7.6 16.7 18.2 19.2 20.1 20.5 23.1
XXII	4.0 8.0 10.0 13.5 16.1 16.4 17.0 17.4 19.2 20.0 20.3
XXIII	4.1 5.0 6.3 7.7 8.5 9.1 10.5 16.7 18.4 20.2 21.4
XXIV	2.9 7.4 7.8 8.7 9.5 10.0 12.2 18.0 18.6 19.0 22.7
XXV	3.1 5.2 7.4 8.7 10.4 12.7 16.6

	18.1 19.2 20.0 20.7 23.2 24.4
XXVI	3.7 8.4 9.0 17.1 17.7 18.7 20.1 22.3 23.0
XXVII	3.9 4.5 7.1 7.5 9.6 10.6 11.8 13.0 15.3 18.7
XXVIII	7.6 9.5 12.2 16.5 17.0 18.0 20.5 21.5 22.3
XXIX	8.0 10.2 11.5 14.5 15.3 18.0 19.6 20.2 22.3 24.9
XXX	3.1 9.0 9.7 12.0 16.5 17.0 20.9 21.6 22.5 24.3

Further, Table 13 lists additional combinations of 2θ peaks for Forms XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium, i.e., an additional set of x-ray diffraction lines that are unique to each form.

Table 13 Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX

Form	Degree 2θ
Form XX I	3.1 4.1 5.0 7.6 16.7 18.2 19.2 23.1
Form XXII	4.0 10.0 13.5 17.0 19.2 20.3
Form XXIII	4.1 5.0 6.3 7.7 8.5 9.1 10.5 16.7 21.4
Form XXIV	2.9 7.4 7.8 8.7 9.5 12.2 18.6 19.0 22.7
Form XXV	3.1 5.2 7.4 8.7 23.2 24.4
Form XXVI	3.7 8.4 9.0 17.1 18.7 20.1 23.0
Form XXVII	3.9 4.5 7.5 9.6 10.6 13.0 15.3 18.7

Form XXVIII	7.6 9.5 12.2 16.5 17.0 18.0 21.5 22.3
Form XXX	9.0 9.7 12.0 16.5 17.0 21.6 22.5 24.3

SMALL ANGLE POWDER X-RAY DIFFRACTION

Methodology

Powder materials of different lots of atorvastatin calcium were packed in either glass or quartz x-ray capillaries with diameter of 1 to 2 mm. Small-Angle X-Ray Diffraction (SAXD) experiments were performed at the beamline ID2, European Synchrotron Radiation Facility (ESRF), Grenoble, France. The radiation wavelength was 0.996 Á (silicon channel-cut monochromator). The 2-dimensional SAXD images were recorded using image-intensified charge coupled device (CCD) detector and the data was expressed as reciprocal spacing q in nm^{-1} units. The exposure time was adjusted to use the maximum dynamic of the detectors for every particular sample and was less than 1s in the majority of cases. The 2-dimensional images were normalized to an absolute intensity scale after performing the standard detector corrections and azimuthally integrated to obtain the corresponding 1-dimensional x-ray diffraction curves. Peaks positions were measured using Gaussian fit using single peak analysis. The SAXD and (wide angle x-ray diffraction) WAXD q-scales were calibrated with silver behenate and silicon powders, respectively.

Table 14 shows the SAXRD peaks for Forms XX, XXII, XXIV, XXV, XXVII and XXX atorvastatin calcium.

Table 14. SAXRD Data

Form	Position of peaks, q, nm^{-1}
XX	2.11 3.93
XXII	2.85 3.48 4.16
XXIV	2.09 2.24 2.84 3.33 3.54 3.69 4.50 5.23

XXV	2.22 2.86 3.62 4.46 5.28
XXVII	2.19 2.76 2.86 3.27 3.33 4.00 4.69 4.97
XXX	2.13 4.26

RAMAN SPECTROSCOPY

Methodology

The Raman spectrum was obtained on a Raman accessory interfaced to a Nicolet Magna 860 Fourier transform infrared spectrometer. The accessory utilizes an excitation wavelength of 1064 nm and approximately 0.45 W of neodymium-doped yttrium aluminum garnet (Nd:YAG) laser power. The spectrum represents 6 or 128 co-added scans acquired at 4 cm^{-1} resolution. The sample was prepared for analysis by placing a portion into a 5-mm diameter glass tube and positioning this tube in the spectrometer. Peak tables were generated using the Nicolet software with default threshold and sensitivity settings. The spectrometer was calibrated (wavelength) with sulfur and cyclohexane at the time of use.

Table 15 shows the Raman spectra for Forms XX, XXII, XXIV, XXV, XXVII, and XXVIII atorvastatin calcium.

Table 15. Raman Peak Listing

Peak Positions in Wavenumbers (cm^{-1})

Form	cm^{-1}
XX	618 818 855 892 999 1034 1158 1178 1244 1412 1480 1528 1558 1604 1649 3059
XXII	618 820 855

	27
	998 1033 1157 1243 1364 1410 1526 1603 1671 3059
XXIV	133 217 247 298 422 500 617 643 697 789 811 825 857 900 925 961 1000 1034 1056 1112 1160 1179 1240 1301 1370 1398 1413 1473 1527 1603 1651 2263 2555 2922 2972 3062
XXV	138 224 245 300 422 495 617 644 697 726 825 859 901 1001 1034

	28
	1058 1112 1159 1181 1243 1320 1368 1397 1412 1477 1528 1604 1654 2257 2933 3063
XXVII	130 288 366 512 581 618 634 736 821 858 898 998 1034 1112 1158 1240 1314 1368 1411 1481 1527 1559 1578 1604 1658 2927 3063
XXVIII	148 248 296 341 405 522 478 617 642 699 755 824 863 999 1034 1062 1090 1159

1180
1242
1298
1316
1369
1412
1468
1525
1603
1640
2882
2940
3060
3376

SOLID STATE NUCLEAR MAGNETIC RESONANCE (NMR)

Methodology

Solid-state ^{13}C NMR and ^{19}F NMR spectra were obtained at 293K on 500 MHz NMR spectrometer. Approximately 80 mg of sample were tightly packed into a 4 mm ZrO spinner for analysis. The one-dimensional solid state spectra were collected at ambient pressure and 293 K on a wide-bore Bruker-Biospin Avance DSX 500 MHz NMR spectrometer using a Bruker 4 mm HFX BL cross-polarization magic angle spinning (CPMAS) probe. To minimize the spinning side bands, spinning speed was set to 15.0 kHz, the maximum specified spinning speed for the 4 mm HFX BL probe. ^{13}C CPMAS and ^{19}F MAS peaks were peak-picked using Bruker-Biospin TOPSPIN 1.3 software, by suitably setting the spectral window and the peak picking threshold intensity to eliminate peak picking of spinning side bands. The detection sensitivity parameter (PC) was typically set to 0.5.

^{13}C CPMAS

The one-dimensional ^{13}C spectra were collected using ^{1}H-^{13}C cross-polarization magic angle spinning (CPMAS). To optimize the signal sensitivity, the cross-polarization contact time was adjusted to 2.3 ms, and the decoupling power was set to 80 kHz. The carbon spectra were acquired with approximately 1,100 scans with a recycle delay of 8 seconds. They were referenced using an external sample of adamantane, setting its upfield resonance to 29.5 ppm.

^{19}F MAS

The one-dimensional ^{19}F spectra were collected using magic angle spinning (MAS) with proton decoupling. The decoupling field was set to approximately 65 kHz. ^{19}F detected ^{1}H T1 relaxation times were calculated based on inversion recovery experiments. For all samples, the probe background was reduced by subtracting signal from interleaved scans, during which a ^{19}F presaturation pulse was applied. The spectra were acquired with approximately 64 scans with a recycle delay of 10 seconds. The samples were referenced using an external sample of trifluoroacetic acid (diluted to 50% V/V by H_2O), setting its resonance to -76.54 ppm.

Table 16 shows the ^{13}C solid state NMR spectrum for Forms XX, XXII, XXIV, XXV, XXVII, XXVIII, and XXX atorvastatin calcium. Table 17 shows the ^{19}F solid state NMR spectrum for Forms XX, XXII, XXIV, XXV , XXVII, XXVIII, and XXX atorvastatin calcium.

Table 16.

CPMAS ^{13}C Data

Form	Solid State Chemical Shift[a] [ppm]
XX	180.7 166.8 162.9 161.0 134.7 128.5 122.5 118.6 69.8 41.8 26.1 21.7
XXII	182.1 166.6 164.1 161.8 143.7 139.4 136.1 134.2 129.1 123.4 119.7 115.7 68.7 45.1 43.9 39.1 37.4 26.8 22.7 20.6 18.3
XXIV	187.5 185.2 184.2 180.5 179.0 178.4 177.4 166.8 162.7 160.9 138.7 136.2 133.7 128.7

	124.4 122.4 121.2 120.5 118.0 115.7 69.8 67.4 65.7 46.4 44.3 43.5 40.6 26.7 25.5 21.8 19.6 0.0
XXV	186.3 185.0 182.5 177.0 167.0 166.2 162.8 160.9 138.6 136.1 133.4 129.2 128.5 126.0 124.0 121.5 120.7 118.0 116.8 116.0 69.9 68.0 46.4 43.3 40.9 25.7 25.2 21.3 20.0 0.6
XXVII	179.7 166.0 163.6 161.7 140.7 133.8 128.8 122.4 115.3 72.5 70.9 66.6

	41.8 27.3 22.0
XXVIII	184.1 183.4 181.2 180.9 168.8 162.5 160.5 138.1 137.5 135.3 134.5 132.8 131.4 131.1 130.0 129.6 127.7 123.9 123.1 121.4 120.6 118.4 117.6 113.1 73.7 73.1 71.7 66.8 65.9 63.9 46.7 43.0 26.5 24.7 23.8 21.4 21.0
XXX	181.0 177.2 167.2 162.5 160.5 137.8 137.1 135.4 134.4 132.3 131.2 129.9 128.2 127.4 123.7 123.1 121.8 120.9 118.6 117.8 113.9

	67.9 65.4 63.9 47.5 47.0 46.2 43.3 41.5 40.5 26.2 25.5 24.9 21.8 21.4

[a]Referenced using an external standard of crystalline adamantane, setting its upfield resonance to 29.5 ppm.

Table 17.

MAS ^{19}F Data

Form	Fluorine chemical shift[a] [ppm]
XX	-113.9
XXII	-112.0 -114.8 -118.9
XXIV	-114.0 -116.8 -117.9
XXV	-113.2 -116.3 -118.4
XXVII	-112.2 -113.0 -117.2
XXVIII	-116.4 -117.1 -119.2
XXX	-116.7 -118.6

[a] Referenced using an external sample of trifluoroacetic acid (diluted to 50% V/V by H_2O), setting its resonance to -76.54 ppm.

Additionally, Forms XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium may be characterized by an x-ray powder diffraction and a solid state ^{19}F nuclear magnetic resonance spectrum. For example:

A Form XXII atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_a radiation: 10.0, 16.1, and 19.2, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -112.0, -114.8, and -118.9.

A Form XXIV atorvastatin calcium having an X-ray powder diffraction containing the following 2θ values measured using CuK_α radiation: 7.4, 9.5 and 12.2, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -114.0, -116.8, and -117.9.

A Form XXV atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_α radiation: 7.4, 8.7, 19.2, and 20.0, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -113.2, -116.3, and -118.4.

A Form XXVII atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_α radiation: 3.9, 7.5, and 18.7, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -112.2, -113.0, and -117.2.

A Form XXVIII atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_α radiation: 7.6, 9.5, 20.5, and 22.3, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -116.4, -117.1, and -119.2.

A Form XXX atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_α radiation: 3.1, 9.0, and 21.6, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -116.7 and -118.6.

The forms of atorvastatin calcium described in the present invention may exist in anhydrous forms as well as containing various amounts of water and/ or solvents. In general, these forms are equivalent to the anhydrous forms and are intended to be encompassed within the scope of the present invention.

The forms of atorvastatin calcium of the present invention, regardless of the extent of water and/ or solvent having equivalent x-ray powder diffractograms are within the scope of the present invention.

The new forms of atorvastatin calcium described in the present application have advantageous properties.

The ability of a material to form good tablets at commercial scale depends upon a variety of physical properties of the drug, such as, for example, the Tableting Indices described in Hiestand H. and Smith D., Indices of Tableting Performance, Powder Technology, 1984, 38; 145-159. These indices may be used to identify forms of atorvastatin calcium which have superior tableting performance. One such index is the Brittle Fracture Index (BFI), which reflects brittleness, and ranges from 0 (good-low brittleness) to 1 (poor – high brittleness).

The present invention provides a process for the preparation of Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium which comprises forming atorvastatin calcium from a solution or slurry in solvents under conditions which yield Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium.

The precise conditions under which Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium are formed may be empirically determined, and it is only possible to give a number of methods which have been found to be suitable in practice.

The compounds of the present invention can be prepared and administered in a wide variety of oral and parenteral dosage forms. Thus, the compounds of the present invention can be administered by injection, that is, intravenously, intramuscularly, intracutaneously, subcutaneously, intraduodenally, or intraperitoneally. Also, the compounds of the present invention can be administered by inhalation, for example, intranasally. Additionally, the compounds of the present invention can be administered

transdermally. It will be obvious to those skilled in the art that the following dosage forms may comprise as the active component a compound of the present invention.

For preparing pharmaceutical compositions from the compounds of the present invention, pharmaceutically acceptable carriers can be either solid or liquid. Solid form preparations include powders, tablets, pills, capsules, cachets, suppositories, and dispersible granules. A solid carrier can be one or more substances which may also act as diluents, flavoring agents, solubilizers, lubricants, suspending agents, binders, preservatives, tablet disintegrating agents, or an encapsulation material.

In powders, the carrier is a finely divided solid which is in a mixture with the finely divided active component.

In tablets, the active component is mixed with the carrier having the necessary binding properties in suitable proportions and compacted in the shape and size desired.

The powders and tablets preferably contain from two or ten to about seventy percent of the active compound. Suitable carriers are magnesium carbonate, methylcellulose, sodium carboxymethylcellulose, a low melting wax, cocoa butter, and the like. The term 'preparation' is intended to include the formulation of the active compound with encapsulating material as a carrier providing a capsule in which the active component, with or without other carriers, is surrounded by a carrier, which is thus in association with it. Similarly, cachets and lozenges are included. Tablets, powders, capsules, pills, cachets, and lozenges can be used as solid dosage forms suitable for oral administration.

For preparing suppositories, a low melting wax, such as a mixture of fatty acid glycerides or cocoa butter, is first melted and the active component is dispersed homogeneously therein, as by stirring. The molten homogeneous mixture is then poured into convenient sized molds, allowed to cool, and thereby to solidfy.

Liquid form preparations include solutions, suspensions, retention enemas, and emulsions, for example water or water propylene glycol solutions. For parenteral injection, liquid preparations can be formulated in solution in aqueous polyethylene glycol solution.

Aqueous solutions suitable for oral use can be prepared by dissolving the active component in water and adding suitable colorants, flavors, stabilizing and thickening agents, as desired.

Aqueous suspensions suitable for oral use can be made by dispersing the finely divided active component in water with viscous material, such as natural or synthetic gums, resins, methylcellulose, sodium carboxymethylcellulose, and other well-known suspending agents.

Also included are solid form preparations which are intended to be converted, shortly before use, to liquid form preparations for oral administration. Such liquid forms include solutions, suspensions, and emulsions. These preparations may contain, in addition to the active component, colorants, flavors, stabilizers, buffers, artificial and natural sweeteners, dispersants, thickeners, solubilizing agents, and the like.

The pharmaceutical preparation is preferably in unit dosage form. In such form, the preparation is subdivided into unit doses containing appropriate quantities of the active component. The unit dosage form can bea packaged preparation, the package containing discrete quantities of preparation, such as packeted tablets, capsules, and powders in vials or ampoules. Also, the unit dosage form can be a

capsule, tablet, cachet, or lozenge itself, or it can be the appropriate number of any of these in packaged form.

The quantity of active component in a unit dosage preparation may be varied or adjusted from 0.5 mg to 100 mg, preferably 2.5 to 80 mg according to the particular application and the potency of the active component. The composition can, if desired, also contain other compatible therapeutic agents.

In therapeutic use as hypolipidemic and/ or hypocholesterolemic agents and agents to treat BPH, osteoporosis, and Alzheimer's disease, the Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium utilized in the pharmaceutical method of this invention are administered at the initial dosage of about 2.5 mg to about 80 mg daily. A daily dose range of about 2.5 mg to about 20 mg is preferred. The dosages, however, may be varied depending upon the requirements of the patient, the severity of the condition being treated, and the compound being employed.

Determination of the proper dosage for a particular situation is within the skill of the art. Generally, treatment is initiated with smaller dosages which are less than the optimum dose of the compound. Thereafter, the dosage is increased by small increments until the optimum effect under the circumstance is reached. For convenience, the total daily dosage may be divided and administered in portions during the day if desired.

The following nonlimiting examples illustrate the inventors' preferred methods for preparing the compounds of the invention:

EXAMPLE 1

[R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]-1H-pyrrole-1-heptanoic acid hemi calcium salt (Forms XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX atorvastatin calcium).

Form XX atorvastatin calcium

Method A

A 12.2 g sample of Form I atorvastatin calcium was suspended in 300 mL of methanol (MeOH):H_20 (95:5, v:v) and sonicated. The resulting suspension was filtered into a 1 L flask. The sample was evaporated on a rotary evaporator with an unheated water bath and the vacuum provided with an aspirator. The solid obtained was dried under vacuum at ambient temperature overnight to afford Form XX atorvastatin calcium.

Crystalline Form I atorvastatin may be prepared as described in United States Patent No. 5,969,156:

Crystalline Form I atorvastatin may be prepared by crystallization under controlled conditions. In particular, it can be prepared either from an aqueous solution of the corresponding basic salt such as, an alkali metal salt, for example, lithium, potassium, sodium, and the like; ammonia or an amine salt; preferably, the sodium salt by addition of a calcium salt, such as, for example, calcium acetate and the like, or by suspending amorphous atorvastatin in water. In general, the use of a hydroxylic co-solvent such as, for example, a lower alkanol, for example methanol and the like, is preferred.

When the starting material for the preparation of the desired crystalline Form I atorvastatin is a solution of the corresponding sodium salt, one preferred preparation involves treating a solution of the sodium salt in water containing not less than about 5% v/v methanol, preferably about 5% to 33% v/v methanol, particularly preferred about 10% to 15% v/v methanol, with an aqueous solution of calcium acetate, preferably at an elevated temperature at up to about 70° C. such as, for example, about 45-60° C., particularly preferred about 47-52° C. It is preferable to use calcium acetate and, in general, 1 mole of calcium acetate to 2 moles of the sodium salt of atorvastatin. Under these conditions, calcium salt formation as well as crystallization should preferably be carried out at an elevated temperature, for example within the above-mentioned temperature ranges. It has been found that it may be advantageous to include in the starting solution a

small amount of methyl tert-butyl ether (MTBE) such as, for example, about 7% w/w. It has frequently been found desirable to add "seeds" of crystalline Form I atorvastatin to the crystallization solution in order to consistently produce crystalline Form I atorvastatin.

When the starting material is amorphous atorvastatin or a combination of amorphous and crystalline Form I Atorvastatin, the desired crystalline Form I atorvastatin may be obtained by suspending the solid in water containing up to about 40% v/v, such as, for example, about 0% to 20% v/v, particularly preferred about 5% to 15% v/v co-solvent such as, for example, methanol, ethanol, 2-propanol, acetone, and the like until conversion to the required form is complete, followed by filtration. It has frequently been found desirable to add "seeds" of crystalline Form I atorvastatin to the suspension in order to ensure complete conversion to crystalline Form I atorvastatin. Alternatively, a water-wet cake consisting principally of amorphous atorvastatin can be heated at elevated temperatures such as, for example, up to about 75° C., particularly preferred about 65-70° C., until a significant amount of crystalline Form I atorvastatin is present, whereupon the amorphous/crystalline Form I mixture can be slurried as described above.

Form I Atorvastatin

Method A

For example, mixture of (2R-trans)-5-(4-fluorophenyl)-2-(1-methylethyl)-N,4-diphenyl-1-[2-(tetrahydro-4-hydroxy-6-oxo-2H-pyran-2-yl)ethyl]-1H-pyrrole-3-carboxamide (atorvastatin lactone) (U.S. Pat. No. 5,273,995) (75 kg), methyl tertiary-butyl ether (MTBE) (308 kg), methanol (190 L) is reacted with an aqueous solution of sodium hydroxide (5.72 kg in 950 L) at 48-58° C. for 40 to 60 minutes to form the ring-opened sodium salt. After cooling to 25-35° C., the organic layer is discarded, and the aqueous layer is again extracted with MTBE (230 kg). The organic layer is discarded, and the MTBE saturated aqueous solution of the sodium salt is heated to 47-52° C. To this solution is added a solution of calcium acetate hemihydrate (11.94 kg) dissolved in water (410 L), over at least 30 minutes. The mixture is seeded with a slurry of crystalline Form I atorvastatin (1.1 kg in 11 L water and 5 L methanol) shortly after addition of the calcium acetate solution. The mixture is then heated to 51-57° C. for at least 10 minutes and then cooled to 15-40° C. The mixture is filtered, washed with a solution of water (300 L) and methanol (150 L) followed by water (450 L). The solid is dried at 60-70° C. under vacuum for 3 to 4 days to give crystalline Form I atorvastatin (72.2 kg).

Method B

Amorphous atorvastatin (9 g) and crystalline Form I atorvastatin (1 g) are stirred at about 40° C. in a mixture of water (170 mL) and methanol (30 mL) for a total of 17 hours. The mixture is filtered, rinsed with water, and dried at 70° C. under reduced pressure to give crystalline Form I atorvastatin (9.7 g) ([R-(R*,R*)]-2-(4-Fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3 -phenyl-4-[(phenylamino)carbonyl]-1H-pyrrole-1-heptanoic acid hemi calcium salt).

Method B

A 24 mg sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was dissolved in 7 mL of ethanol (EtOH):H_2O (4:1, v:v) and filtered through a 0.2 μm nylon filter. The resulting solution was evaporated in an open vial to dryness to afford Form XX atorvastatin calcium.

Form XXI atorvastatin calcium

Method A

A 3.6 g sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was dissolved in 10 mL of tetrahydrofuran: water (9:1, v/v) at 43 °C. A 1-mL aliquot was filtered into a vial and

approximately 1 mL of pre-warmed acetonitrile (ACN) was added drop-wise. The clear solution was placed in a refrigerator. Solids formed within 1 day, recovered with vacuum filtration, and air-dried at ambient temperature to afford Form XXI atorvastatin calcium.

Method B

A 10.5g sample of Form I (United States Patent No. 5,969,156) was slurried in 450 mL of isopropyl alcohol (IPA)/50 mL H_2O (9:1) at room temperature for 20 days. The sample was then vacuum filtered. The sample was then slurried in 450 mL of ACN/ 50 mL H_2O (9:1) overnight. The sample was vacuum filtered for 5 hours to afford Form XXI atorvastatin calcium.

Form XXII atorvastatin calcium

An 11.5 g sample of Form XX atorvastatin calcium (prepared as described above) was mixed with 29 mL of MeOH and stirred on an ambient temperature orbital shaker for 1 day. The sample was then vacuum dried at ambient temperature for 1 day. The recovered solid was mixed with 29 mL of MeOH and slurried on an ambient temperature orbital shaker for less than 1 hour. The gel that formed was then mixed with an additional 40 mL of MeOH and slurried on the ambient temperature orbital shaker for 3 days. The solids were vacuum dried at ambient temperature for 1 day to afford Form XXII atorvastatin calcium.

Form XXIII atorvastatin calcium

Method A

A 1.5 g sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was slurried with approximately 75 mL of ACN:water (9:1, v/v) in a flask and placed on an ambient temperature orbital shaker block for 1 day. The sample was divided into four portions and centrifuged and the supernatant decanted and discarded. The recovered solids were returned to the shaker block for 1 hour. The samples were air dried for less than 1 day. The four portions were recombined and the sample was further air-dried at ambient conditions for 3 hours to afford Form XXIII atorvastatin calcium.

Method B

An 11.0 g sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was slurried with approximately 430 mL of ACN:water (9:1, v/v) on an ambient temperature magnetic stir plate at 500 rpm for 2 days. The sample was vacuum filtered through a 0.22-µm nylon membrane filter and the filtered solids were air dried at ambient conditions for 1 day to afford Form XXIII atorvastatin calcium.

Form XXIV atorvastatin calcium

A 1.0 g sample containing a mixture of amorphous atorvastatin calcium and Form XX atorvastatin calcium (prepared as described above) was slurried with 195 mL of ACN:water (9:1, v/v) in a flask and placed on a magnetic stir plate set at 55 °C and 500 rpm for 1 day. The sample was vacuum filtered using a 0.22-µm nylon

membrane filter and the solids were slurried with 195 mL of the fresh solvent at the same conditions for 1 day. Again, the sample was vacuum filtered using 0.22-µm nylon membrane filter and the solids were slurried with 195 mL of the fresh solvent at the same conditions for 1 day. The solids were isolated by vacuum filtration and were air dried in a petri dish at ambient conditions for 4 days to afford Form XXIV atorvastatin calcium.

Amorphous atorvastatin calcium may be prepared as described in United States Patent No. 6,087,511:

[R-(R*,R*)]-2-(4-fluorophenyl)-β,δ-dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]-1H-pyrrole-1-heptanoic Acid Hemi Calcium Salt (Amorphous Atorvastatin)

Crystalline Form I atorvastatin (Example 1) (30 kg) is dissolved with agitation in tetrahydrofuran (75 L) at ambient temperature under a nitrogen atmosphere. Toluene (49.4 L) is added slowly once solution is achieved. The solution is then transferred through a 0.45 micron Pall filter to a 200 L Comber Turbodry Vertical Pan Dryer. The transfer system is rinsed to the dryer with additional tetrahydrofuran (4.5 L). Full vacuum is applied, and the solution is concentrated at 35° C. with mild agitation. Near the end of the concentration process, the agitator is lifted. The product turns into a brittle glassy foam. The agitator is gradually lowered, breaking the brittle foam into a free flowing powder. The powder is agitated and the temperature is raised to 85° C. under vacuum (6 to 8 mm Hg) to lessen the residual solvent levels. After 4 days of drying, the desired residual solvent levels of 0.01% tetrahydrofuran and 0.29% toluene are achieved. The free flowing white powder (27.2 kg) is unloaded from the dryer. The product is amorphous by X-ray powder diffraction.

Form XXV atorvastatin calcium

A 58 mg sample of Form XX atorvastatin calcium (prepared as described above) was slurried in 2 mL of ACN: water (9:1) on a magnetic stir plate for 5 days and then filtered to afford Form XXV atorvastatin calcium.

Form XXVI atorvastatin calcium

Method A

A 2.0 g sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was slurried with 0.57 mL of water in a vial, 5.1 mL of MeOH added, and the sample was placed on an orbital shaker block at 58 to 60 °C for 3 days. The resulting sample was vacuum dried between 70-75 °C for 3 days to afford Form XXVI atorvastatin calcium.

Method B

A 5.0 g sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was dissolved in 200 mL of 80:20 (v/v) water/MeOH at 60°C. After forming a solution, a slurry resulted while stirring at 60 °C. The slurry was isolated via vacuum filtration after 2.5 hours. The material was vacuum dried at 45°C overnight to afford Form XXVI atorvastatin calcium.

Form XXVII atorvastatin calcium

Method A

A sample of Form VIII atorvastatin calcium was heated on a sample holder in a Variable Temperature X-ray powder diffraction unit at 5 °C/ minute ramp rate. The temperature was held at 35°, 80°, 100°, 115°, and 140 °C for approximately 15 minutes before reaching 165 °C to afford Form XXVII atorvastatin calcium. The Form XXVII atorvastatin calcium remained unchanged upon cooling to 40 °C.

Method B

A sample of Form VIII atorvastatin calcium (United States Patent No. 6,605,729) was heated using a variable temperature XRPD with humidity conditions remaining uncontrolled throughout the experiment. The sample was heated in a series of 4 steps beginning at 35 °C. It continued up to 135 °C (holding for 13.5 min) and then on to 148 °C (holding for 15.5 min) before returning to 35 °C (holding for 15.5 min) to afford Form XXVII atorvastatin calcium. Form XXVII atorvastatin calcium was obtained at 148 °C and remained unchanged upon cooling to 35 °C.

Form VIII atorvastatin calcium maybe prepared as described in United States Patent No. 6,605,729:

Form VIII Atorvastatin

Method A

A solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in dimethylformamide/water (saturated) (9:1), was seeded with crystalline Form VII and evaporated to afford crystalline Form VIII atorvastatin.

Method B

Fast evaporation of a solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in dimethylformamide/water (9:1) affords crystalline Form VIII atorvastatin. Crystalline Form VIII atorvastatin, mp 151° C., dihydrate Karl Fischer 2.98% (2 mol of water).

Form VII atorvastatin may be prepared also as described in U.S. Patent No. 6,605,729:

Form VII Atorvastatin

Method A

A solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in acetone/water (1:1) (5.8 mg/mL) was stirred overnight. A solid formed which was filtered to afford crystalline Form VII atorvastatin.

Method B

A solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in acetone/water (1:1) was evaporated at 50° C. to afford crystalline Form VII atorvastatin.

Method C

A saturated solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in acetone/water (1:1) was seeded with crystalline Form VII atorvastatin to afford crystalline Form VII atorvastatin.

Method D

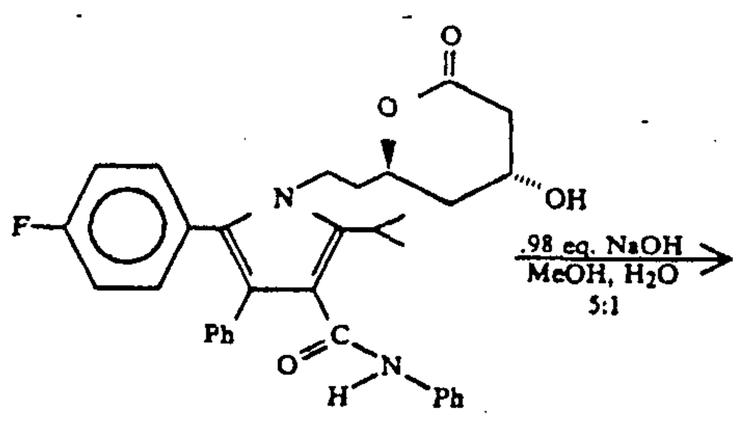
Fast evaporation of a saturated solution of amorphous atorvastatin calcium (U.S. Pat. No. 5,273,995) in acetone/water (1:1) was seeded with crystalline Form VII to afford crystalline Form VII atorvastatin. Crystalline Form VII atorvastatin, mp 195.9° C., 1.5 hydrate Karl Fischer 2.34% (1.5 mol of water).

A solution of amorphous atrovastatin calcium may be prepared as described in United States Patent No. 5,273,995:

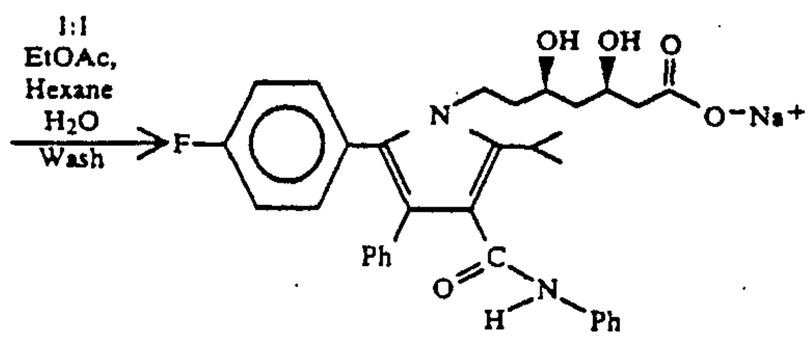
Calcium Salt from Sodium Salt and/or Lactone

Dissolve one mole lactone (540.6 g) in 5 L of MeOH; after dissolution add 1 L H_2O. While stirring, add one equivalent NaOH and follow by HPLC until 2% or less lactone and methyl ester of the diolacid remains (cannot use an excess of NaOH, because $Ca(OH)_2$ will form an addition of $CaCl_2$). Charge NaOH as caustic (51.3 ml, 98 eq.) or as pellets (39.1 g, 0.98 eq.).

The above procedure is shown as follows:



m.w. = 540.6 g



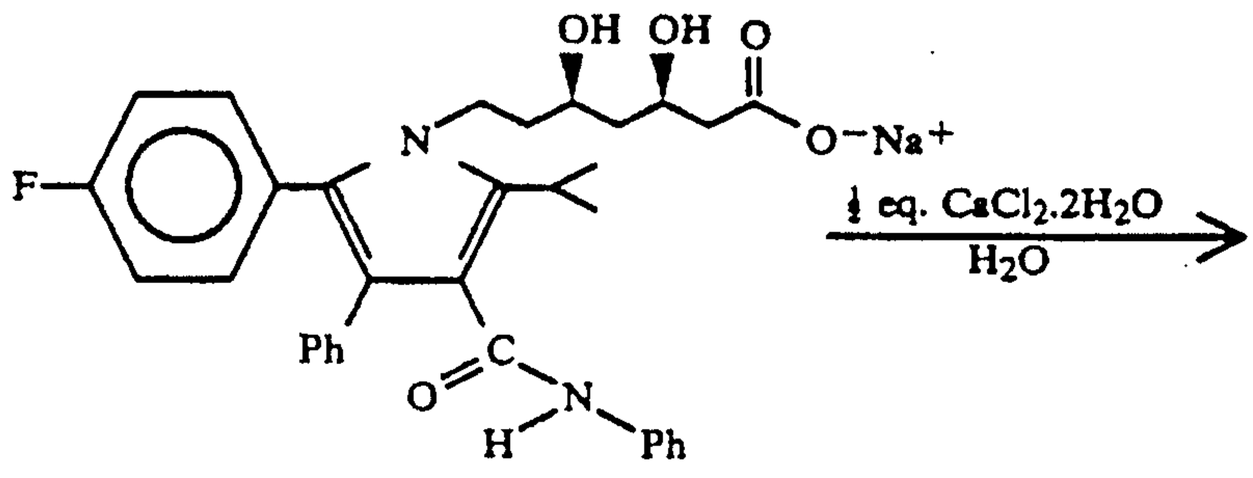
Upon completion of hydrolysis, add 10 L H_2O, then wash at least two times with a 1:1 mixture of EtOAc/Hexane. Each wash should contain 10 L each of EtOAc/Hexane. If sodium salt is pure, add 15 L of

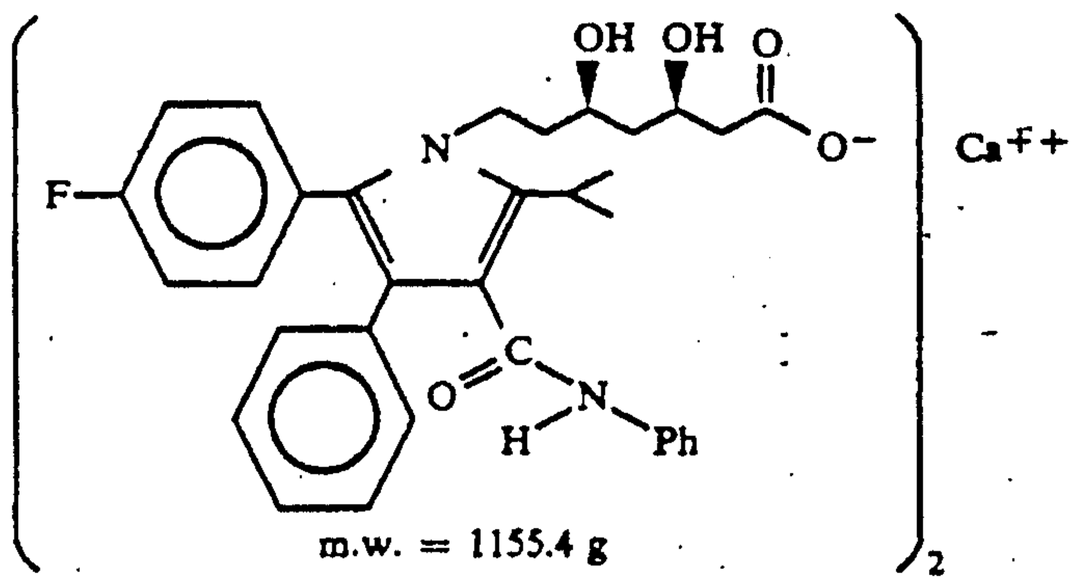
MeOH. If it is impure and/or contains color, add 100 g of G-60 charcoal, stir for two hours and filter over supercel. Wash with 15 L MeOH. Perform a wt/vol % on the reaction mixture, by HPLC, to determine the exact amount of salt in solution.

Dissolve 1 eq. or slight excess $CaC1_2.2H_2O$ (73.5 g) in 20 L H_2O. Heat both reaction mixture and $CaC1_2$ solution to 60° C. Add $CaC1_2$ solution slowly, with high agitation. After complete addition, cool slowly to 15° C. and filter. Wash filter cake with 5 L H_2O. Dry at 50° C. in vacuum oven.

Can be recrystallized by dissolving in 4 L of EtOAc (50° C.) filtering over supercel, washing with 1 L EtOAc, then charging 3 L of hexane to the 50° C. rxn solution.

The above procedure is shown as follows:





Form XXVIII atorvastatin calcium

A 0.3 g sample of amorphous atorvastatin calcium (United States Patent No. 6,087,511) was slurried with 1 mL of ethylene glycol at 50 °C for 24 hours. The solids were isolated by vacuum filtration at ambient conditions to afford Form XXVIII atorvastatin calcium.

Form XXIX atorvastatin calcium

A 1.0 g sample of amorphous atorvastatin calcium (United States Patent No. 6,087,511) was slurried with 8 mL of water: tetrahydrofuran (4:1, v/v) at ambient temperature. The mixture was seeded with

atorvastatin calcium Form XII (United States Patent No. 6,605,729) and stirred at ambient conditions for 5 hours. The solids were isolated by vacuum filtration to afford Form XXIX atorvastatin calcium.

Form XXX atorvastatin calcium

Method A

A slurry containing 3.0 g of amorphous atorvastatin calcium (United States Patent No. 6,087,511) and 24 mL of ethylene glycol was shaken on an ambient temperature orbital shaker block for about 1 day. The slurry was vacuum filtered and the solids were air dried at ambient temperature for 6 days to afford Form XXX atorvastatin calcium.

Method B

A 200 mg sample of Form I atorvastatin calcium (United States Patent No. 5,969,156) was exposed to ACN vapor at ambient temperature inside a sealed chamber for two months to afford Form XXX atorvastatin calcium.

CLAIMS

1. A Form XXVII atorvastatin calcium having an X-ray powder diffraction containing the following 2θ values measured using CuK_a radiation: 3.9, 4.5, 7.1, 7.5, 9.6, 10.6, 11.8, 13.0, 15.3, and 18.7.

2. A Form XXVII atorvastatin calcium having an x-ray powder diffraction containing the following 2θ values measured using CuK_a radiation: 3.9, 7. 5, and 18.7, and a solid state ^{19}F nuclear magnetic resonance having the following chemical shifts expressed in parts per million: -112.2, -113.0, and -117.2.

FIG. 1

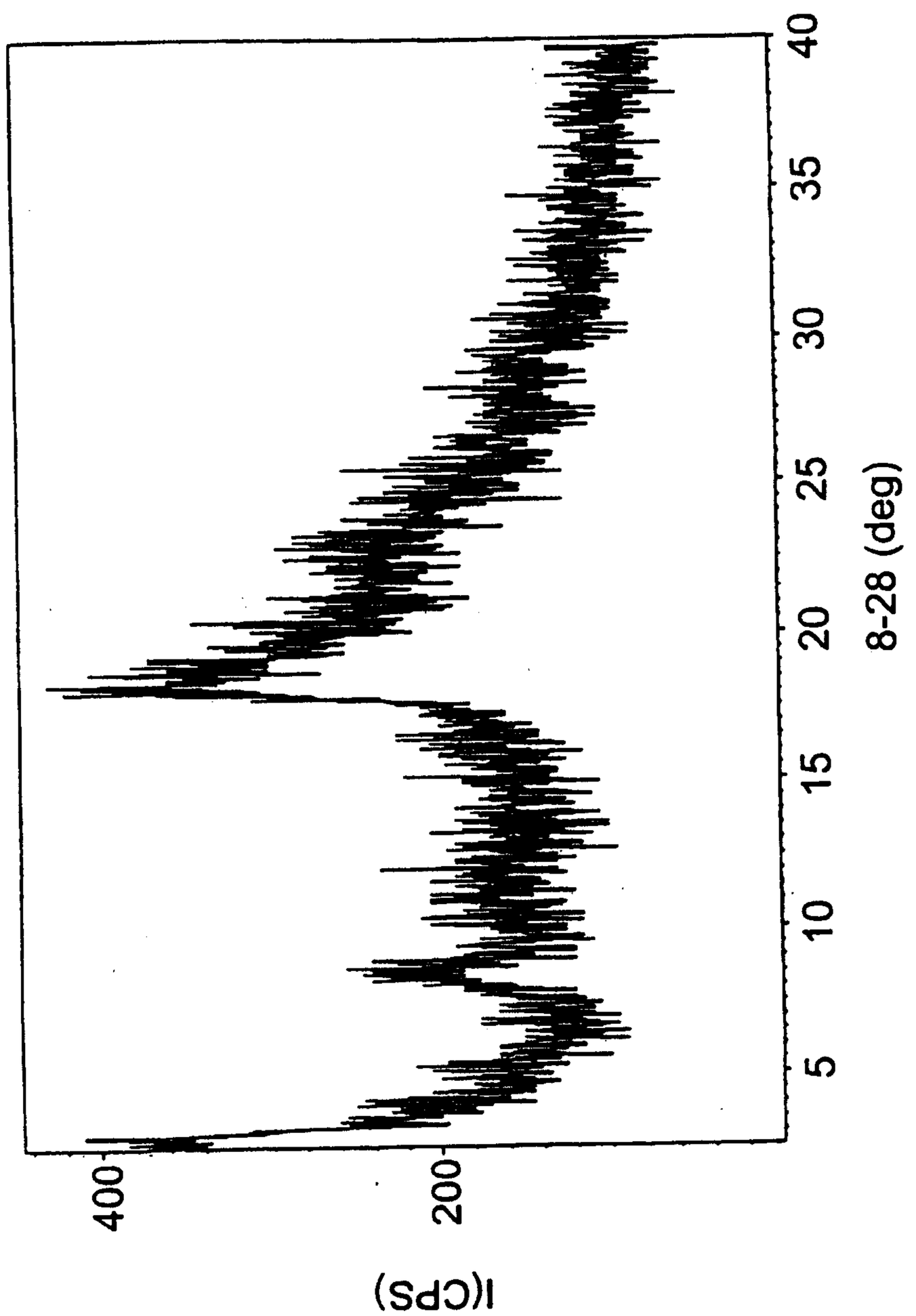


FIG. 2

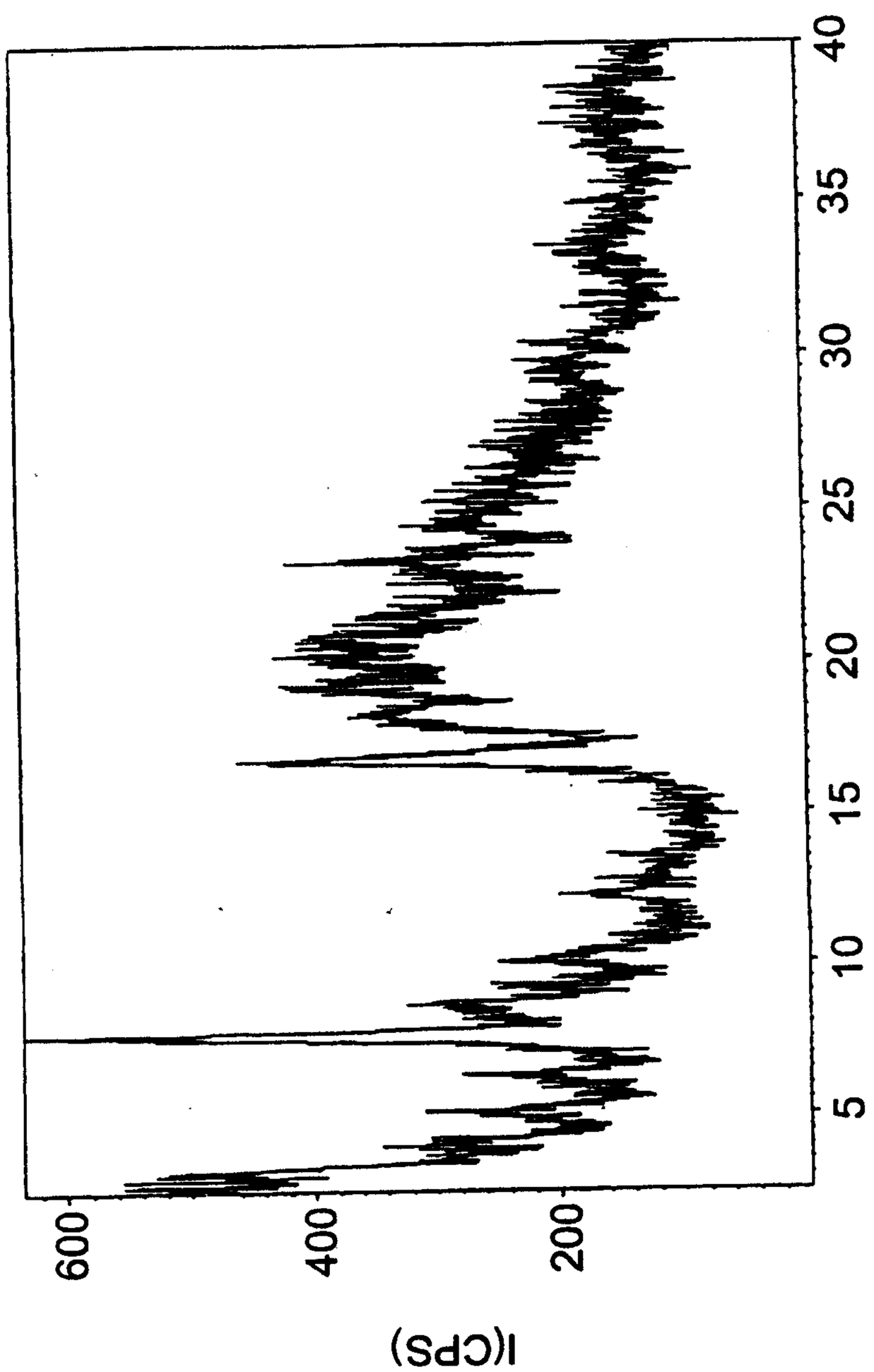


FIG. 3

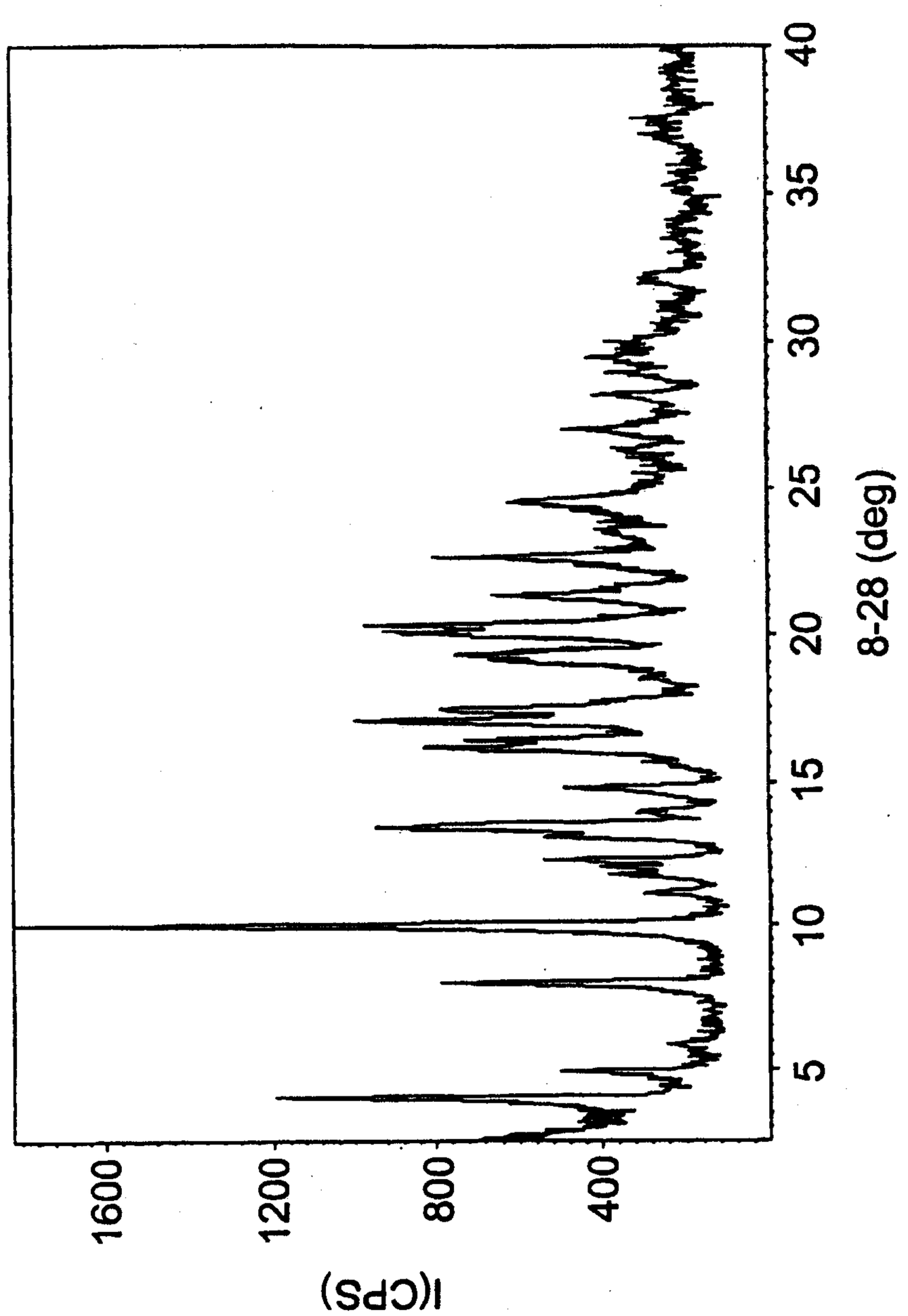


FIG. 4

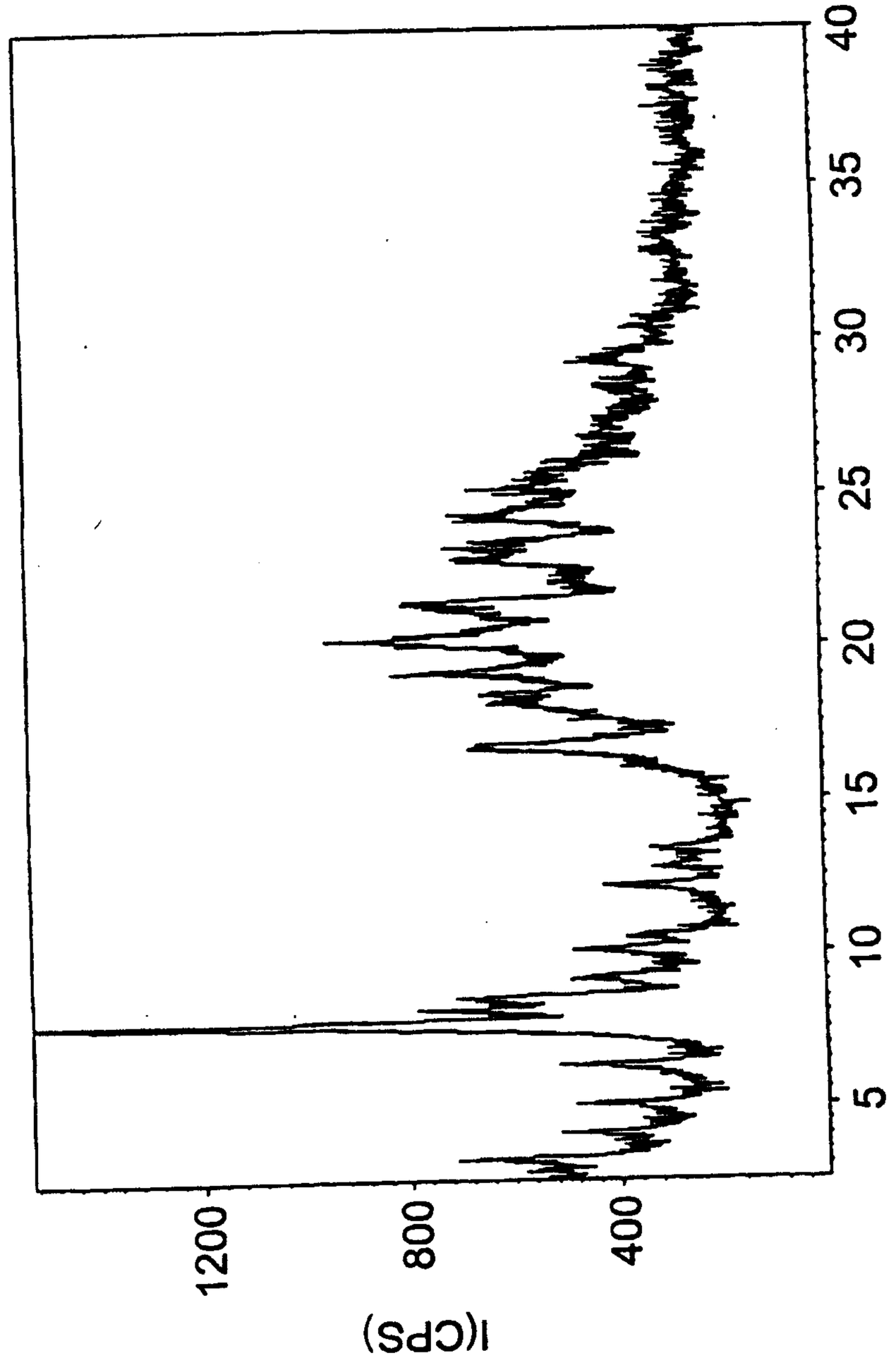


FIG. 5

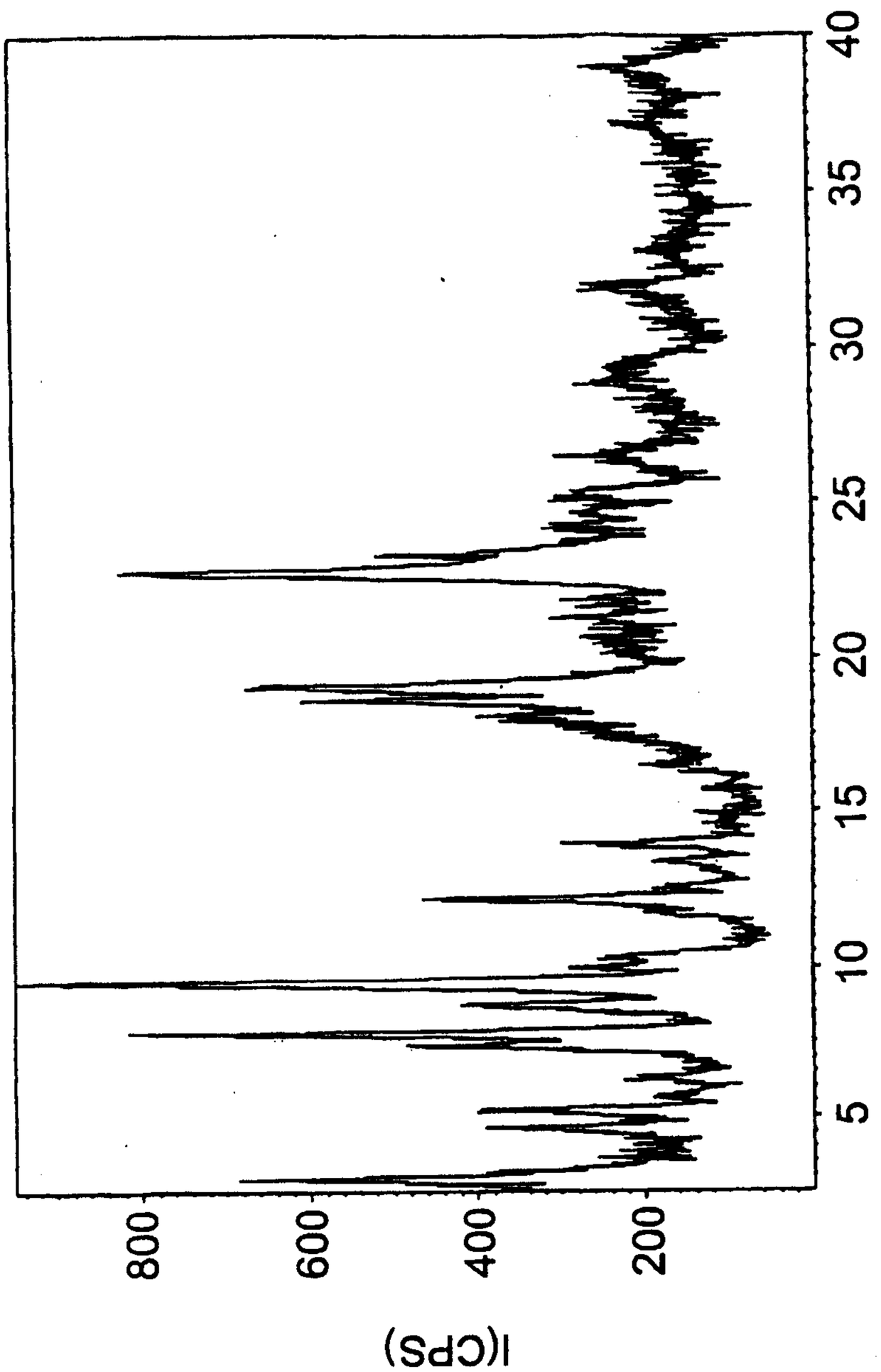
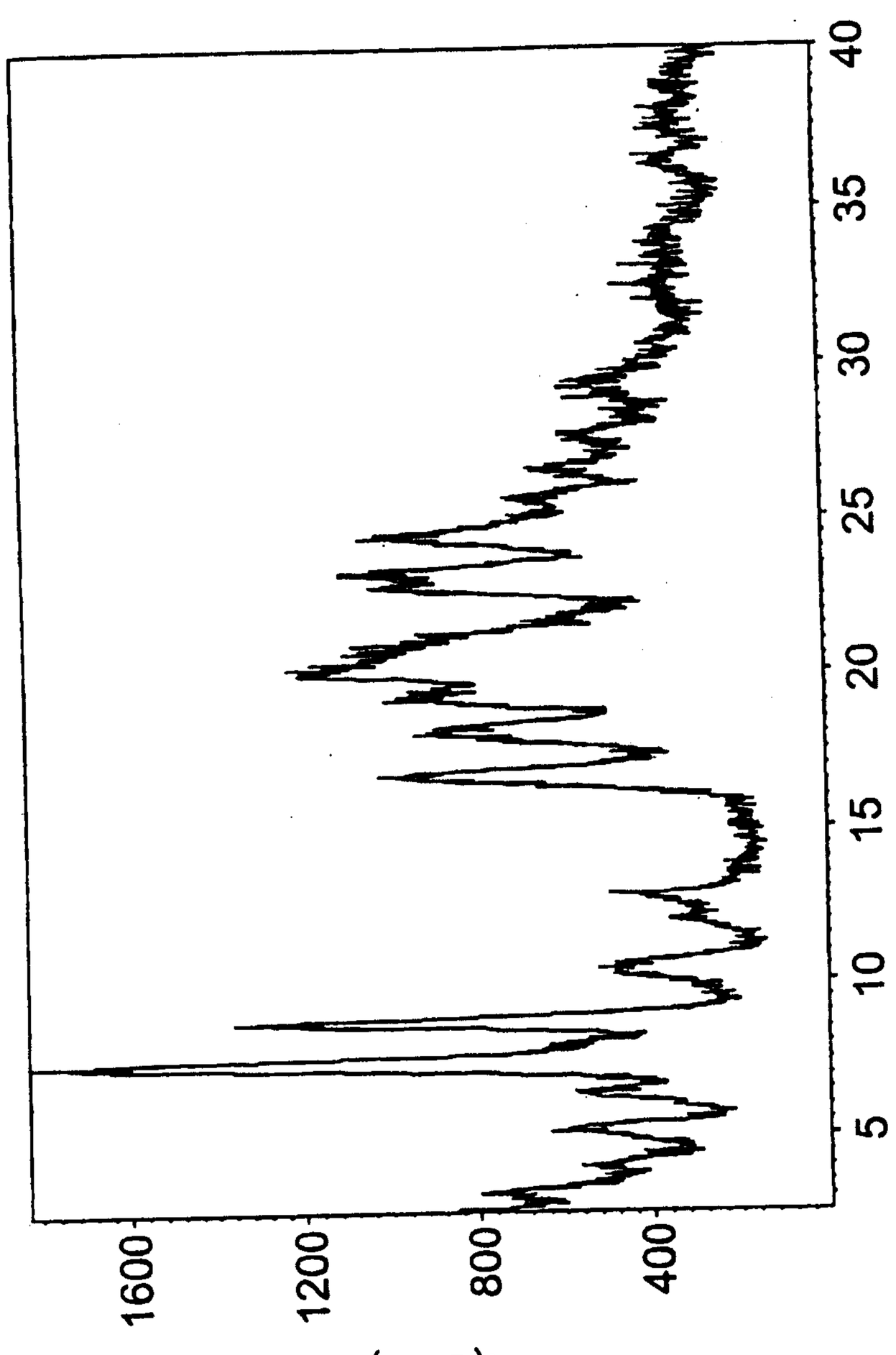


FIG. 6



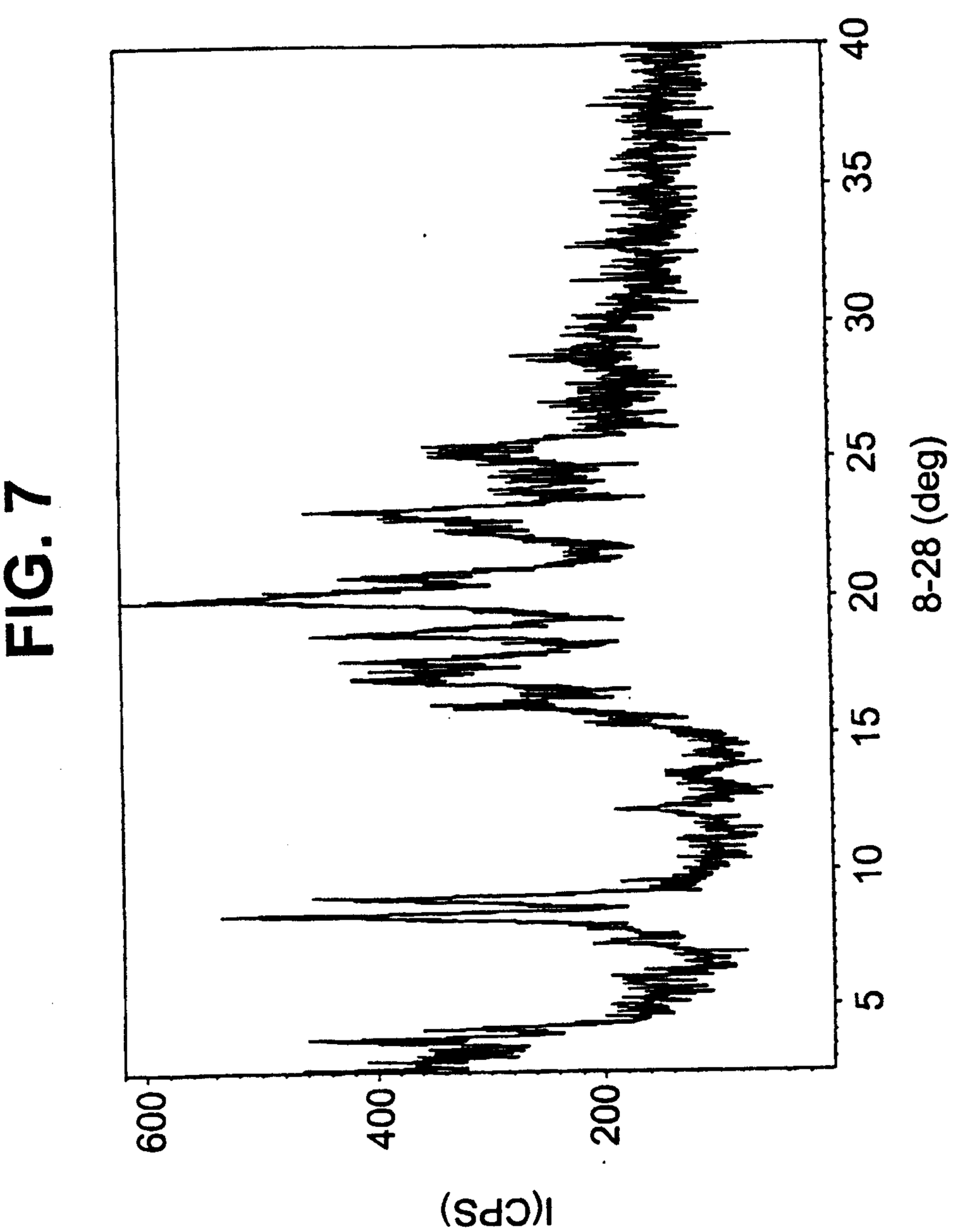


FIG. 7

FIG. 8

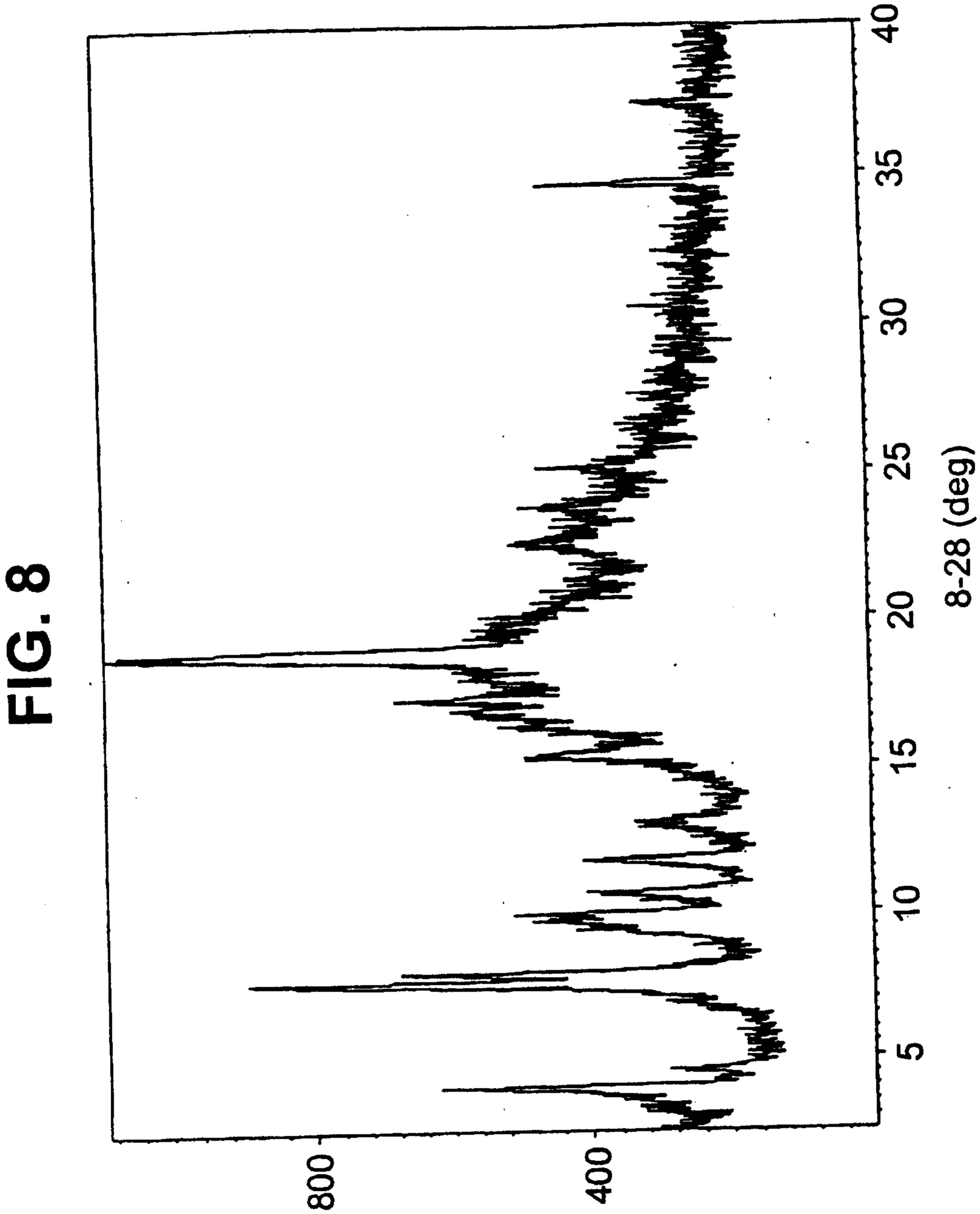


FIG. 9

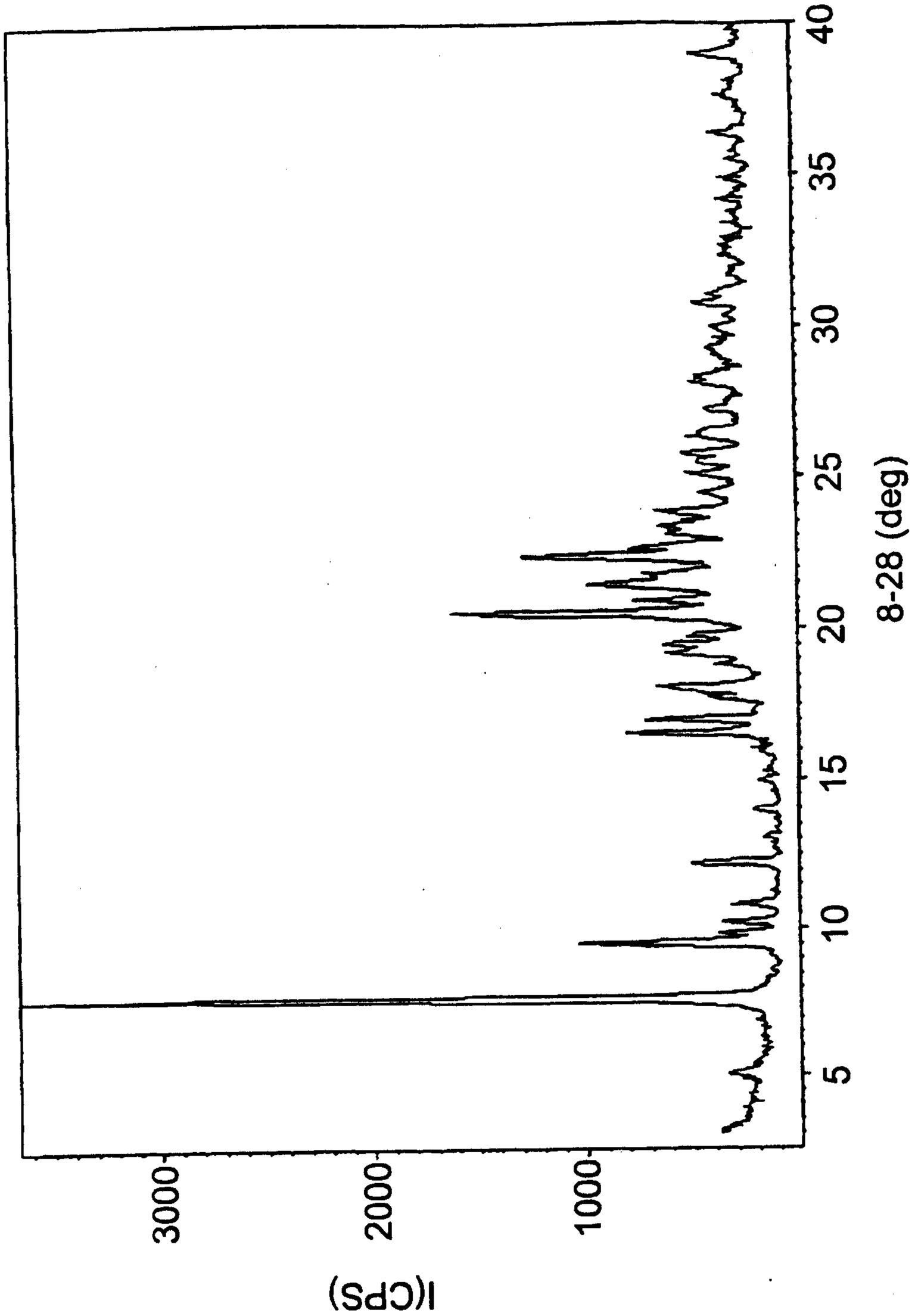


FIG. 10

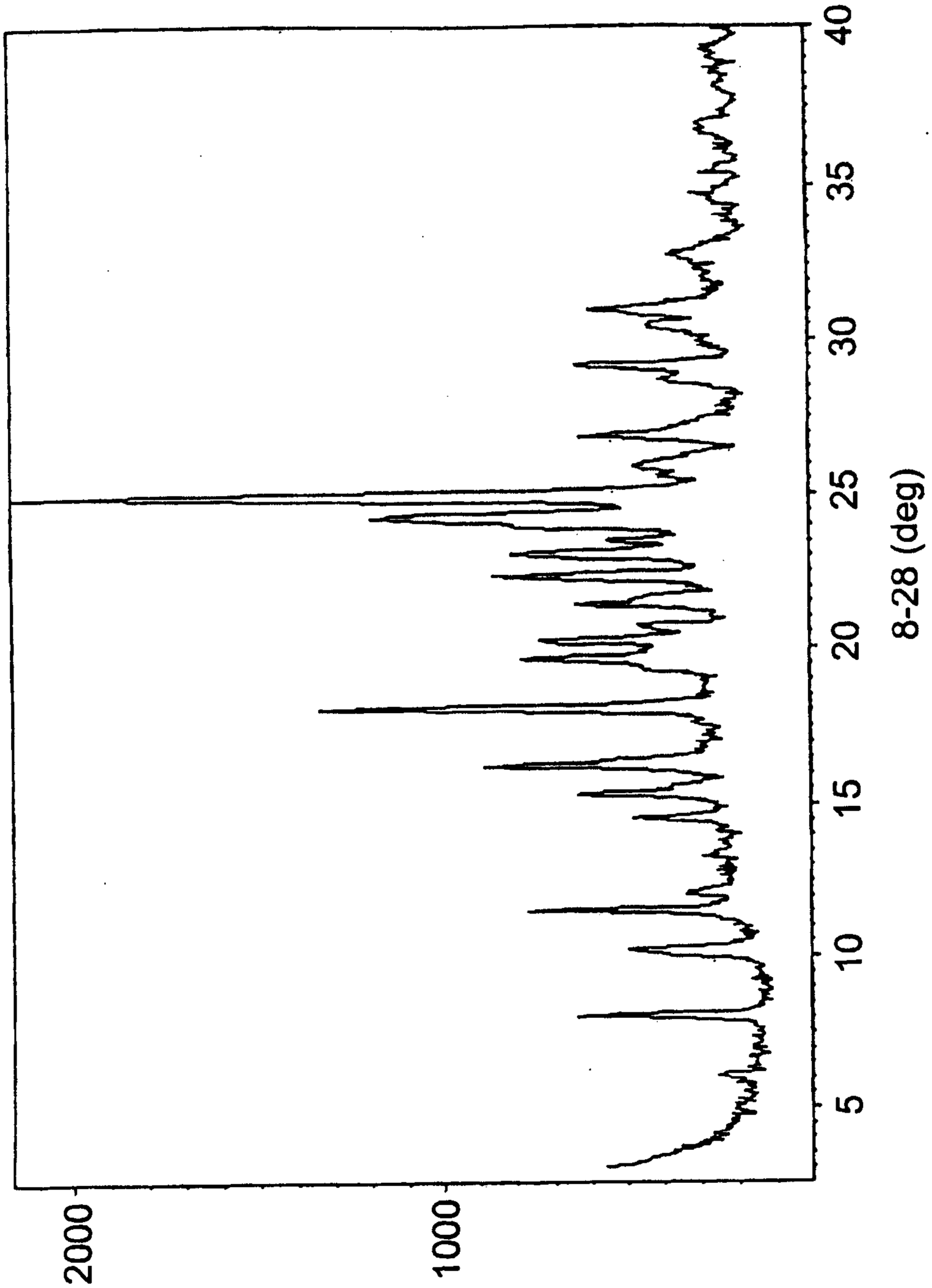


FIG. 11

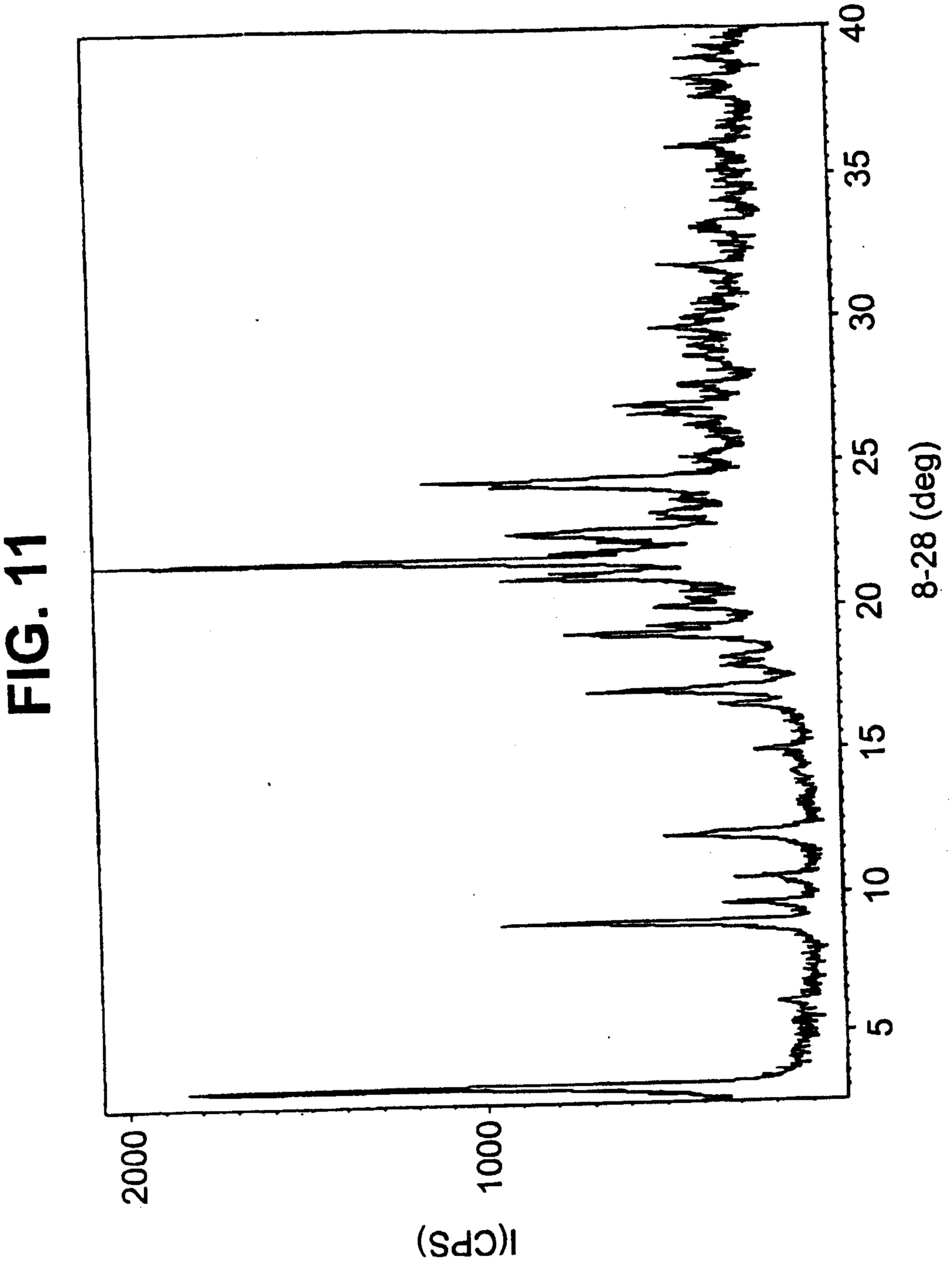


FIG. 12

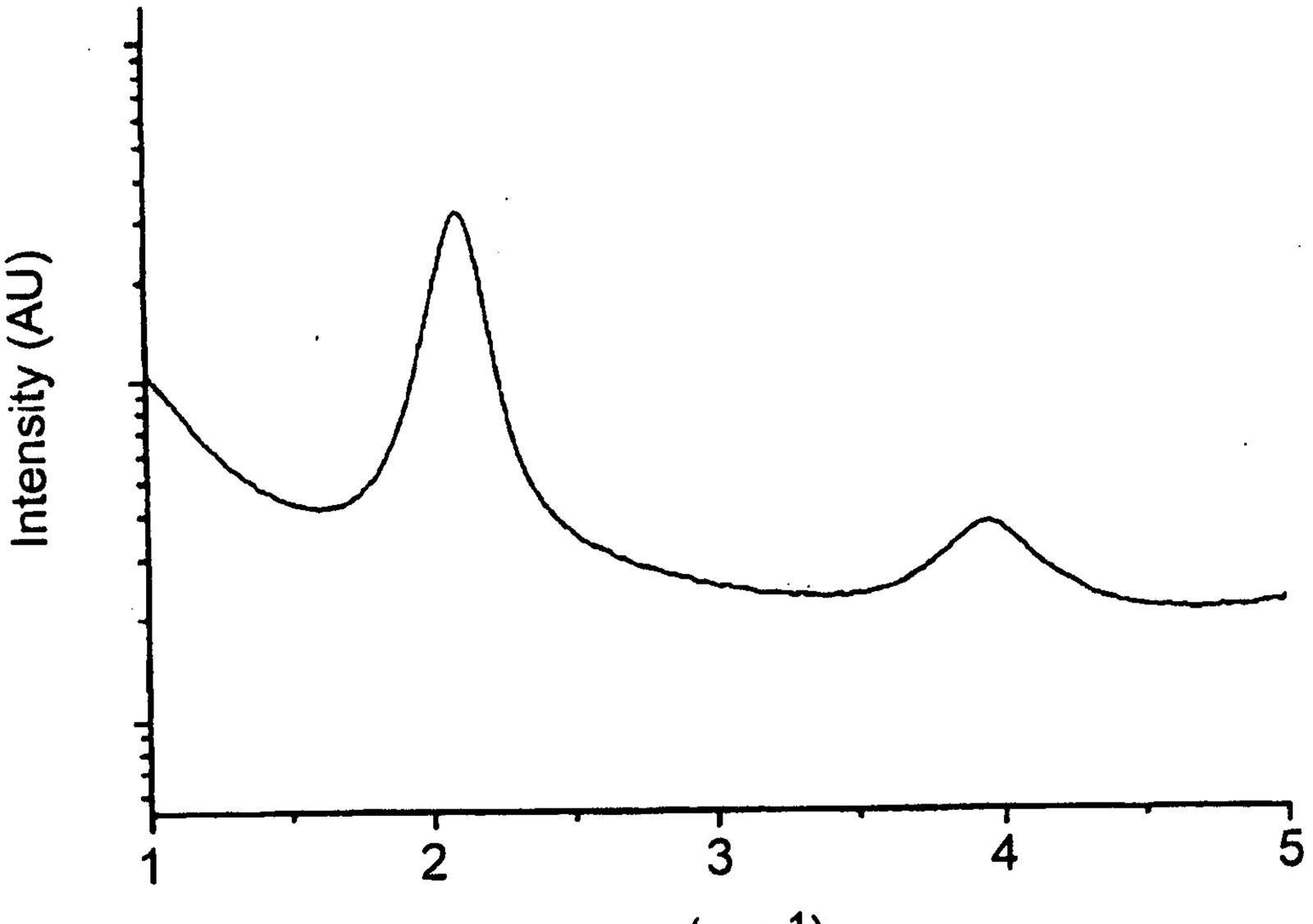


FIG. 13

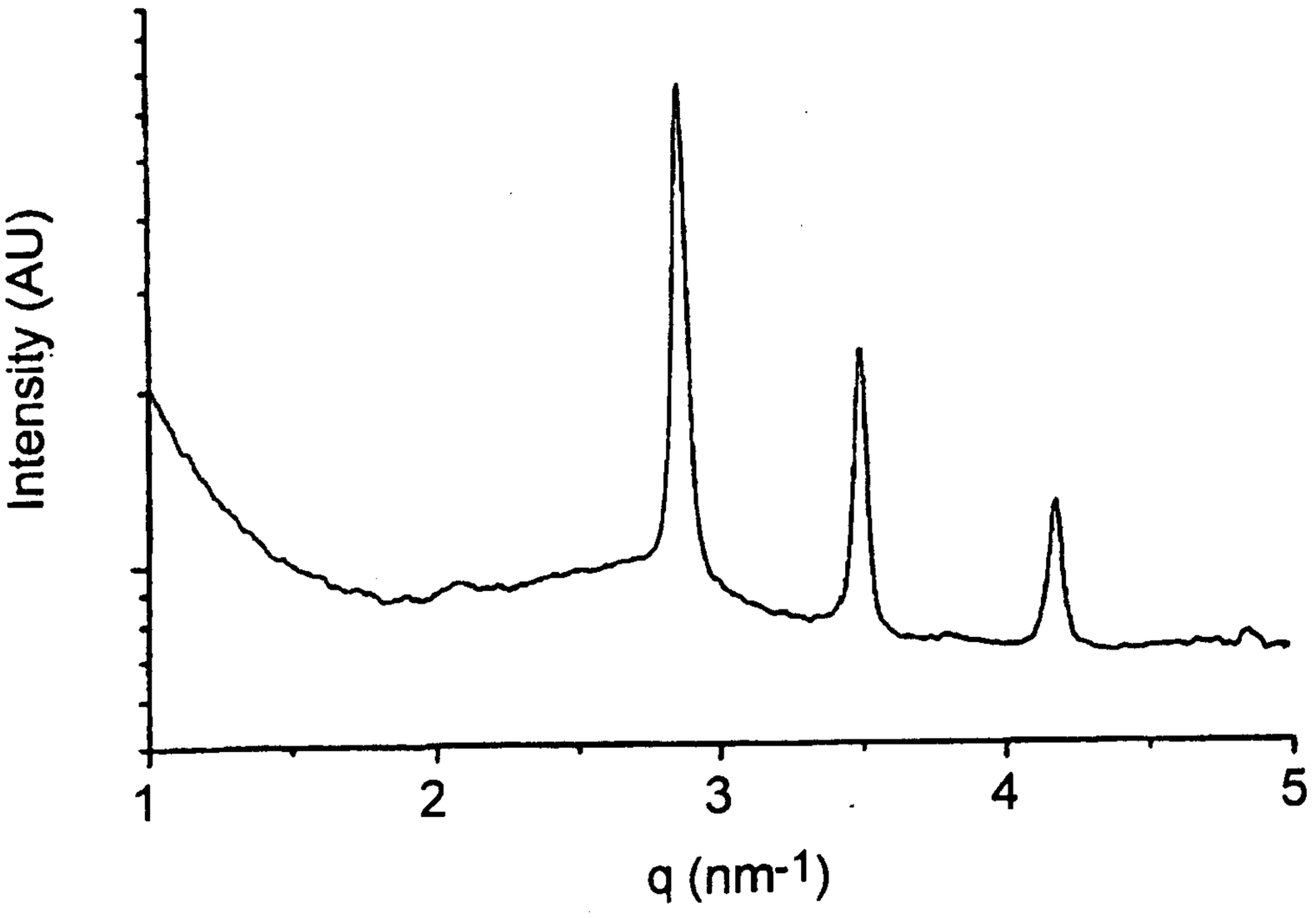


FIG. 14

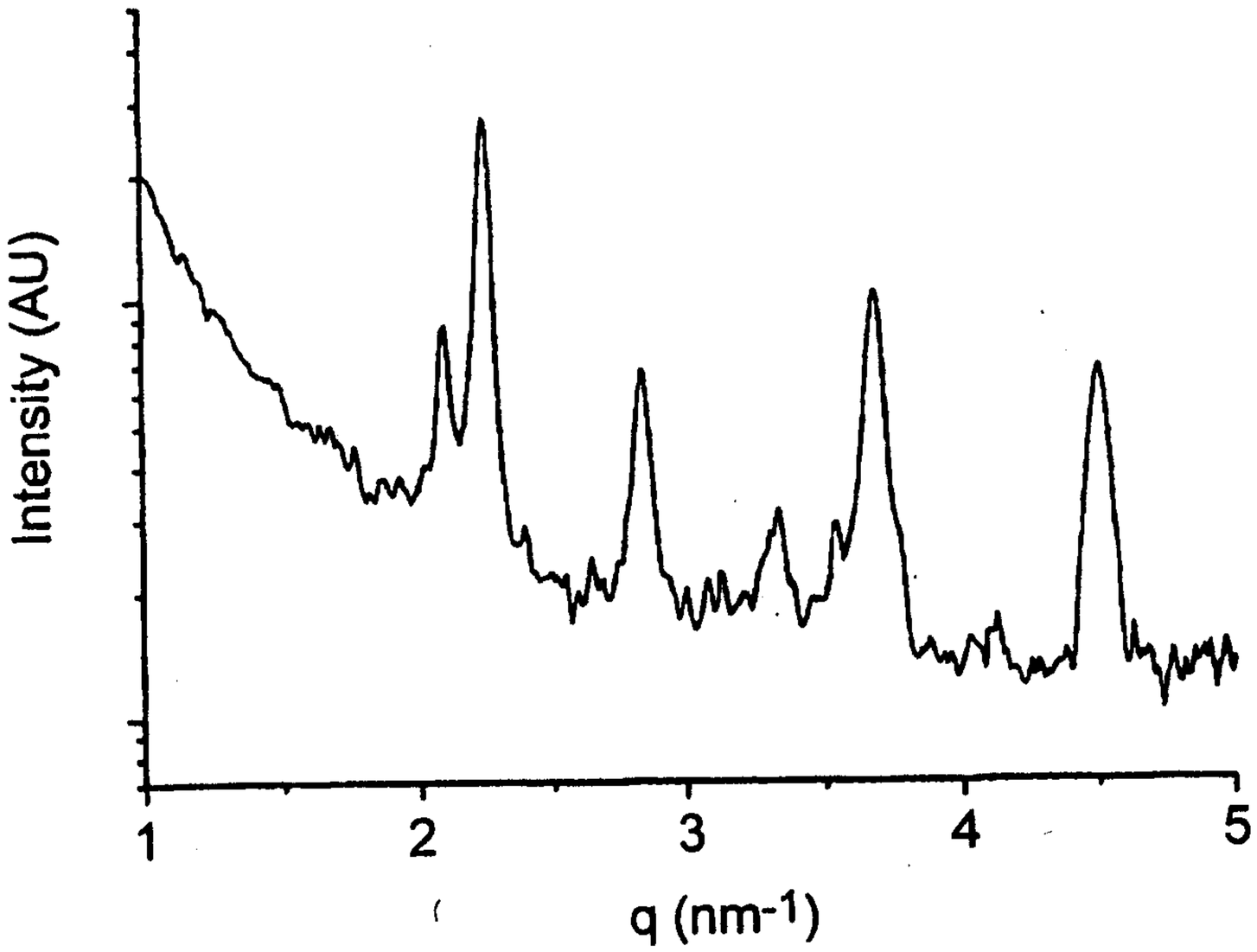


FIG. 15

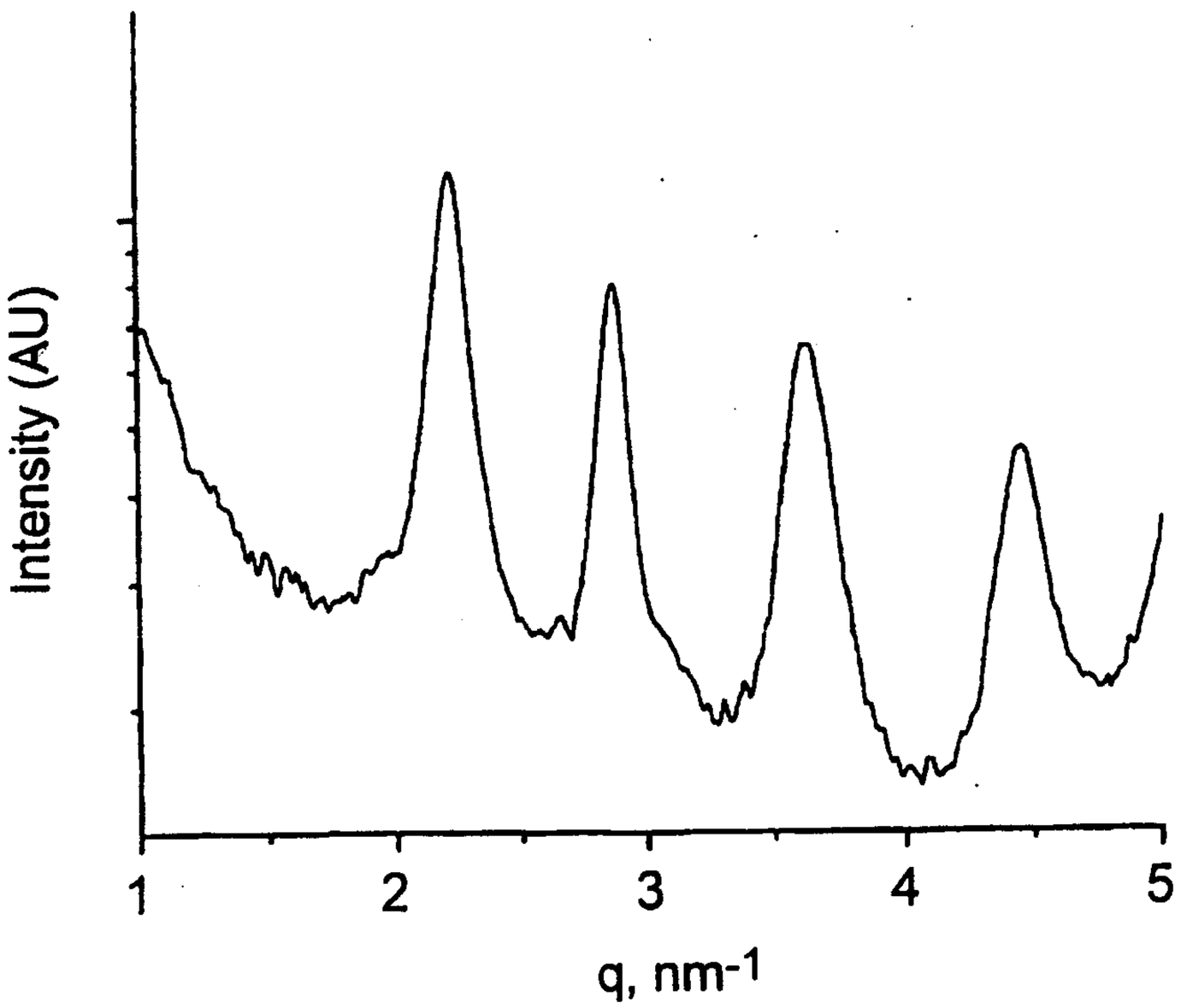


FIG. 16

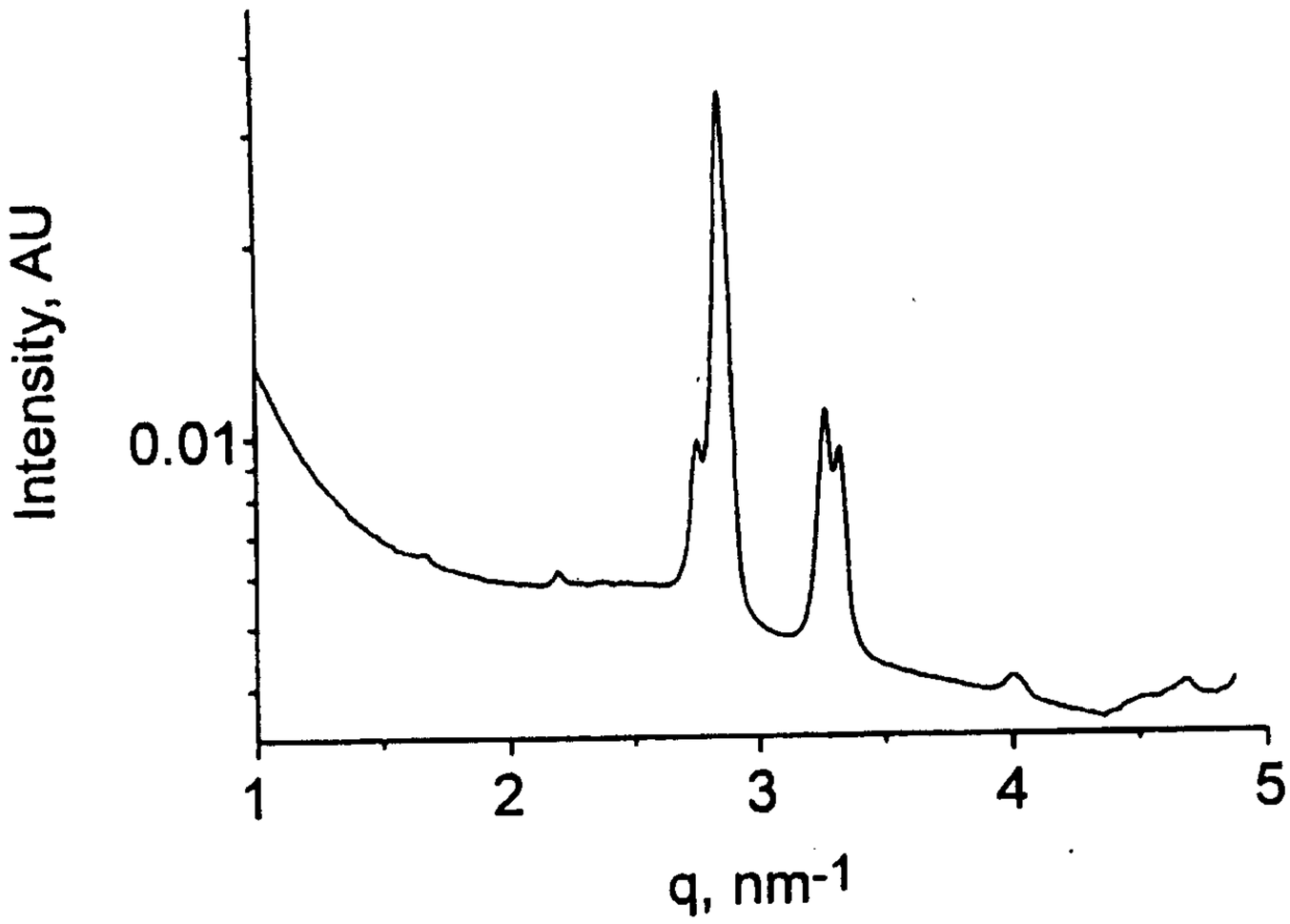


FIG. 17

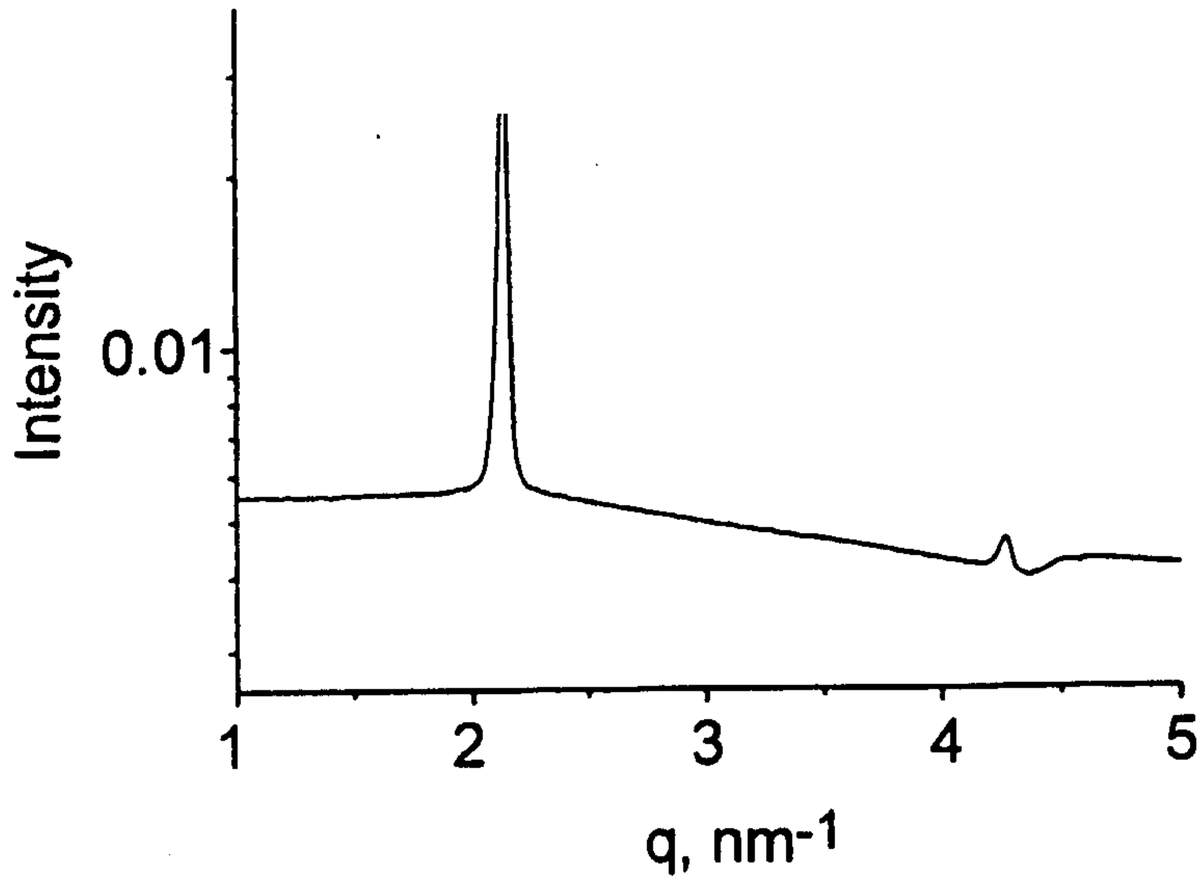


FIG. 18

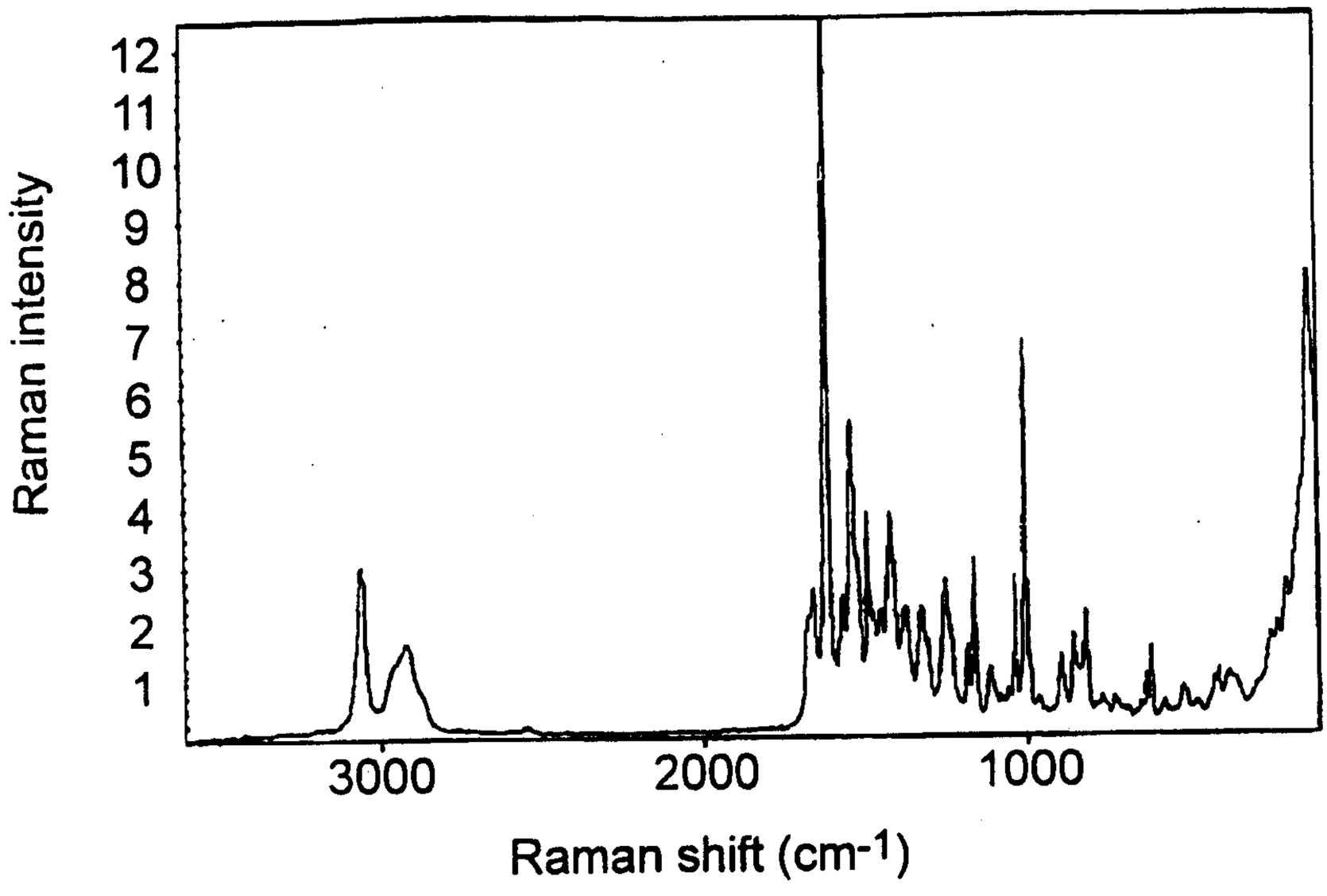

Raman intensity
12
11
10
9
8
7
6
5
4
3
2
1
3000
2000
1000
Raman shift (cm-1)

FIG. 19

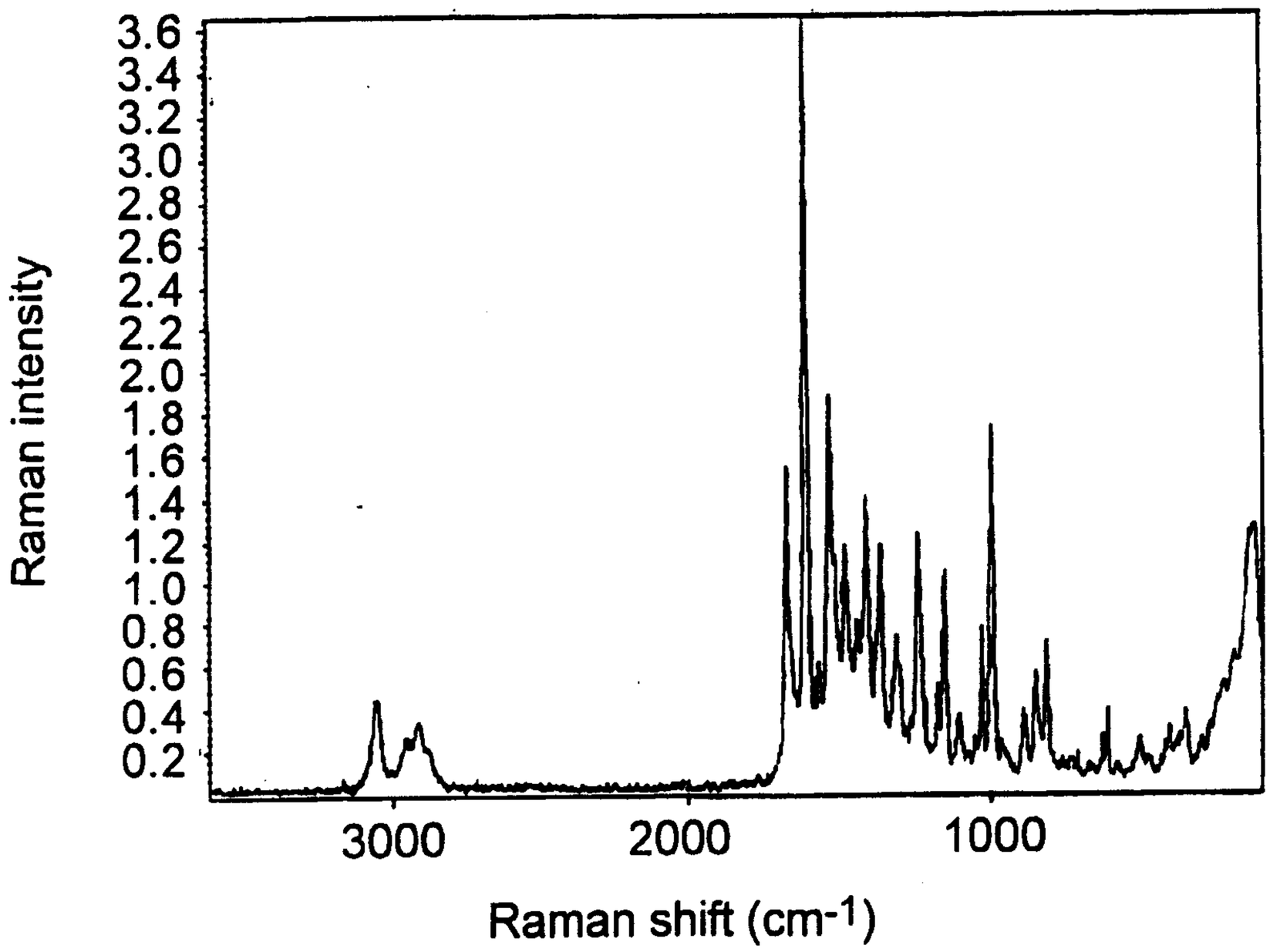

Raman intensity
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
3000
2000
1000
Raman shift (cm-1)

FIG. 20

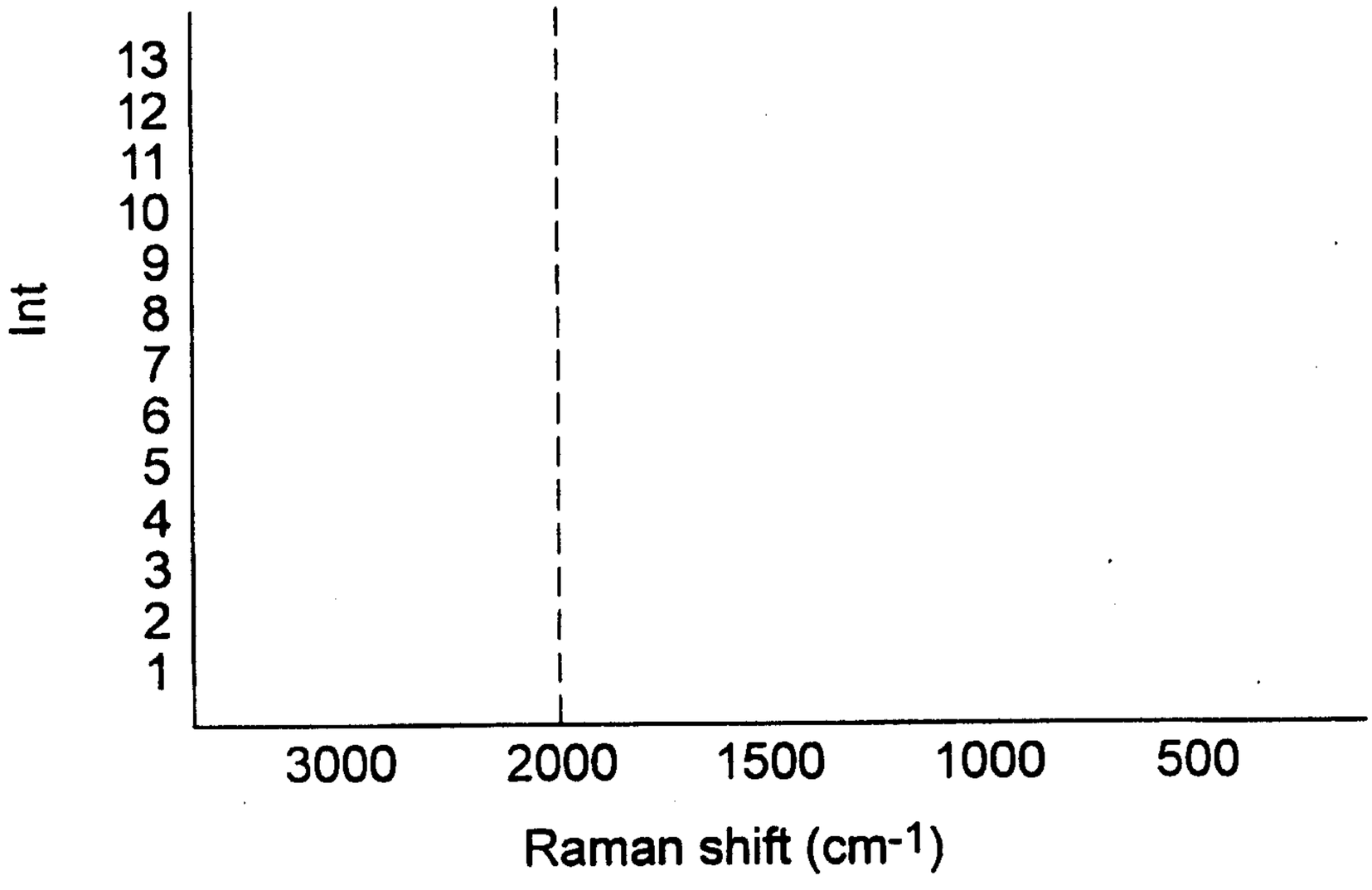

Int
13
12
11
10
9
8
7
6
5
4
3
2
1
3000
2000
1500
1000
500
Raman shift (cm-1)

FIG. 21

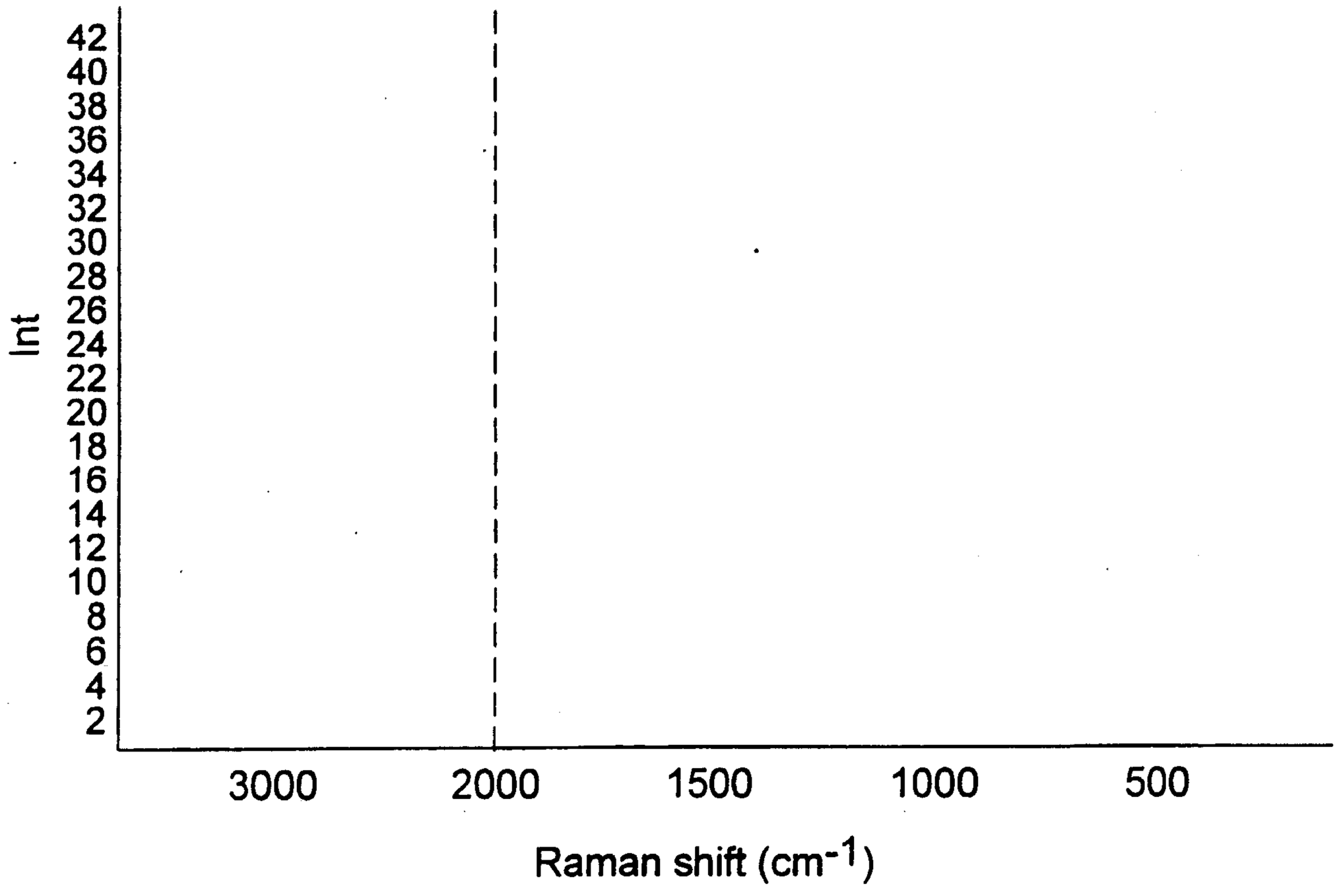

Int
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
3000
2000
1500
1000
500
Raman shift (cm-1)

FIG. 22

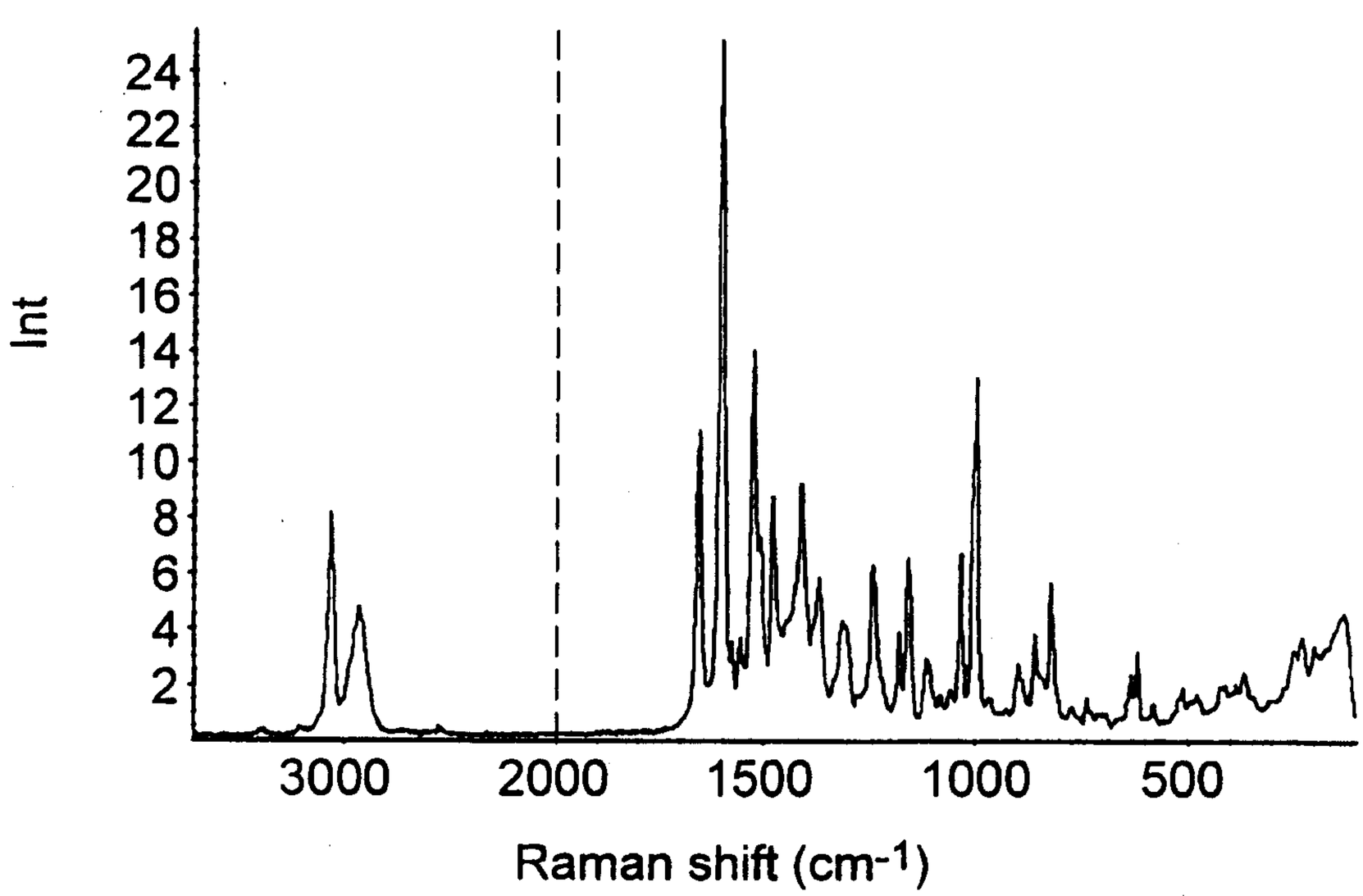

Int
24
22
20
18
16
14
12
10
8
6
4
2
3000
2000
1500
1000
500
Raman shift (cm-1)

FIG. 23

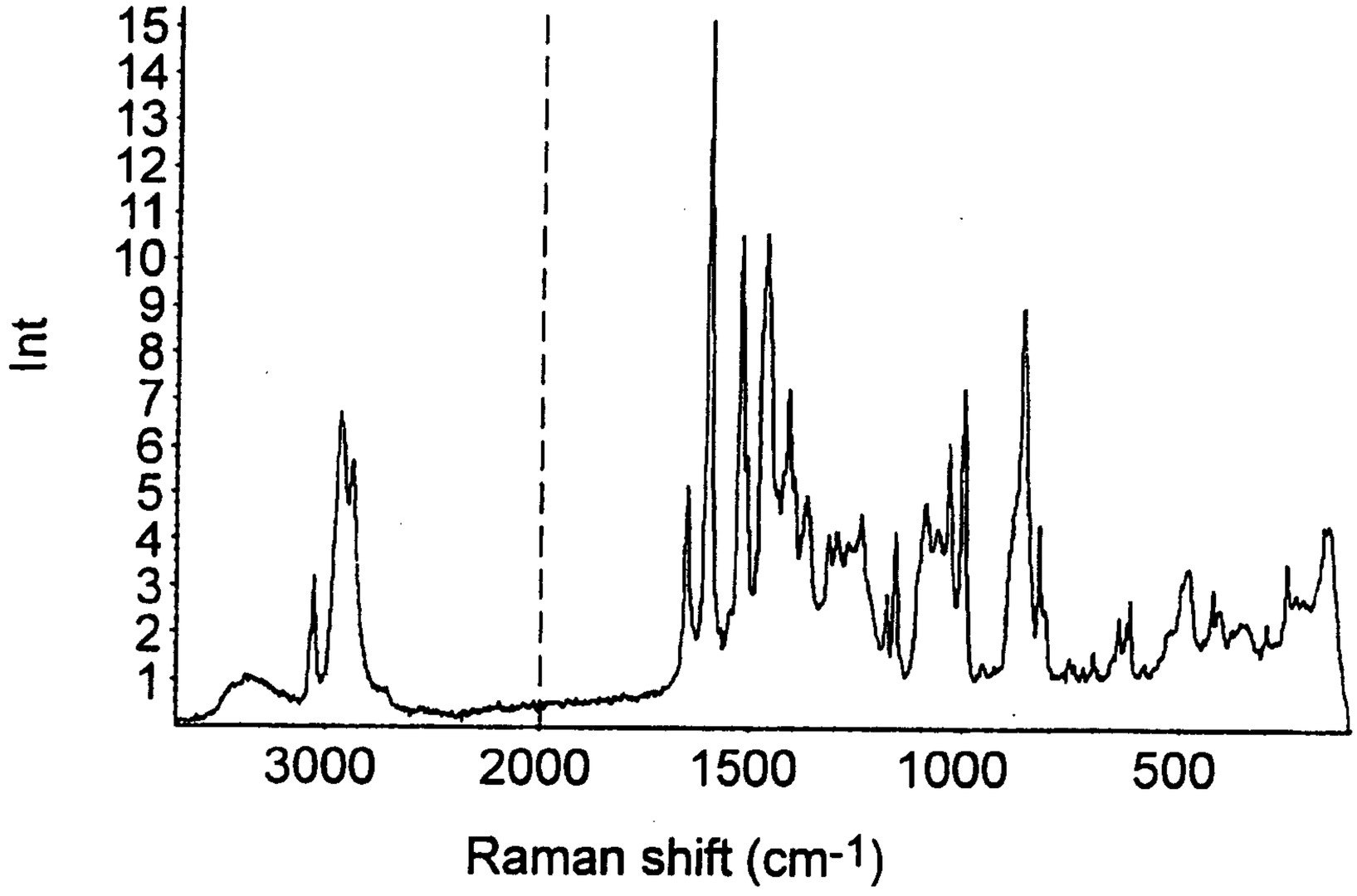

Int
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
3000
2000
1500
1000
500
Raman shift (cm-1)

FIG. 24

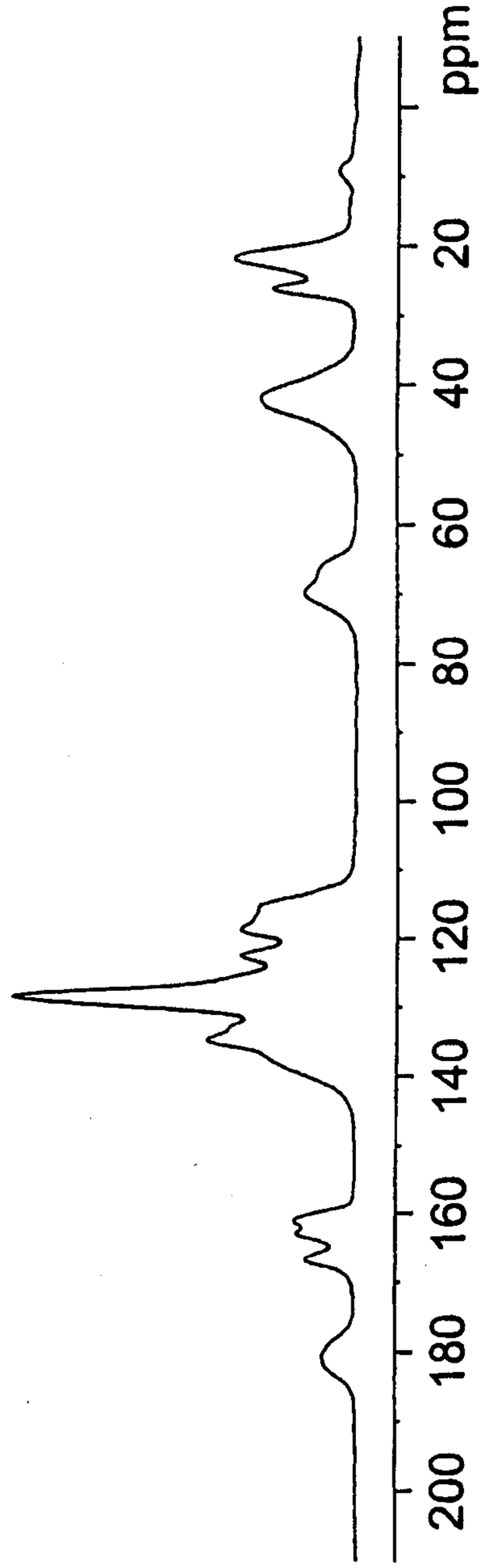

ppm
0
20
40
60
80
100
120
140
160
180
200

FIG. 25

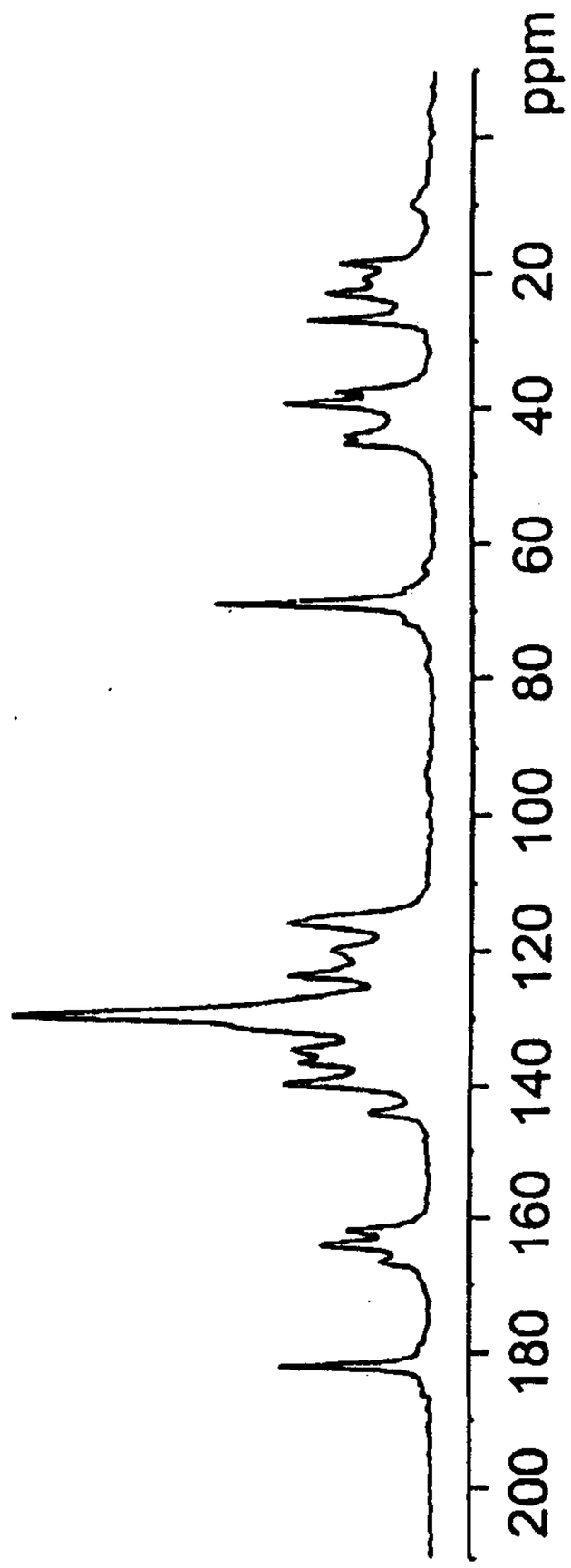

ppm
0
20
40
60
80
100
120
140
160
180
200

FIG. 26

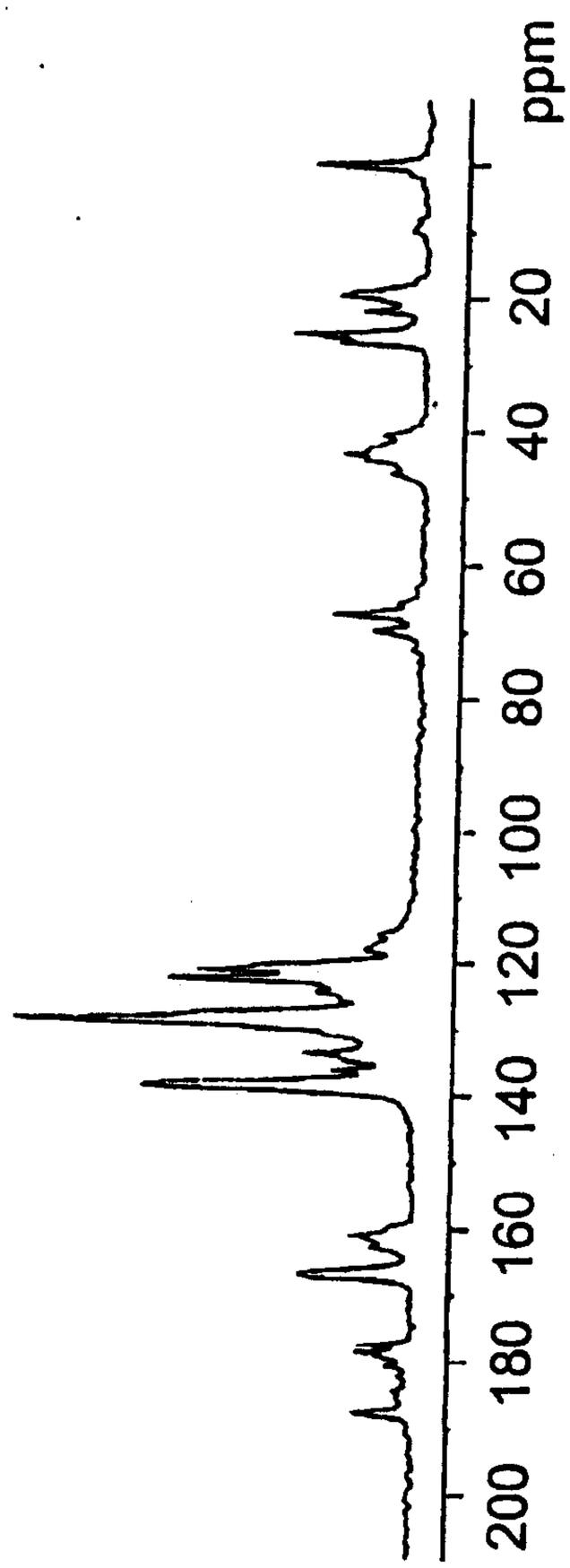

ppm
20
40
60
80
100
120
140
160
180
200

FIG. 27


ppm
20
40
60
80
100
120
140
160
180
200

FIG. 28

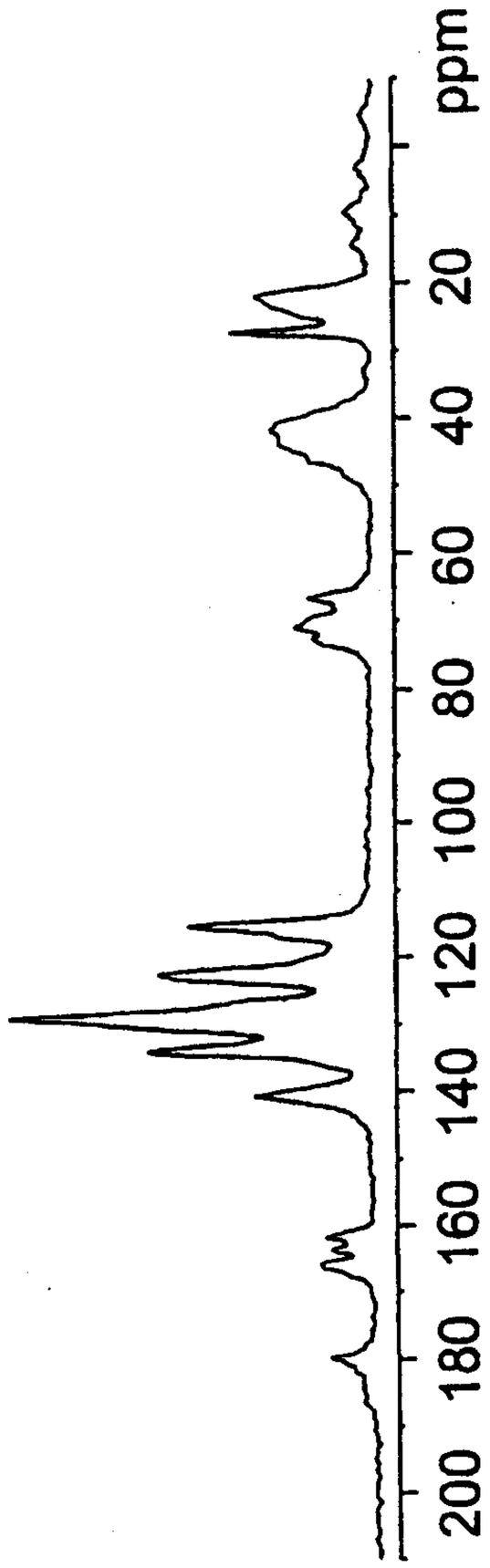

ppm
20
40
60
80
100
120
140
160
180
200

FIG. 29

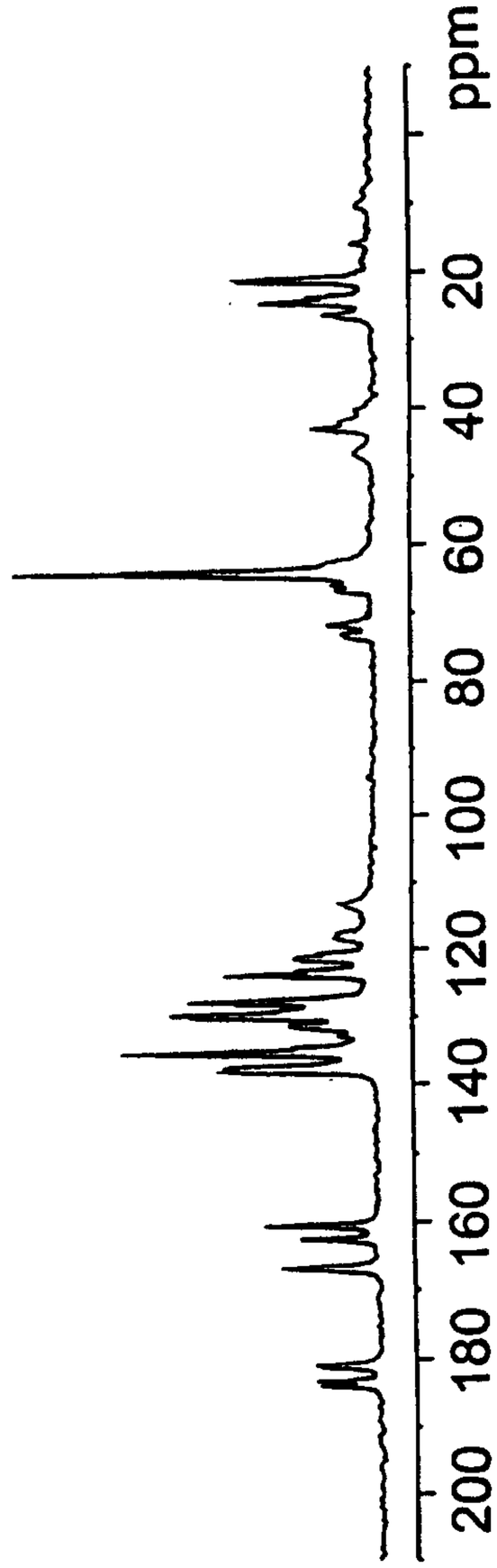

ppm
20
40
60
80
100
120
140
160
180
200

FIG. 30

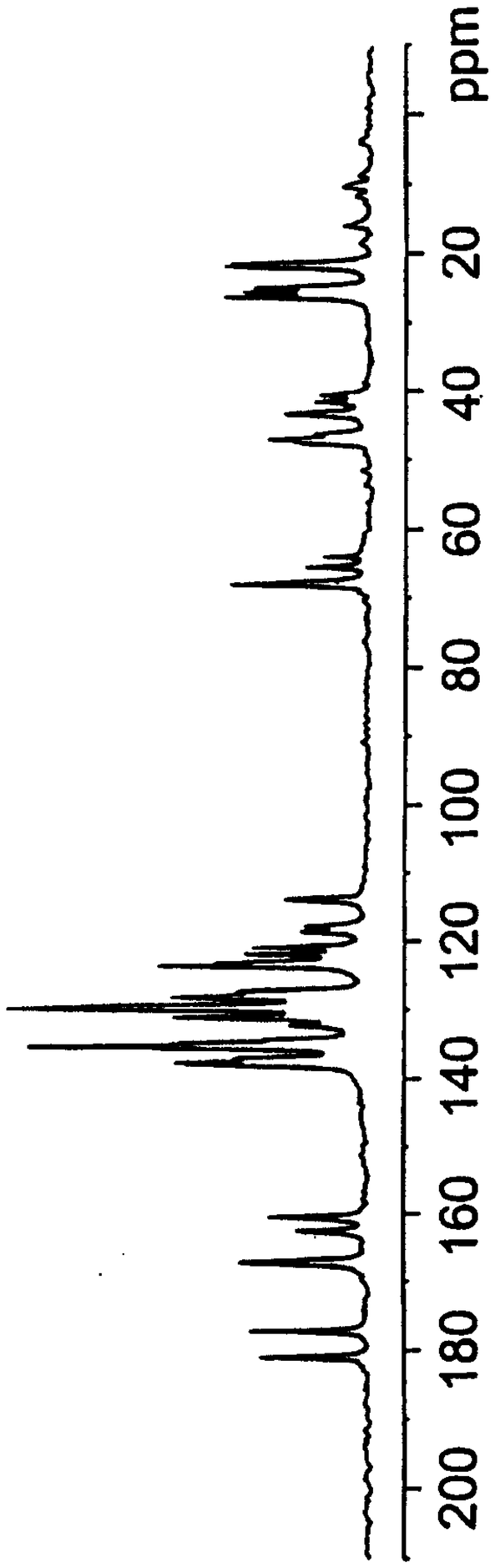

ppm
20
40
60
80
100
120
140
160
180
200

FIG. 31

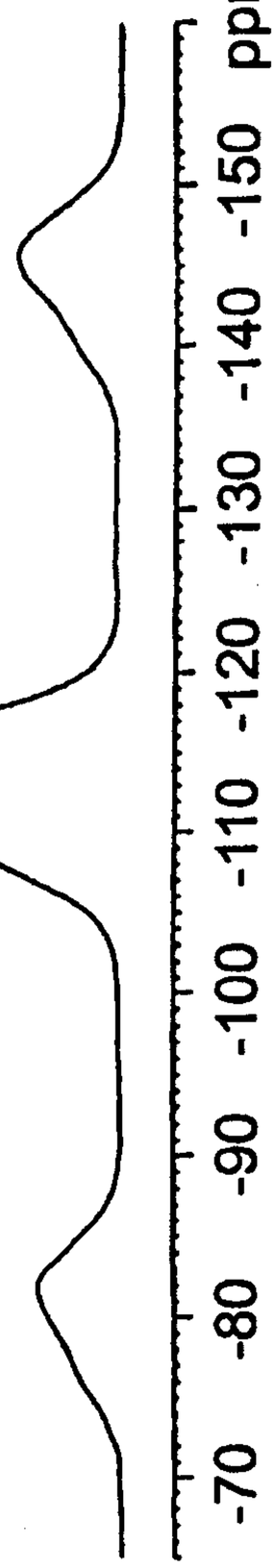

ppm
-140
-150
-130
-120
-110
-100
-90
-80
-70

FIG. 32

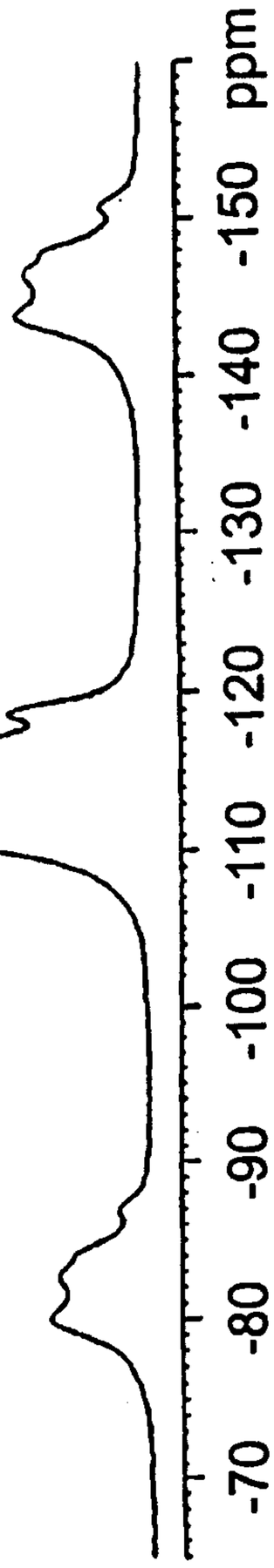

ppm
-150
-140
-130
-120
-110
-100
-90
-80
-70

FIG. 33

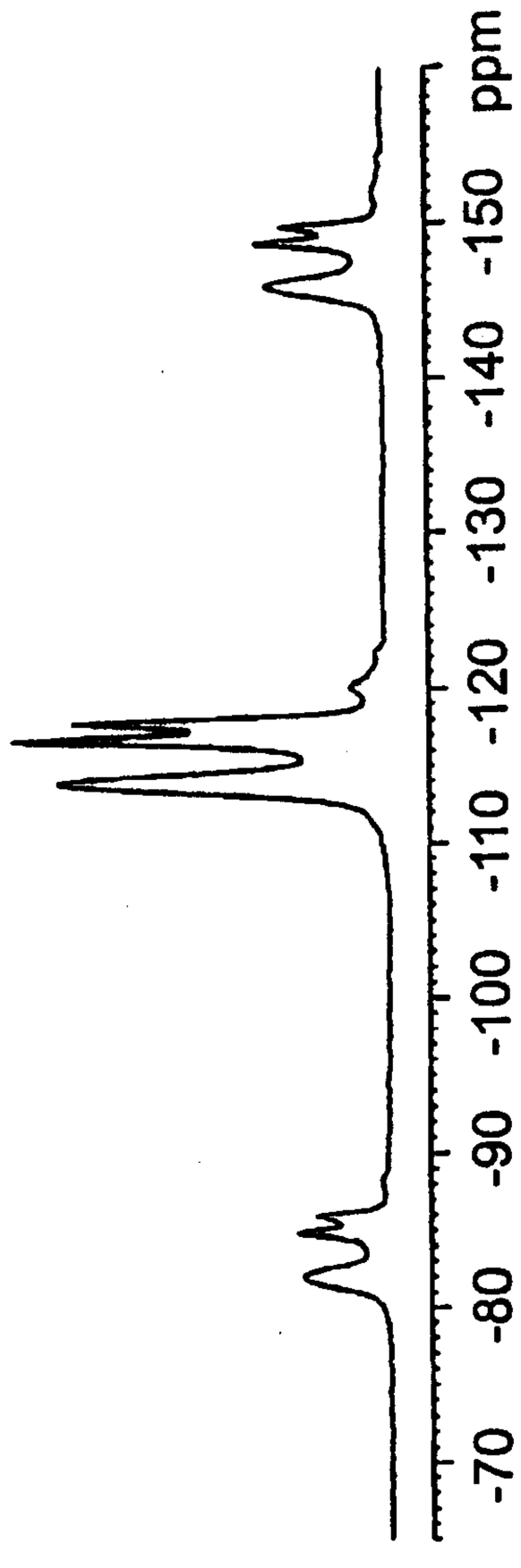

ppm
-150
-140
-130
-120
-110
-100
-90
-80
-70

FIG. 34

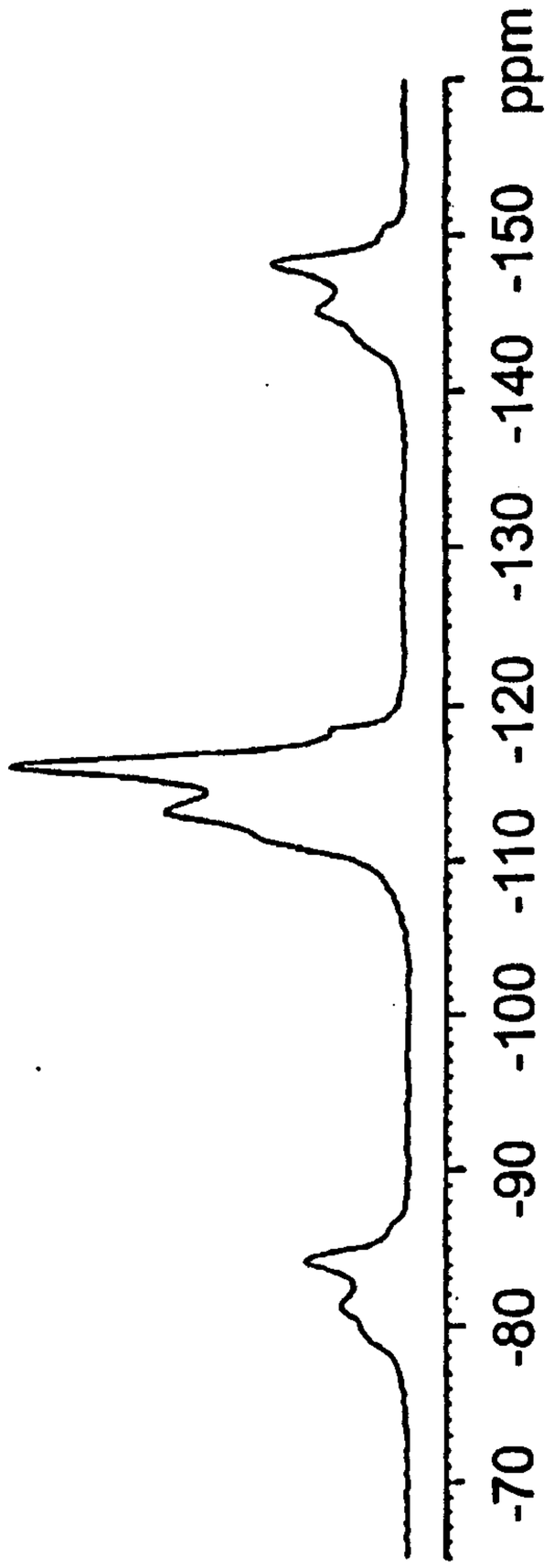

-70
-80
-90
-100
-110
-120
-130
-140
-150
ppm

FIG. 35

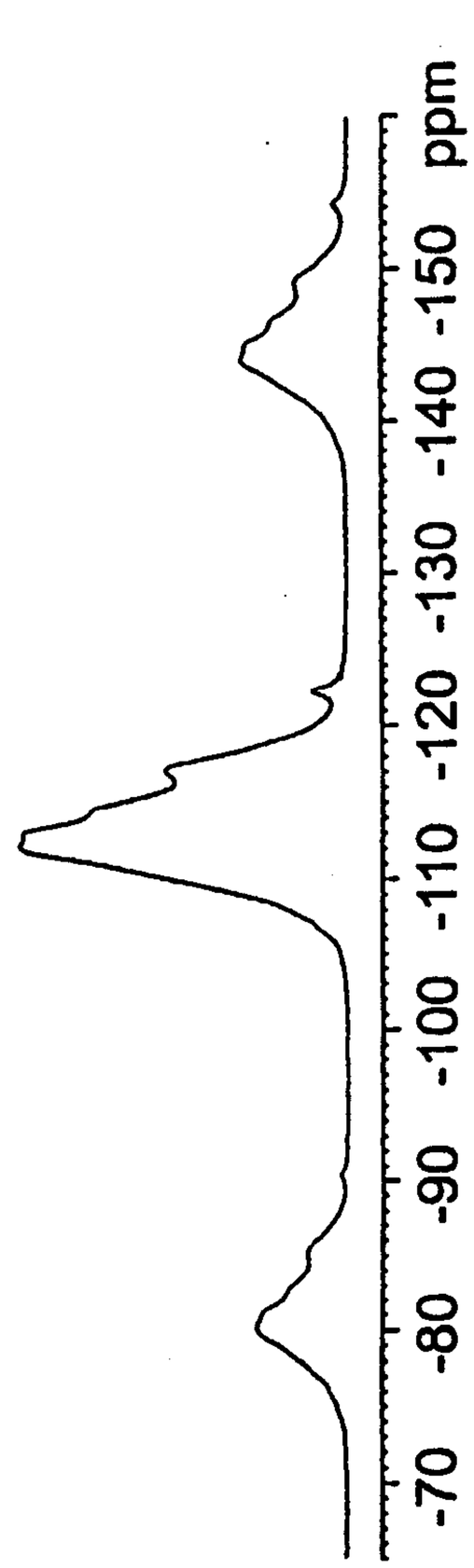

-70
-80
-90
-100
-110
-120
-130
-140
-150
ppm

FIG. 36

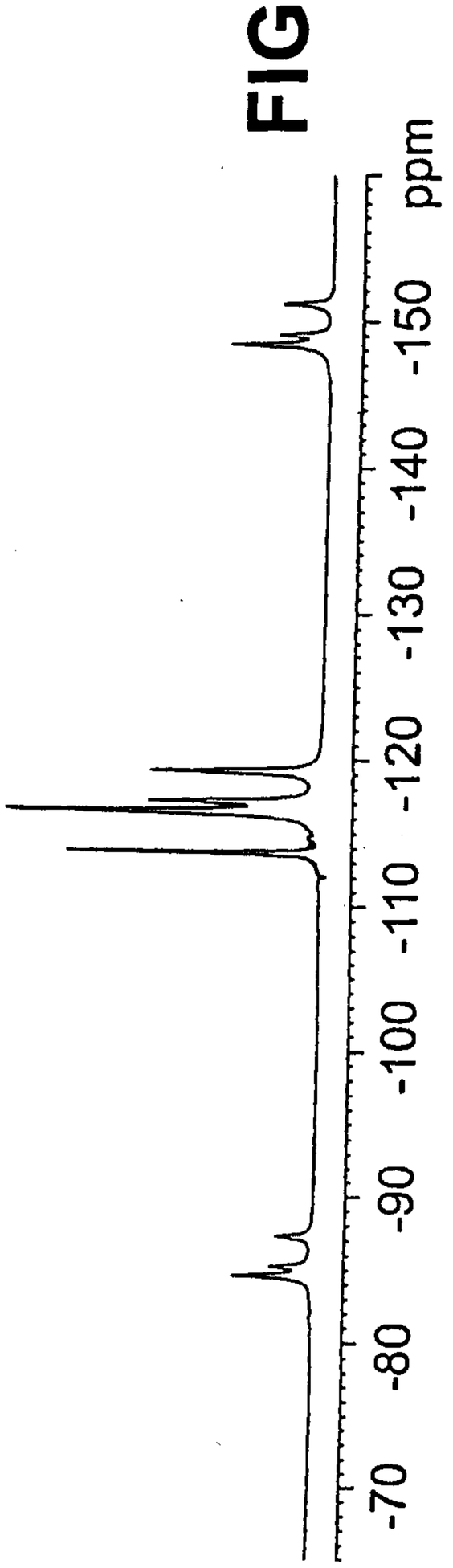
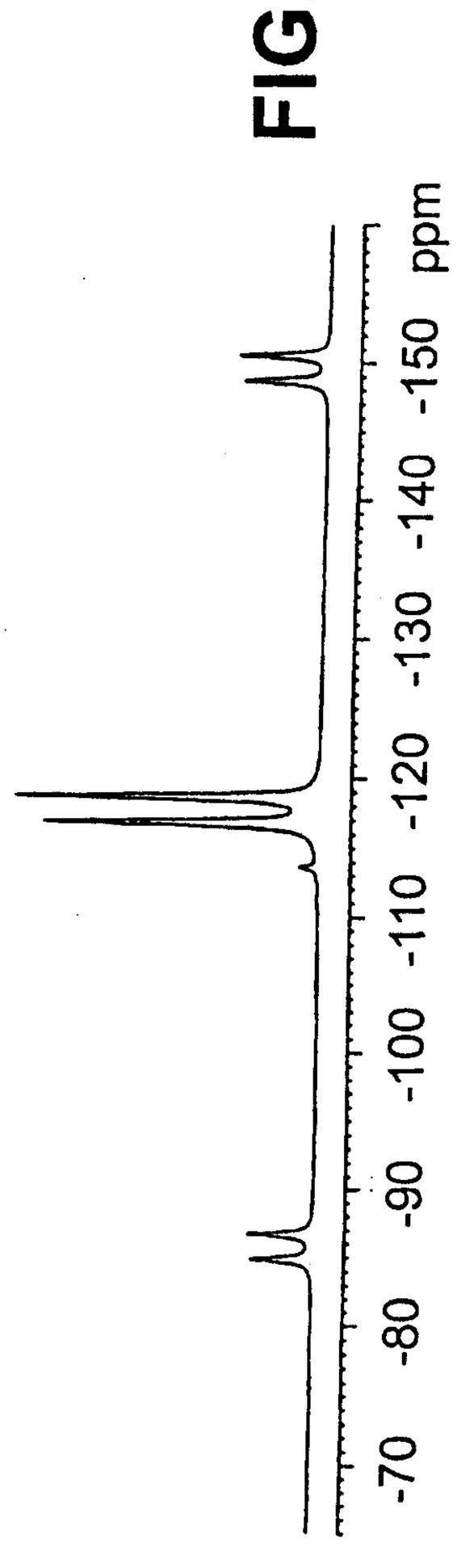

-70
-80
-90
-100
-110
-120
-130
-140
-150
ppm

FIG. 37


-70
-80
-90
-100
-110
-120
-130
-140
-150
ppm