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Canadian Intellectual Property Office

CA 3196706 C 2024/06/25

(11)(21) 3 196 706

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2021/11/11
(87) Date publication PCT/PCT Publication Date: 2022/05/19
(45) Date de délivrance/Issue Date: 2024/06/25
(85) Entrée phase nationale/National Entry: 2023/03/23
(86) N° demande PCT/PCT Application No.: JP 2021/041552
(87) N° publication PCT/PCT Publication No.: 2022/102713
(30) Priorité/Priority: 2020/11/12 (US63/112,893)

(51) Cl.Int./Int.Cl. *C07D 403/12* (2006.01),
A61K 31/4184 (2006.01)

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(54) Titre : SEL ET FORMES CRISTALLINES STABLES DU 2-[3-({1-[2-(DIMETHYLAMINO)ETHYL]-2-(2,2-DIMETHYLPROPYL)-1H-1,3-BENZODIAZOL-5-YL}SULFONYL)AZETIDIN-1-YL]ETHAN-1-OL

(54) Title: STABLE SALT AND CRYSTAL FORMS OF 2-[3-({1-[2-(DIMETHYLAMINO)ETHYL]-2-(2,2-DIMETHYLPROPYL)-1H-1,3-BENZODIAZOL-5-YL}SULFONYL)AZETIDIN-1-YL]ETHAN-1-OL

(57) Abrégé/Abstract:
This invention relates to novel salts and crystal forms of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, simply abbreviated as Compound A, which is a selective CB2 receptor agonist. The present invention provides a salt of Compound A, a crystal form thereof, a method for preparing the said salt and a pharmaceutical composition thereof and its use. The salts of Compound A of the present invention show good pharmaceutical formulation properties such as high aqueous solubility, good crystallinity, high melting point, good chemical and physical stability, or non-deliquescent.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 May 2022 (19.05.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/102713 A1

(51) International Patent Classification:

C07D 403/12 (2006.01)	*A61P 13/12* (2006.01)
A61K 31/4184 (2006.01)	*A61P 17/00* (2006.01)
A61P 1/02 (2006.01)	*A61P 17/06* (2006.01)
A61P 1/04 (2006.01)	*A61P 19/02* (2006.01)
A61P 1/08 (2006.01)	*A61P 19/10* (2006.01)
A61P 1/10 (2006.01)	*A61P 25/00* (2006.01)
A61P 1/12 (2006.01)	*A61P 25/04* (2006.01)
A61P 1/16 (2006.01)	*A61P 25/08* (2006.01)
A61P 3/10 (2006.01)	*A61P 27/06* (2006.01)
A61P 9/00 (2006.01)	*A61P 29/00* (2006.01)
A61P 9/10 (2006.01)	*A61P 35/02* (2006.01)
A61P 11/00 (2006.01)	*A61P 37/08* (2006.01)
A61P 11/02 (2006.01)	*A61P 43/00* (2006.01)
A61P 11/06 (2006.01)	

(21) International Application Number:
PCT/JP2021/041552

(22) International Filing Date:
11 November 2021 (11.11.2021)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/112,893 12 November 2020 (12.11.2020) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

WO 2022/102713 A1

(54) Title: STABLE SALT AND CRYSTAL FORMS OF 2-[3-({1-[2-(DIMETHYLAMINO)ETHYL]-2-(2,2-DIMETHYLPROPYL)-1H-1,3-BENZODIAZOL-5-YL}SULFONYL)AZETIDIN-1-YL]ETHAN-1-OL

(57) Abstract: This invention relates to novel salts and crystal forms of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, simply abbreviated as Compound A, which is a selective CB2 receptor agonist. The present invention provides a salt of Compound A, a crystal form thereof, a method for preparing the said salt and a pharmaceutical composition thereof and its use. The salts of Compound A of the present invention show good pharmaceutical formulation properties such as high aqueous solubility, good crystallinity, high melting point, good chemical and physical stability, or non-deliquescent.

Description

Title of Invention: STABLE SALT AND CRYSTAL FORMS OF 2-[3-({1-[2-(DIMETHYLAMINO)ETHYL]-2-(2,2-DIMETHYLPROPYL)-1H-1,3-BENZODIAZOL-5-YL}SULFONYL)AZETIDIN-1-YL]ETHAN-1-OL

Technical Field

[0001] This invention relates to novel salts and crystal forms of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, which is a selective CB2 receptor agonist, wherein the compound may be called Compound A through the present specification.

Background Art

[0002] Classical cannabinoids such as the marijuana derived cannabinoid (CB) delta^9 - tetrahydro-cannabinol, (delta^9-THC) produce their pharmacological effects via interaction with specific cannabinoid receptors in the body. The cannabinoid receptors are members of the endocannabinoid system and are involved in a variety of physiological processes including appetite, pain-sensation, mood, and memory ({NPL 1} Goutopoulos A. et al., Pharmacol. Ther. 2002, 95: 103-117; {NPL 2} Wright, K. L. et al., Br. J. Pharmacol. 2008, 153: 263-270; and {NPL 3} Aizpurua-Olaizola, O. et al., Drug Discovery Today 2017, 22: 105-110), as well playing an important role in the regulation of inflammatory and immune-responses ({NPL 4} Tanaka M. et al., Front. Neurol. 2020, 11: 87). These receptors belong to the rhodopsin family of G protein-coupled receptors (GPCRs). There are currently two known subtypes, termed Cannabinoid Receptor 1 (CB1) and Cannabinoid Receptor 2 (CB2) ({NPL 5} Matsuda, L. A. et al., Nature 1990, 346: 561-564; Gerard, C. M. et al., Biochem. J. 1991, 279: 129-134). CB1 is expressed most abundantly in the neurons of the central nervous system (CNS), but is also present at lower concentrations in a variety of peripheral tissues and cells ({NPL 5}). In contrast, CB2 is expressed predominantly, although not exclusively, in non-neural tissues, e.g. in hematopoietic cells, endothelial cells, osteoblasts, osteoclasts, the endocrine pancreas, and cancerous cell lines ({NPL 6} Munro, S. et al., Nature 1993, 365: 61-65 and {NPL 7} Pacher, P. et al., Pharmacol. Rev. 2006, 58: 389-462). CB2 is also widely distributed in the brain where it is found primarily on microglia and not neurons ({NPL 8} Cabral, G. A. et al., Br. J. Pharmacol. 2008, 153: 240-51). As such, CB1 is believed to be primarily responsible for mediating the psychotropic effects of cannabinoids on the body, whereas CB2 is unrelated to cannabinoid psychoactivity and believed to be primarily responsible for

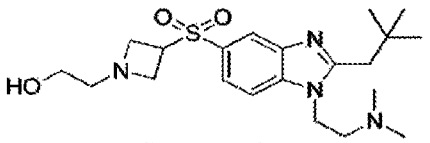
most of their non-neural effects represented by cannabinoid-induced immune modulation ({NPL 9} Howlett, A. C. et al., Pharmacol. Rev. 2002, 54: 161-202; and {NPL 10} Chung, Y. C. et al., Exp. Mol. Med. 2016, 48: e205). There is a considerable interest in the development of selective CB2 receptor agonists since it is believed high selectivity for CB2 may offer avenues for harnessing the beneficial effect of CB receptor agonists while avoiding the central adverse events seen with cannabinoid structures ({NPL 11} Expert Opin. Investig. Drugs 2007, 16: 951-965).

[0003] In general, CB2 receptor agonists could be beneficial for the treatment of a variety of indications in different therapeutic areas including chronic and acute pain (e.g. inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic low back pain, visceral pain, complex regional pain syndrome, neuralgias); immunological and inflammatory disorders also with a pain component (e.g arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, Crohn's disease, ulcerative colitis, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus); gastrointestinal disorders, including irritable bowel syndrome (IBS), gastroesophageal reflux disease (GERD), constipation, diarrhea, functional gastrointestinal disorder), oncology (e.g. cutaneous T cell lymphoma, pancreatic cancer); neurodegenerative disorders, such as multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis; fibrotic disorders of heterogeneous aethiology (systemic fibrosis, systemic sclerosis, vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis); lung disorders (e.g. acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease or COPD), and many metabolic and multi-aethiology disorders including diabetes, glaucoma, age-related macular degeneration, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, geographic atrophy, osteoporosis, regulation of bone mass, glomerulonephritis, renal ischemia, nephritis, hepatitis, acute liver failure, chronic allograft nephropathy, diabetic nephropathy, liver cirrhosis or tumors, myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, cryptogenic fibrosing alveolitis, bronchitis, thermal injury, burn injury, hypertrophic scars, keloids, gingivitis, pyrexia, psychiatric diseases, psychosis, malaria, encephalitis, and acute allograft rejection ({NPL 12} Hohmann, A. G. et aL J. Pharmacol. Exp. Ther. 2004, 308: 446-453; {NPL 13} Ibrahim, M. M. et al,, Proc. Natl. Acad. Sci. U S A 2003, 100: 10529-10533; {NPL 14} Mathison, R. et al., Br. J. Pharmacol. 2004, 142: 1247-1254; {NPL 15} Pacher, P. et al., Prog. Lipid Res. 2011, 50: 193-211; {NPL 16} Van Der Stelt, M. et al., J. Med. Chem. 2011, 54: 7350-7362; {NPL 17} Guindon, J. et al., Br. J. Pharmacol. 2008, 153: 319-334; {NPL 18} Kusakabe, K. et al., Bioorg. Med. Chem. 2013, 21: 3154-3163; {NPL 19}

Mukhopadhyay, P. et al., Free Radic. Biol. Med. 2010, 48: 457-467; {NPL 20} Gruden, G. et al., Br. J. Pharmacol. 2015, 173: 1116-1127; {NPL 21} Julien, B. et al., Gastroenterology 2005, 128; 742-755; {NPL 22} Batkai, S. et al., FASEB J. 2007, 21: 1788-1800; {NPL 23} Rajesh, M. et al., J. Leukoc. Biol. 2007, 82: 1382-1389; {NPL 24} Horvath, B. et al., Br. J. Pharmacol. 2012, 165: 2462-2478; and {NPL 25} Montecucco, F. et al., J. Mol. Cell. Cardiol. 2009, 46: 612-620). The classifications of the diseases described above are shown in Appendix Table A.

[0004] Accordingly, small-molecule compounds that have selective CB2 receptor agonistic activity are particularly desirable as a means to treat or prevent disease states associated with CB2 stimulation. One such small-molecule is 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, which has the chemical structure:

[Chem.1]



Compound A

[0005] 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol (Compound A), its preparation, and its use as a medicament for the treatment of conditions or diseases mediated by CB2 receptor activity are described in the {PL1} U.S. Patent Number 8,653,063. Compound A is exemplified therein in free base form and the synthesis is also described in the experimental part as Example 23. Furthermore, the in vitro agonistic activities for human CB1 and CB2, in vivo and in vitro pharmacokinetic parameters, and in vivo efficacy of Compound A are described in the {NPL 26} Iwata, Y. et al., Bioorg. Med. Chem. Lett. 2015, 25, 236, as Compound 40. The present invention relates to a novel salt and crystalline solid form of the said salt of Compound A that demonstrate improved properties for use in a pharmaceutical dosage form, particularly for oral solid dosage forms.

[0006] Based on a chemical structure, it had not been possible so far to predict with any degree of certainty whether a compound would crystallize under any condition, how many crystalline solid forms of the compound may exist, or the solid-state structure of any of those forms. Due to the many factors influencing the rate and mechanism of crystallization, identifying a robust and reproducible process enabling consistent results in obtaining good quality and stable crystals requires a long and rigorous process of optimization. A key characteristic of any crystalline drug is the polymorphic behavior of such a material. In general, the different physical properties

exhibited by different solid forms of a pharmaceutical compound can affect important pharmaceutical parameters such as storage, compressibility, density (important in formulation and product manufacturing), and dissolution rates (important in determining bioavailability). Stability differences may result from changes in chemical reactivity (e.g., differential hydrolysis or oxidation, such that a formulation comprising a certain polymorph can discolor more rapidly than a formulation comprising a different polymorph), mechanical changes (e.g., tablets can crumble on storage as a kinetically favored crystalline form converts to thermodynamically more stable crystalline form), or both (e.g., tablets of one polymorph can be more susceptible to breakdown at high humidity). Solubility differences between polymorphs may, in extreme situations, result in transitions to crystalline forms that lack potency. In addition, the physical properties of a crystalline form may also be important in pharmaceutical processing. For example, a particular crystalline form may form solvates more readily or may be more difficult to filter and wash free of impurities than other crystalline forms (i.e., particle shape and size distribution might be different between one crystalline form relative to other forms). These variety of characteristics are almost impossible to be speculated or expected before finding facts.

[0007] In general, the ideal physical form of a drug product cannot be defined a priori because different physical forms provide different advantages. Thus, it is important to seek a variety of unique drug forms, e.g., salts, polymorphs, non-crystalline forms, which may be used in various formulations. The selection of a drug form for a specific formulation, route of administration, or therapeutic application requires consideration of a variety of properties, with a different degree of priority or acceptability parameters based on a particular application. Specifically, a drug form used in solid oral dosage forms including tablets and capsules must be sufficiently stable, must retain its crystal polymorph form during the solid manufacturing process, and must not degrade during a normal shelf-life storage. Moreover, low melting point forms are regarded as undesirable as formulation issues such as exudation and spots due to melting of the drug during the different stage of manufacturing may occur. With regard to general solid formulation development, the melting point should not be below 80 °C and should preferably exceed 120 °C ({NPL 27} Stefan Balbach, Pharmaceutical evaluation of early development candidates "the 100 mg-approach", International Journal of Pharmaceutics 275 (2004) 1-12).

[0008] Different crystalline solid forms of the same compound often possess different solid-state properties such as melting point, solubility, dissolution rate, hygroscopicity, powder flow, mechanical properties, chemical stability, and physical stability. These solid-state properties may offer advantages in filtration, drying, dosage form manufacturing unit operations and eventually improve in vivo performance in terms of

DMPK and efficacy parameters. Thus, once different crystalline solid forms of the same compound have been identified, the optimum crystalline solid form under any given set of processing and manufacturing conditions may be determined as well as the different solid-state properties of each crystalline solid form. However, only limited crystalline solid forms of a compound are suitable for use as active pharmaceutical ingredients (APIs). Therefore, the identification of the form with the desirable properties becomes an essential, but also time consuming and challenging component of drug development.

[0009] Polymorphs of a molecule can be obtained by a number of methods which are not entirely predictable a priori and therefore can constitute an important component of innovation, and consequently, of the originality of an invention. Such methods include, but are not limited to, melt recrystallization, melt cooling, solvent recrystallization, desolvation, rapid evaporation, rapid cooling, slow cooling, vapor diffusion and sublimation. Polymorphs can be detected, identified, classified and characterized using well-known techniques such as, but not limited to, differential scanning calorimetry (DSC), thermogravimetry (TGA), X-ray powder diffractometry (XRPD), single crystal X-ray diffractometry, solid state nuclear magnetic resonance (NMR), infrared (IR) spectroscopy, Raman spectroscopy, and hot-stage optical microscopy.

[0010]

Citation List

Patent Literature

[0011] {PL 1} U.S. Patent Number 8,653,063

Non Patent Literature

[0012] {NPL 1} Goutopoulos A. et al., Pharmacol. Ther. 2002, 95: 103-117
{NPL 2} Wright, K. L. et al., Br. J. Pharmacol. 2008, 153: 263-270
{NPL 3} Aizpurua-Olaizola, O. et al., Drug Discovery Today 2017, 22: 105-110
{NPL 4} Tanaka M. et al., Front. Neurol. 2020, 11: 87
{NPL 5} Matsuda, L. A. et al., Nature 1990, 346: 561-564; Gerard, C. M. et al., Biochem. J. 1991, 279: 129-134
{NPL 6} Munro, S. et al., Nature 1993, 365: 61-65
{NPL 7} Pacher, P. et al., Pharmacol. Rev. 2006, 58: 389-462
{NPL 8} Cabral, G. A. et al., Br. J. Pharmacol. 2008, 153: 240-51
{NPL 9} Howlett, A. C. et al., Pharmacol. Rev. 2002, 54: 161-202
{NPL 10} Chung, Y. C. et al., Exp. Mol. Med. 2016, 48: e205
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{NPL 12} Hohmann, A. G. et al., J. Pharmacol. Exp. Ther. 2004, 308: 446-453
{NPL 13} Ibrahim, M. M. et al., Proc. Natl. Acad. Sci. U S A 2003, 100:

10529-10533
{NPL 14} Mathison, R. et al., Br. J. Pharmacol. 2004, 142: 1247-1254
{NPL 15} Pacher, P. et al., Prog. Lipid Res. 2011, 50: 193-211
{NPL 16} Van Der Stelt, M. et al., J. Med. Chem. 2011, 54: 7350-7362
{NPL 17} Guindon, J. et al., Br. J. Pharmacol. 2008, 153: 319-334
{NPL 18} Kusakabe, K. et al., Bioorg. Med. Chem. 2013, 21: 3154-3163
{NPL 19} Mukhopadhyay, P. et al., Free Radic. Biol. Med. 2010, 48: 457-467
{NPL 20} Gruden, G. et al., Br. J. Pharmacol. 2015, 173: 1116-1127
{NPL 21} Julien, B. et al., Gastroenterology 2005, 128; 742-755
{NPL 22} Batkai, S. et al., FASEB J. 2007, 21: 1788-1800
{NPL 23} Rajesh, M. et al., J. Leukoc. Biol. 2007, 82: 1382-1389
{NPL 24} Horvath, B. et al., Br. J. Pharmacol. 2012, 165: 2462-2478
{NPL 25} Montecucco, F. et al., J. Mol. Cell. Cardiol. 2009, 46: 612-620
{NPL 26} Iwata, Y. et al., Bioorg. Med. Chem. Lett. 2015, 25: 236-240
{NPL 27} Stefan Balbach, Pharmaceutical evaluation of early development candidates "the 100 mg-approach", International Journal of Pharmaceutics 275 (2004) 1-12

Summary of Invention

Technical Problem

[0013] Compound A is disclosed in PL 1 and NPL 26 as a potent selective CB2 receptor agonist, which is useful in the treatment or alleviation of pain (i.e. chronic regional pain syndrome, trigeminal neuralgia, and other neuralgias) and inflammation, and also of gastrointestinal (GI) disorders, such as irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and colitis.

[0014] The previously known methods for preparation, described in PL 1 and NPL 26, have produced a free base of Compound A as a grease or solids, which are not crystalline and not amenable to drug development and formulation.

[0015] Therefore, the present invention aims to identify and produce a pharmaceutically acceptable form of Compound A and/or a salt of Compound A capable of enabling stable and effective pharmaceutical compositions, particularly those in solid dosage form. Important criteria to be satisfied are, inter alia, that the selected salt should be crystalline, non-deliquescent, and possess solid-state stability and properties, be of suitable melting point and have acceptable solubility characteristics.

Solution to Problem

[0016] Thus, the invention provides:

[1] A salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol with an acid, wherein the acid is selected from the

group consisting of hydrochloric acid (HCl), maleic acid, and methanesulfonic acid.

[2] The salt according to [1], wherein the acid is hydrochloric acid (HCl).

[3] A crystalline form of the HCl salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol.

[4] The HCl salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol according to [2], wherein said salt is in crystalline form Pattern 2 and said Pattern 2 is characterized by at least one of the following:

(i) a powder X-ray diffraction (XRPD) pattern comprising peaks, in terms of 2-Theta, at 5.9, 6.6, 8.9, 11.8, 13.2, 14.5, 15.6, 16.0, 17.4, 18.3, 19.5, 20.2, 22.0, 26.6, and 27.0 degrees 2-Theta +/- 0.2 degrees 2-Theta;

(ii) an XRPD pattern substantially and coinciding with the pattern shown by Fig. 1-1 (Figure A).

[5] The HCl salt according to any one of [2] to [4], having a melting endotherm at onset 191°C in differential scanning calorimetry (DSC) or at onset 192°C in thermogravimetry/differential thermal analysis (TG/DTA).

[6] The HCl salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol according to [4], wherein Pattern 2 of said salt is least 90 weight % based on weight of said salt.

[7] The HCl salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol according to [2], wherein said salt is in crystalline form Pattern 1 and said Pattern 1 is characterized by at least one of the following:

(i) a powder X-ray diffraction (XRPD) pattern comprising peaks, in terms of 2-Theta, at 6.6, 13.2, 15.6, 16.0, 17.2, 17.4, 17.9, 18.9, 20.1, 22.1, 23.4, 26.6, and 27.0 degrees 2-Theta +/- 0.2 degrees 2-Theta;

(ii) an XRPD pattern substantially in accordance with the pattern shown by Fig. 1-4 (Figure D).

[8] The HCl salt according to [7], having a melting endotherm at onset 192°C in differential scanning calorimetry (DSC) or at onset 200°C in thermogravimetry/differential thermal analysis (TG/DTA).

[9] The HCl salt of 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol according to [7], wherein Pattern 1 of said salt is least 90 weight % based on weight of said salt.

[10] A pharmaceutical composition comprising the salt according to [1].

Date Reçue/Date Received 2023-03-23

[11] A method for preventing or treating a disorder or condition selected from pain, inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgias (e.g. trigeminal neuralgia), multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhoea, functional gastrointestinal disorder, arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis, cutaneous T cell lymphoma, pancreatic cancer, systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars, acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis, glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy, hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH), myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL), attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/ sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome, malaria, and pyrexia, comprising administering to a subject suffering from said disease or condition an effective amount of the salt according to [1].

[12] The method according to [11], wherein the disease is pain.

[13] The method according to [11], wherein the disease is inflammation.

[14] The method according to [11], wherein the disease is irritable bowel syndrome (IBS).

[15] The method according to [11], wherein the disease is inflammatory bowel disease (IBD).

[16] The method according to [11], wherein the disease is colitis.

[17] A process of producing an HC1 salt of

2- [3-({ 1-[2-(dimethylamino)ethyl] -2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}s

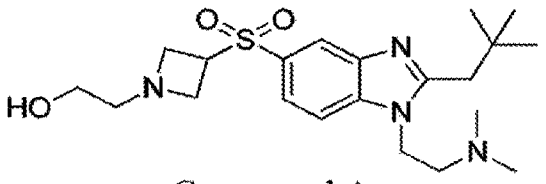
ulfonyl)azetidin-1-yl]ethan-1-ol, comprising dissolving 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol in a suitable solvent.

[18] The process according to [17], wherein the suitable solvent is selected from the group consisting of acetone, acetonitrile, 1-butanol, cyclohexane, dichloromethane, di-isopropyl ether, dimethylacetamide, dimethyl sulfoxide, dioxane, ethanol, ethyl acetate, heptane, isopropyl acetate, methyl tert-butyl ether, methyl ethyl ketone, methyl isobutyl ketone, methanol, 2-propanol, toluene, tetrahydrofuran, water and the mixture of the solvents thereof.

In consideration of all the above an exhaustive and careful study of Compound A and/or salts of Compound A has led to the novel and unforeseen discovery that certain salts of Compound A meet the foregoing requirements and have advantages with regard to the ability to prepare solid dosage forms over the corresponding free base or other salts. Particularly, novel and "essentially pure" (here from meant as greater than or equal to 95% by weight purity) crystalline polymorph forms of the hydrochloride (HCl salt) of Compound A have the best characters as the API. More preferably, the final product will be 98% by weight purity and optimally greater than or equal to 99% by weight purity.

[0017] In one embodiment, the invention is directed to a salt comprising Compound A:

[Chem.2]



Compound A

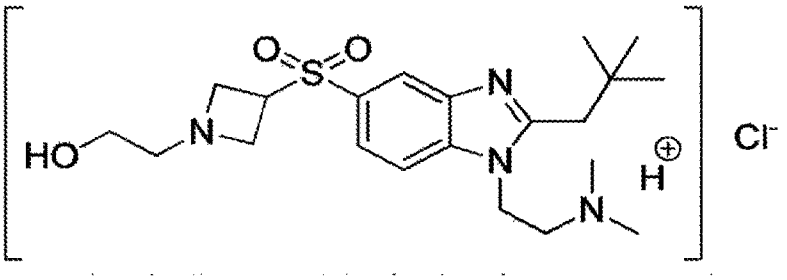
and an acid, wherein the acid is selected from the group consisting of acetic acid, L-ascorbic acid, L-aspartic acid, benzenesulfonic acid, citric acid, ethane-1,2-disulfonic acid (edisilic acid, EDSA), fumaric acid, 2,5-dihydroxybenzoic acid (gentisic acid), D-gluconic acid, D-glucuronic acid, L-glutamic acid, glutaric acid, glycolic acid, hippuric acid, hydrochloric acid (HCl), L-lactic acid, maleic acid, L-malic acid, methanesulfonic acid (MSA), phosphoric acid, p-toluenesulfonic acid (p-TSA), succinic acid, sulfuric acid (H_2SO_4), and L-tartaric acid.

[0018] In a preferred embodiment, the acid is selected from the group consisting of acetic acid, ethane-1,2-disulfonic acid (edisilic acid, EDSA), fumaric acid, glutaric acid, glycolic acid, hydrochloric acid (HCl), L-lactic acid, maleic acid, methanesulfonic acid (MSA), succinic acid, and sulfuric acid (H_2SO_4).

[0019] In another preferred embodiment, the acid is selected from the group consisting of glycolic acid, hydrochloric acid (HCl), L-lactic acid, maleic acid, and methanesulfonic acid (MSA). In one embodiment, the salt is the hydrochloric acid (HCl) salt, the maleic acid salt, or the methanesulfonic acid (MSA) salt. It is contemplated that the hydrochloric acid (HCl) salt of Compound A could be formed by protonating one or more nitrogen atoms of Compound A. In one embodiment, the nitrogen atom of the dimethylamino group (-NMe_2) of Compound A is protonated (-$NHMe_2^+$) to form the salt.

[0020] In one preferred embodiment, the hydrochloric acid (HCl) salt of Compound A is represented by the formula below:

[Chem.3]



HCl salt (hydrochloric acid) of Compound A

[0021] In another embodiment, the present invention provides essentially pure, crystalline, HCl salt of Compound A polymorph form Pattern 2, which is characterized by an X-ray powder diffraction (XRPD) pattern having approximate characteristic peak locations of 5.9, 6.6, 8.9, 11.8, 13.2, 14.5, 15.6, 16.0, 17.4, 18.3, 19.5, 20.2, 22.0, 26.6, and 27.0 degrees 2-Theta. In the invention, it is contemplated that the approximate characteristic peaks will have a deviation of up to about +/- 0.2 degrees 2-Theta. The XRPD pattern of Pattern 2 is approximate to the pattern shown by Figure 1-1 (Figure A). HCl salt of Compound A polymorph form Pattern 2 is further characterized by differential scanning calorimetry (DSC) in which it exhibits an endothermic thermal event at about 191 °C. The DSC pattern of Pattern 2 is approximate to the pattern shown by Figure 1-2 (Figure B). HCl salt of Compound A particularly polymorph form Pattern 2 is yet further characterized by thermogravimetry/differential thermal analysis (TG/DTA) in which it exhibits an endothermic thermal event at about 192 °C. The TG/DTA pattern of Pattern 2 is approximate to the pattern shown by Figure 1-3 (Figure C). This crystalline polymorph of the HCl salt of Compound A, polymorph form Pattern 2 provides for a reproducible form of Compound A suitable for use in preparing pharmaceutical formulations.

[0022] In still another embodiment, the present invention provides essentially pure and crystalline HCl salt of Compound A polymorph form Pattern 1, which is characterized

by an XRPD pattern having approximate characteristic peak locations of 6.6, 13.2, 15.6, 16.0, 17.2, 17.4, 17.9, 18.9, 20.1, 22.1, 23.4, 26.6, and 27.0 degrees 2-Theta +/- 0.2 degrees 2-Theta. The XRPD pattern of Pattern 1 is the pattern shown by Figure 1-4 (Figure D). HCl salt of Compound A polymorph form Pattern 1 is further characterized by TG/DTA in which it exhibits an endothermic thermal event at about 200 ° C. HCl salt of Compound A polymorph form Pattern 1 is further characterized by differential scanning calorimetry (DSC) in which it exhibits an endothermic thermal event at about 192 °C. The DSC pattern of Pattern 1 is approximate to the pattern shown by Figure 1-5 (Figure E). The TG/DTA pattern of Pattern 1 is approximate to the pattern shown by Figure 1-6 (Figure F). This crystalline polymorph of the HCl salt of Compound A, particularly polymorph form Pattern 1 also provides for a reproducible form of Compound A suitable for use in preparing pharmaceutical formulations.

[0023] In yet another embodiment, the present invention provides essentially pure and crystalline HCl salt of Compound A polymorph form Pattern 3 and polymorph form Pattern 4. It will be appreciated that these crystal forms are not to be regarded only as synthetic intermediates that can be further processed to HCl salt of Compound A polymorph form Pattern 2 and polymorph form Pattern 1, but they also have the same therapeutic properties. However, HCl salt of Compound A polymorph form Pattern 3 and polymorph form Pattern 4 are not as suitable as polymorph form Pattern 2 and polymorph form Pattern 1 for use in preparing pharmaceutical formulations, principally because the former crystal forms are less stable as compared with the latter. HCl salt of Compound A polymorph form Pattern 3 and polymorph form Pattern 4 are characterized by PXRD, as detailed in Table 1-1:

[0024] [Table 1-1]

Form	PXRD peaks at 2-Theta° +/- 0.2	Figure
Pattern 3	5.6, 6.7, 16.6, 17.1, 18.8, 19.9, 24.0, 25.9, 26.8	Figure 1-7 (Figure G)
Pattern 4	6.2, 7.0, 8.2, 16.6, 18.6, 19.3, 19.8, 20.4, 23.3, 24.4, 24.7	Figure 1-8 (Figure H)

[0025] In a further embodiment, the present invention provides a pharmaceutical composition for preventing or treating conditions or diseases mediated by CB2 receptor activity in a mammal comprising a pharmaceutically acceptable carrier and a therapeutically effective amount of the HCl salt of Compound A having a crystalline polymorph form, polymorph form Pattern 2 or polymorph form Pattern 1.

[0026] In a yet further embodiment, the present invention provides a method for treating a disorder or condition using a selective CB2 receptor agonist, particularly for the curative, prophylactic, or palliative treatment including administration of a therapeutically effective amount of HCl salt of Compound A polymorph form Pattern 2 and

polymorph form Pattern 1 to a mammal, including a human, in need of such treatment.

[0027] In an alternative embodiment, the present invention provides a method for preparing an HCl salt of Compound A having a crystalline polymorph form, particularly polymorph form Pattern 2 or polymorph form Pattern 1. The methods typically include suspending Compound A in a solvent or a mixture of solvents, contacting HCl (hydrochloric acid or hydrogen chloride gas) with Compound A to provide a mixture, heating the mixture, cooling the mixture, and isolating the HCl salt.

Brief Description of Drawings

[0028] [Fig.1-1]Figure 1-1 (Figure A) provides an X-ray powder diffraction (XRPD) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 2.

[0029] [Fig.1-2]Figure 1-2 (Figure B) provides a differential scanning calorimetry (DSC) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 2.

[0030] [Fig.1-3]Figure 1-3 (Figure C) provides a thermogravimetry/differential thermal analysis (TG/DTA) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 2.

[0031] [Fig.1-4]Figure 1-4 (Figure D) provides an X-ray powder diffraction (XRPD) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 1.

[0032] [Fig.1-5]Figure 1-5 (Figure E) provides a differential scanning calorimetry (DSC) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 1.

[0033] [Fig.1-6]Figure 1-6 (Figure F) provides a thermogravimetry/differential thermal analysis (TG/DTA) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 1.

[0034] [Fig.1-7]Figure 1-7 (Figure G) provides an X-ray powder diffraction (XRPD) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 3.

[0035] [Fig.1-8]Figure 1-8 (Figure H) provides an X-ray powder diffraction (XRPD) pattern of the hydrochloride (HCl salt) of Compound A polymorph form Pattern 4.

[0036] [Fig.2-1]Figure 2-1 provides an XRPD pattern of AAT-730 (Lot No. 33-13).

[0037] [Fig.2-2]Figure 2-2 provides a TG/DTA thermogram for AAT-730 analyzed from 30-300 °C at 10 °C per minute.

[0038] [Fig.2-3]Figure 2-3 provides a DSC thermogram for AAT-730 analyzed from 30-150 °C at 10 °C per minute.

[0039] [Fig.2-4]Figure 2-4 provides a ^{1}H NMR spectrum of AAT-730 (analyzed in CD_3OD).

[0040] [Fig.2-5]Figure 2-5 provides a ^{1}H NMR spectrum of AAT-730 (analyzed in DMSO-d_6).

[0041] [Fig.2-6]Figure 2-6 provides a photomicrograph of AAT-730.

[0042] [Fig.2-7]Figure 2-7 provides an XRPD analysis of AAT-730 free base samples after

elevated relative humidity and temperature stressing.

[0043] [Fig.2-8]Figure 2-8 provides a ^{1}H NMR spectrum of AAT-730 free base after 1 week at 25 °C/60% RH.

[0044] [Fig.2-9]Figure 2-9 provides a ^{1}H NMR spectrum of AAT-730 free base after 1 week at 40 °C/75% RH.

[0045] [Fig.2-10]Figure 2-10 provides a ^{1}H NMR spectrum of AAT-730 free base after 1 week at 70 °C/75% RH.

[0046] [Fig.3-1]Figure 3-1 provides an XRPD trace of AAT-730 Pattern A material.

[0047] [Fig.3-2]Figure 3-2 provides a TG/DTA thermogram of AAT-730 Pattern A analyzed from 30 to 300 °C at 10 °C per minute.

[0048] [Fig.3-3]Figure 3-3 provides an XRPD trace of AAT-730 Pattern B material.

[0049] [Fig.3-4]Figure 3-4 provides a TG/DTA thermogram of AAT-730 Pattern B solids analyzed from 30 to 300 °C at 10 °C per minute.

[0050] [Fig.3-5]Figure 3-5 provides an XRPD overlay illustrating thermal stressing of Pattern B material.

[0051] [Fig.3-6]Figure 3-6 provides an XRPD trace of AAT-730 Pattern C material.

[0052] [Fig.3-7]Figure 3-7 provides a TG/DTA thermogram of AAT-730 Pattern C solids analyzed from 30 to 300 °C at 10 °C per minute.

[0053] [Fig.3-8]Figure 3-8 provides a ^{1}H NMR spectrum of AAT-730 Pattern C material analyzed in CD_3OD.

[0054] [Fig.3-9]Figure 3-9 provides an XRPD trace of Pattern D + A mixture (Top) and Pattern A (Bottom).

[0055] [Fig.4-1]Figure 4-1 provides an XRPD diffractogram showing (top) AAT-730 Lot. No. 33-13 and (bottom) typical diffractogram after planetary milling.

[0056] [Fig.4-2]Figure 4-2 provides an XRPD diffractogram of possible AAT-730 acetate.

[0057] [Fig.4-3]Figure 4-3 provides a ^{1}H NMR spectrum of possible AAT-730 acetate.

[0058] [Fig.4-4]Figure 4-4 provides an XRPD pattern of AAT-730 EDSA salt.

[0059] [Fig.4-5]Figure 4-5 provides a ^{1}H NMR spectrum of suspected AAT-730 EDSA salt.

[0060] [Fig.4-6]Figure 4-6 provides an XRPD pattern of possible AAT-730 EDSA salt.

[0061] [Fig.4-7]Figure 4-7 provides a ^{1}H NMR spectrum of possible AAT-730 EDSA salt.

[0062] [Fig.4-8]Figure 4-8 provides an XRPD pattern of suspected AAT-730 fumarate.

[0063] [Fig.4-9]Figure 4-9 provides a ^{1}H NMR spectrum of suspected AAT-730 fumarate.

[0064] [Fig.4-10]Figure 4-10 provides an XRPD pattern of suspected AAT-730 glutarate.

[0065] [Fig.4-11]Figure 4-11 provides a ^{1}H NMR spectrum of AAT-730 glutarate.

[0066] [Fig.4-12]Figure 4-12 provides a TG/DTA thermogram of suspected AAT-730 glutarate analyzed from 30 to 300 °C at 10 °C per minute.

[0067] [Fig.4-13]Figure 4-13 provides an XRPD pattern of suspected AAT-730 glycolate.

[0068] [Fig.4-14]Figure 4-14 provides a ^{1}H NMR spectrum of suspected AAT-730 glycolate.

[0069] [Fig.4-15]Figure 4-15 provides a TG/DTA thermogram of suspected AAT-730 glycolate analyzed from 30 to 300 °C at 10 °C per minute.

[0070] [Fig.4-16]Figure 4-16 provides an XRPD pattern of suspected AAT-730 HCl salt.

[0071] [Fig.4-17]Figure 4-17 provides a ^{1}H NMR spectrum of suspected AAT-730 HCl salt.

[0072] [Fig.4-18]Figure 4-18 provides a TG/DTA thermogram of suspected AAT-730 HCl salt analyzed from 30 to 300 °C at 10 °C per minute.

[0073] [Fig.4-19]Figure 4-19 provides an XRPD pattern of suspected AAT-730 HCl salt (2 mol. eq. of HCl).

[0074] [Fig.4-20]Figure 4-20 provides a ^{1}H NMR spectrum of suspected AAT-730 HCl salt (2 mol. eq. of HCl).

[0075] [Fig.4-21]Figure 4-21 provides a TG/DTA thermogram of suspected AAT-730 HCl salt analyzed from 30 to 300 °C at 10 °C per minute.

[0076] [Fig.4-22]Figure 4-22 provides an XRPD pattern of suspected AAT-730 L-lactate.

[0077] [Fig.4-23]Figure 4-23 provides a ^{1}H NMR spectrum of suspected AAT-730 L-lactate.

[0078] [Fig.4-24]Figure 4-24 provides a TG/DTA thermogram of suspected AAT-730 L-lactate analyzed from 30 to 300 °C at 10 °C per minute.

[0079] [Fig.4-25]Figure 4-25 provides an XRPD pattern of suspected AAT-730 maleate.

[0080] [Fig.4-26]Figure 4-26 provides a ^{1}H NMR spectrum of suspected AAT-730 maleate.

[0081] [Fig.4-27]Figure 4-27 provides a TG/DTA thermogram of suspected AAT-730 maleate analyzed from 30 to 300 °C at 10 °C per minute.

[0082] [Fig.4-28]Figure 4-28 provides an XRPD diffractogram of suspected AAT-730 MSA salt.

[0083] [Fig.4-29]Figure 4-29 provides a ^{1}H NMR spectrum of suspected AAT-730 MSA salt.

[0084] [Fig.4-30]Figure 4-30 provides a TG/DTA analysis of AAT-730 MSA salt analyzed from 30 to 300 °c at 10 °C per minute.

[0085] [Fig.4-31]Figure 4-31 provides an XRPD diffractogram of suspected AAT-730 MSA salt.

[0086] [Fig.4-32]Figure 4-32 provides a ^{1}H NMR spectrum of suspected AAT-730 MSA salt.

[0087] [Fig.4-33]Figure 4-33 provides an XRPD diffractogram of suspected AAT-730 succinate.

[0088] [Fig.4-34]Figure 4-34 provides a ^{1}H NMR analysis of suspected AAT-730 succinate.

[0089] [Fig.4-35]Figure 4-35 provides an XRPD diffractogram of suspected AAT-730 sulfate.

[0090] [Fig.4-36]Figure 4-36 provides a ^{1}H NMR analysis of suspected AAT-730 sulfate.

[0091] [Fig.4-37]Figure 4-37 provides an XRPD diffractogram of suspected AAT-730 sulfate (Pattern B).

[0092] [Fig.5-1]Figure 5-1 provides an XRPD pattern of AAT-730 HCl salt Pattern A.

[0093] [Fig.5-2]Figure 5-2 provides a TG/DTA thermogram for AAT-730 HCl salt Pattern A analyzed from 30-300 °C at 10 °C per minute.

[0094] [Fig.5-3]Figure 5-3 provides a DSC thermogram for AAT-730 HCl salt Pattern A analyzed from 30-300 °C at 10 °C per minute.

[0095] [Fig.5-4]Figure 5-4 provides a ^{1}H NMR spectrum of AAT-730 HCl salt (analyzed in CD_3OD).

[0096] [Fig.5-5]Figure 5-5 provides a Photomicrograph of AAT-730 HCl salt.

[0097] [Fig.5-6]Figure 5-6 provides an XRPD patterns of AAT-730 HCl salts post stressing.

[0098] [Fig.5-7]Figure 5-7 provides a ^{1}H NMR analysis of AAT-730 HCl salt after stressing at 25 °C/60% RH.

[0099] [Fig.5-8]Figure 5-8 provides a ^{1}H NMR analysis of AAT-730 HCl salt after stressing at 40 °C/75% RH.

[0100] [Fig.5-9]Figure 5-9 provides a ^{1}H NMR analysis of AAT-730 HCl salt after stressing at 70 °C/75% RH.

[0101] [Fig.5-10]Figure 5-10 provides an XRPD pattern of AAT-730 maleate.

[0102] [Fig.5-11]Figure 5-11 provides a TG/DTA thermogram of AAT-730 maleate analyzed from 30 to 300 °C at 10 °C per minute.

[0103] [Fig.5-12]Figure 5-12 provides a DSC thermogram for AAT-730 maleate analyzed from 30 to 300 °C at 10 °C per minute.

[0104] [Fig.5-13]Figure 5-13 provides a ^{1}H NMR spectrum of suspected AAT-730 maleate.

[0105] [Fig.5-14]Figure 5-14 provides a Photomicrograph of AAT-730 maleate.

[0106] [Fig.5-15]Figure 5-15 provides an XRPD patterns for AAT-730 maleate post-stressing.

[0107] [Fig.5-16]Figure 5-16 provides a ^{1}H NMR spectrum of AAT-730 maleate after stressing for 7 days at 25 °C/60% RH.

[0108] [Fig.5-17]Figure 5-17 provides a ^{1}H NMR spectrum of AAT-730 maleate after stressing for 7 days at 40 °C/75% RH.

[0109] [Fig.6-1]Figure 6-1 provides an XRPD of amorphous material prepared by evaporation.

[0110] [Fig.6-2]Figure 6-2 provides an XRPD trace of AAT-730 HCl salt Pattern 1.

[0111] [Fig.6-3]Figure 6-3 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 1 analyzed in CD_3OD.

[0112] [Fig.6-4]Figure 6-4 provides a TG/DTA thermogram for AAT-730 HCl salt Pattern 1 between 30 and 300 °C at 10 °C/min.

[0113] [Fig.6-5]Figure 6-5 provides an XRPD trace of AAT-730 HCl salt Pattern 2.

[0114] [Fig.6-6]Figure 6-6 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 2 analyzed in CD_3OD.

[0115] [Fig.6-7]Figure 6-7 provides a TG/DTA thermogram of AAT-730 HCl salt Pattern 2 analyzed between 30 and 300 °C at 10 °C/min.

[0116] [Fig.6-8]Figure 6-8 provides an XRPD comparison of AAT-730 HCl salt Pattern 1 (top) with Pattern 2 (bottom).

[0117] [Fig.6-9]Figure 6-9 provides an XRPD trace of AAT-730 HCl salt Pattern 3.

[0118] [Fig.6-10]Figure 6-10 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 3 analyzed in CD_3OD.

[0119] [Fig.6-11]Figure 6-11 provides a TG/DTA thermogram of AAT-730 HCl salt Pattern 3 analyzed between 30 and 300 °C at 10 °C/min.

[0120] [Fig.6-12]Figure 6-12 provides an XRPD trace of AAT-730 HCl salt Pattern 4.

[0121] [Fig.6-13]Figure 6-13 provides an XRPD trace of interconversion slurry experiments.

[0122] [Fig.6-14]Figure 6-14 provides an XRPD trace of water activity experiments.

[0123] [Fig.6-15]Figure 6-15 provides a DSC thermogram of AAT-730 HCl salt Pattern 2 (sample used was a combined sample from the polymorph screen).

[0124] [Fig.6-16]Figure 6-16 provides an XRPD patterns of humidity stressed samples.

[0125] [Fig.6-17]Figure 6-17 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 2 (post 25 °C/60% RH stressing) analyzed in CD_3OD.

[0126] [Fig.6-18]Figure 6-18 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 2 (post 40 °C/75% RH stressing) analyzed in CD_3OD.

[0127] [Fig.6-19]Figure 6-19 provides a ^{1}H NMR spectrum of AAT-730 HCl salt Pattern 2 (post 70 °C/75% RH stressing) analyzed in CD_3OD.

[0128] [Fig.7]Figure 7 provides an XRPD pattern of AAT-730 HCl salt Pattern 2.

[0129] [Fig.8]Figure 8 provides an Appendix Table A which provides the classifications of diseases related to CB2 receptors.

Detailed description of the invention

[0130] PL1 and NPL 26 describe a series of 5-sulfonylbenzimidazoles as potent and selective CB2 receptor agonists. The free base of Compound A is specifically described therein as a non-crystalline form (grease or low-melting solids) and it is unsuitable for the preparation of pharmaceutical compositions, particularly solid dosage forms. Therefore, we set to identify innovative and original approaches to establish whether we could identify, and robustly and consistently isolate salts showing good properties in terms of crystallinity, chemical and physical stability, and not deliquescent in standard temperature and pressure (STP) and humidity.

[0131] By generating different typologies of salts (e.g. hydrochloride (HCl salt), maleate, and mesylate), we were successful in discovered that the HCl salt (hydrochloride) of Compound A in particular exhibits excellent crystallinity, purity, high melting point, good chemical and physical stability, no deliquescent, and high aqueous solubility. The hydrochloride of Compound A of the present invention is useful for the treatment of CB2 receptor mediated diseases in mammals.

Definition

[0132] The present invention may be understood more readily by reference to the following detailed description of the embodiments of the invention and the Examples included

herein. It is further to be understood that unless specifically defined herein, the terminology used herein is to be given its traditional meaning as known in the relevant art.

As used herein, the singular form "a", "an", and "the" include plural references unless indicated otherwise. For example, "a" substituent includes one or more substituents.

[0133] As used herein, unless otherwise indicated, the term "treat" or "treating" means reversing, alleviating, inhibiting the progress of, or preventing the disorder or condition to which such term applies, or one or more symptoms of such disorder or condition. The term "treatment", as used herein, unless otherwise indicated, refers to the act of treating as "treating" is defined immediately above.

[0134] As used herein, the term "preventing" means the prophylactic treatment of a patient in need thereof. The prophylactic treatment can be accomplished by providing an appropriate dose of a therapeutic agent to a subject at risk of suffering from an ailment, thereby substantially averting onset of the ailment. It is to be understood that in human medicine, it is not always possible to distinguish between "preventing" and "suppressing" since the ultimate inductive event or events may be unknown, latent, or the patient is not ascertained until well after the occurrence of the event or events. Therefore, as used herein the term "prophylaxis" is intended as an element of "treatment" to encompass "preventing" as defined herein.

[0135] The term "therapeutically effective amount" means that amount of a salt of this invention, typically delivered as a pharmaceutical composition, that is sufficient to effect treatment, as defined herein, when administered to a subject in need of such treatment. The therapeutically effective amount will vary depending upon the subject and disease condition being treated, the weight and age of the subject, the severity of the disease condition, the particular compound chosen, the dosing regimen to be followed, timing of administration, the manner of administration, and the like, all of which can be determined readily by one of ordinary skill in the art.

[0136] As used herein, the term "condition" refers to a disease state for which the compounds, salts, compositions, and methods of the present invention are being used against.

[0137] The term "about" as used herein means having a value falling within an accepted standard of error of the mean, when considered by one of ordinary skill in the art, for example +/- 20%, preferably +/- 10% or more preferably +/- 5% of the mean.

[0138] As used herein, the term "approximate to" means that variability typical for a particular method is taken into consideration. For example, with reference to X-ray diffraction peak positions, the term "approximate to" means that typical variability in peak position and intensity are taken into consideration. One skilled in the art will appreciate that the peak positions (2-Theta) will show some variability, typically as much

as +/- 0.2 degrees. Further, one skilled in the art will appreciate that relative peak intensities will show inter-apparatus variability as well as variability due to degree of crystallinity, preferred orientation, prepared sample surface, and other factors known to those skilled in the art and should be taken as qualitative measures only. Similarly, in DSC or TG/DTA measurements there is a certain degree of variability in actual measured onset and peak temperatures, typically as much as +/- 1%, which is dependent on rate of heating, crystal shape and purity, and a number of measurement parameters. NMR chemical shift (ppm from TMS) values show variability, typically as much as +/- 0.2 ppm.

[0139] The term "crystalline" or "crystal" as used herein, means having a regularly repeating arrangement of molecules or external face planes. Crystalline forms or crystal forms may differ with respect to thermodynamic stability, physical parameters, X-ray structure, and preparation processes.

[0140] As used herein, the term "polymorph" means the crystalline form of a substance that is distinct from another crystalline form but that shares the same chemical formula.

[0141] The invention described herein suitably may be practiced in the absence of any element(s) not specifically disclosed herein. Thus, for example, in each instance herein any of the terms "comprising", "consisting essentially of", and "consisting of" may be replaced with either of the other two terms.

Pharmaceutical compositions

[0142] The pharmaceutical compositions of the present invention can be used for preventing or treating a subject suffering from conditions or diseases, wherein the conditions or diseases are mediated by CB2 receptor activity. Such conditions or diseases include but are not limited to, but for example, pain, inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgias (e.g. trigeminal neuralgia), multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhoea, functional gastrointestinal disorder, arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis, cutaneous T cell lymphoma, pancreatic cancer, systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars, acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive

pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis, glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy, hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH), myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL), attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome, malaria, and pyrexia.

[0143] The pharmaceutical compositions of the present invention are comprised of a pharmaceutically acceptable excipient, diluent, or carrier and a therapeutically acceptable amount of the salt of Compound A, wherein the salt is selected from the group consisting of acetic acid salt, L-ascorbic acid salt, L-aspartic acid salt, benzenesulfonic acid salt, citric acid salt, ethane-1,2-disulfonic acid (edisilic acid, EDSA) salt, fumaric acid salt, 2,5-dihydroxybenzoic acid (gentisic acid) salt, D-gluconic acid salt, D-glucuronic acid salt, L-glutamic acid salt, glutaric acid salt, glycolic acid salt, hippuric acid salt, hydrochloric acid (HCl) salt, L-lactic acid salt, maleic acid salt, L-malic acid salt, methanesulfonic acid (MSA)salt, phosphoric acid salt, p-toluenesulfonic acid (p-TSA) salt, succinic acid salt, sulfuric acid (H_2SO_4) salt, and L-tartaric acid salt. In the preferred embodiment, the pharmaceutical compositions of the present invention are comprised of a pharmaceutically acceptable excipient, diluent, or carrier and a therapeutically acceptable amount of the salt of Compound A, wherein the salt is selected from the group consisting of HCl salt, maleic acid salt, and methanesulfonic acid (MSA) salt. In the more preferred embodiment, the pharmaceutical compositions of the present invention are comprised of a pharmaceutically acceptable excipient, diluent, or carrier and a therapeutically acceptable amount of the HCl salt of Compound A having a crystalline polymorph form, Polymorph Form Pattern 2 or Polymorph Pattern 1 is exemplified.

[0144] Thus, the compound of the invention may be administered alone, but will generally be administered in admixture with a suitable pharmaceutical excipient, diluent, or carrier selected with regard to the intended route of administration and standard pharmaceutical practice.

[0145] For example, the compound of the invention may be administered orally in the form of optionally flavored and/or colored tablets, capsules, pills, powders, granules, elixirs, solutions, or suspensions suitable for immediate, delayed, or controlled release applications. The compound may also be administered systemically; by parenteral

injection as a sterile solution, suspension, or emulsion; by rectal administration as a suppository; or by inhalation as an aerosol or as inhaled micronized powder or nanoparticles. Topical administration may be achieved as an ointment, cream, gel, liquid solution, or emulsion suppository.

[0146] Such tablets may contain excipients, such as microcrystalline cellulose, lactose, sodium citrate, calcium carbonate, dibasic calcium phosphate, or glycine, disintegrants, such as starch (preferably corn, potato, or tapioca starch), sodium starch glycollate, croscarmellose sodium or certain complex silicates, and granulation binders such as polyvinylpyrrolidone, hydroxypropylmethylcellulose (HPMC), hydroxypropyl-cellulose (HPC), sucrose, gelatin, or acacia. Additionally, lubricating agents, such as magnesium stearate, stearic acid, glyceryl behenate, or talc may be included.

[0147] Solid compositions of a similar type may also be employed as fillers in gelatin capsules. Preferred excipients in this regard include lactose, starch, a cellulose, milk sugar, or a high molecular weight polyethylene glycol. For aqueous suspensions and/ or elixirs, the compound may be combined with various sweetening or flavoring agents, coloring matter, or dyes, with emulsifying and/or suspending agents and with diluents, such as water, ethanol, propylene glycol, or glycerin, or combinations thereof.

[0148] The compound may also be administered parenterally, for example, intravenously, intra-arterially, intraperitoneally, intrathecally, intraventricularly, intrasternally, in-tracranially, intramuscularly, or subcutaneously, or it may be administered by infusion techniques. It is best used in the form of a sterile aqueous solution which may contain other substances, for example, enough salts or glucose to make the solution isotonic with blood. If necessary, the aqueous solutions may be suitably buffered, preferably to a pH of from 3 to 9. The preparation of suitable parenteral formulations under sterile conditions is readily accomplished by standard pharmaceutical techniques well known to those skilled in the art.

[0149] For oral and parenteral administration to human patients, the daily dosage level of the compound of the invention will usually be from 0.01 to 20 mg/kg (in single or divided doses). Thus, tablets, capsules, or pills of the compound of the invention may contain from 0.5 to 500 mg of active compound for administration either singly or two or more at a time as appropriate. The physician in any event will determine the actual dosage which will be most suitable for any individual patient and it may vary with the age, weight, and response of the particular patient. The above dosages are exemplary of the average case. There can, of course, be individual instances where higher or lower dosage ranges are merited, and such are within the scope of this invention.

[0150] The compound of the invention may also be administered intranasally or by in-halation and is conveniently delivered in the form of a dry powder inhaler or an aerosol spray presentation from a pressurized container, pump, spray, or nebuliser using a

suitable propellant, for example, dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, a hydrofluoroalkane, such as 1,1,1,2-tetrafluoroethane (norflurane, HFA-134a) or 1,1,1,2,3,3,3-heptafluoropropane (apaflurane, HFC-227ea), carbon dioxide, or other suitable gas. In the case of a pressurized aerosol, the dosage unit may be determined by providing a valve to deliver a metered amount. The pressurized container, pump, spray, or nebuliser may contain a solution or suspension of the active compound, for example, by using a mixture of ethanol and the propellant as the solvent, which may additionally contain a lubricant, for example, sorbitan trioleate. Capsules and cartridges (made, for example, from gelatin) for use in an inhaler or insufflator may be formulated to contain a powder mix of the compound and a suitable powder base such as lactose or starch.

[0151] Aerosol or dry powder formulations are preferably arranged so that each metered dose or 'puff' contains from 25 μg to 50 mg of the compound of the invention for delivery to the patient. The overall daily dose with an aerosol will be in the range of from 100 μg to 100 mg which may be administered in a single dose or, more usually, in divided doses throughout the day.

[0152] Alternatively, the compound of the invention may be administered in the form of a suppository or pessary or it may be applied topically in the form of a lotion, solution, cream, ointment, or dusting powder. The compound may also be administered transdermally, for example, by means of a skin patch, or by the ocular route.

[0153] For ocular administration, the compound of the invention may be formulated as micronized suspensions in isotonic and pH-adjusted sterile saline or, preferably, as solutions in isotonic and pH-adjusted sterile saline, optionally in combination with a preservative, such as a benzylalkonium chloride. Alternatively, it may be formulated in an ointment, such as petrolatum.

[0154] For topical application to the skin, the compound of the invention may be formulated as a suitable ointment containing the active compound suspended or dissolved in, for example, a mixture with one or more of the following: mineral oil, liquid petrolatum, white petrolatum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax, or water. Alternatively, it may be formulated as a suitable lotion or cream, suspended or dissolved in, for example, a mixture of one or more of the following: mineral oil, sorbitan monostearate, a polyethylene glycol, liquid paraffin, polysorbate 60, cetyl esters wax, cetearyl alcohol, 2-octyldodecanol, benzyl alcohol, or water.

[0155] Particularly preferred compositions in accordance with the invention include conventional, controlled release, and fast dispersion dosage forms such as tablets, capsules, pills, powders, or granules, all of which may readily be prepared by conventional means using the polymorph form of the invention.

[0156] Finally, the invention also provides for the use of the salt of Compound A, polymorph forms of the invention for the manufacture of a medicament for the curative, prophylactic, or palliative treatment of a medical disease or condition for which an agonist of CB2 receptors is indicated and for a method of curative, prophylactic or palliative treatment of a disease or medical condition for which an agonist of CB2 receptors is indicated which comprises the administration of a therapeutically effective amount of the salt of Compound A polymorph forms of the invention, wherein the salt is selected from the group consisting of acetic acid salt, L-ascorbic acid salt, L-aspartic acid salt, benzenesulfonic acid salt, citric acid salt, ethane-1,2-disulfonic acid (edisilic acid, EDSA) salt, fumaric acid salt, 2,5-dihydroxybenzoic acid (gentisic acid) salt, D-gluconic acid salt, D-glucuronic acid salt, L-glutamic acid salt, glutaric acid salt, glycolic acid salt, hippuric acid salt, hydrochloric acid (HC1) salt, L-lactic acid salt, maleic acid salt, L-malic acid salt, methanesulfonic acid (MSA)salt, phosphoric acid salt, p-toluenesulfonic acid (p-TSA) salt, succinic acid salt, sulfuric acid (H_2SO_4) salt, and L-tartaric acid salt. In the preferred embodiment, the salt is selected from the group consisting of HC1 salt, maleic acid salt, and methanesulfonic acid (MSA) salt.

[0157] In the more preferred embodiment, the salt is HC1 salt of Compound A polymorph forms of the invention, which is for the manufacture of a medicament for the curative, prophylactic, or palliative treatment of a medical disease or condition for which an agonist of CB2 receptors is indicated and for a method of curative, prophylactic or palliative treatment of a medical disease or condition for which an agonist of CB2 receptors is indicated which comprises the administration of a therapeutically effective amount of the HC1 salt of Compound A polymorph forms of the invention.

[0158] Such diseases or conditions include pain, inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgias (e.g. trigeminal neuralgia), multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhoea, functional gastrointestinal disorder, arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis, cutaneous T cell lymphoma, pancreatic cancer, systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars, acute respiratory distress syndrome (ARDS), re-

versible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis, glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy, hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH), myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL), attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome, malaria, and pyrexia.

Combination therapies

[0159] The salts of the present invention may also optionally be combined with another pharmacologically active compound, or with two or more other pharmacologically active compounds. For example, the salts of the present invention, as defined above, may be administered simultaneously, sequentially, or separately in combination with one or more agents selected from:

analgesic compounds such as: acetaminophen; and NSAIDs, for example aspirin, choline and magnesium salicylates, choline salicylate, celecoxib, diclofenac potassium or sodium, diflunisal, etodolac, flurbiprofen, ibuprofen, indomethacin, ketoprofen, magnesium salicylate, meclofenamate sodium, mefenamic acid, meloxicam, nabumetone, naltrexone, naproxen, naproxen sodium, oxaprozin, piroxicam, salsalate, sodium salicylate, sulindac, tolmetin sodium or valdecoxib;

gastrointestinal anti-inflammatory agents, for example 5-aminosalicylates (5-ASA), mesalamine, sulfasalazine and vedolizumab;

immunosuppressive agents, for example azathioprine;

purine antagonists, for example 6-mercaptopurine;

oral corticosteroid therapeutics, for example prednisone, budesonide, or equivalent steroids;

anti-inflammatory agents, for example anti-TNF-a agents, for example infliximab, adalimumab, ustekinumab, and certolizumab pegol;

probiotics, for example Culturelle, Saccharomyces boulardii;

antibiotics used for the treatment of Crohn's Disease, for example ciprofloxacin and metronidazole;

antidiarrheals, for example loperamide and diphenoxylate with atropine;

and the pharmaceutically acceptable salts and solvates thereof.

[0160] The present invention extends to a combination comprising the salts of Compound A

and one or more therapeutic agents, such as those listed above, for simultaneous, separate or sequential use in the curative, prophylactic, or palliative treatment of conditions or diseases, wherein the conditions or diseases are mediated by CB2 receptor activity. Such conditions or diseases are not limited to, but for example, pain, inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgias (e.g. trigeminal neuralgia), multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhoea, functional gastrointestinal disorder, arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis, cutaneous T cell lymphoma, pancreatic cancer, systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars, acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis, glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy, hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH), myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL), attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/ sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome, malaria, and pyrexia. Preferably, the conditions or diseases mediated by CB2 receptor activity is for example, pain and inflammation, gastrointestinal (GI) disorders, such as irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and colitis. In the preferred embodiment, the salt of Compound A is selected from the group consisting of acetic acid salt, L-ascorbic acid salt, L-aspartic acid salt, benzenesulfonic acid salt, citric acid salt, ethane-1,2-disulfonic acid (edisilic acid, EDSA) salt, fumaric acid salt, 2,5-dihydroxybenzoic acid (gentisic acid) salt, D-gluconic acid salt, D-glucuronic acid salt, L-glutamic acid salt, glutaric acid salt, glycolic acid salt, hippuric acid salt, hydrochloric acid (HC1) salt, L-lactic acid

salt, maleic acid salt, L-malic acid salt, methanesulfonic acid (MSA)salt, phosphoric acid salt, p-toluenesulfonic acid (p-TSA) salt, succinic acid salt, sulfuric acid (H_2SO_4) salt, and L-tartaric acid salt. In the preferred embodiment, the salt is selected from the group consisting of HCl salt, maleic acid salt, and methanesulfonic acid (MSA) salt. In the preferred embodiment, the salt is selected from the group consisting of HCl salt, maleic acid salt, and methanesulfonic acid (MSA) salt. In the more preferred embodiment, the salt of Compound A is HCl salt.

Preparation method

[0161] The invention also provides a method for preparing a pharmaceutically acceptable salt of Compound A. In general, the method includes:

(a) suspending the free base of Compound A in a single solvent or mixture of solvents;

(b) contacting HCl (hydrochloric acid or hydrogen chloride gas), maleic acid, or methanesulfonic acid with Compound A to provide a mixture;

(c) heating the mixture at the temperature of from 20 °C to 100 °C;

(d) cooling the mixture at the temperature of from -20 °C to 40 °C;

(e) and isolating the salt.

[0162] In some embodiments of the method for preparing the salt, the mixture is cooled, and the salt is precipitated out of the solution.

[0163] In some embodiments of the method for preparing the salt, the mixture is heated and refluxed prior to cooling.

[0164] In some embodiments of the method of preparing the salt, the isolating step further includes filtering the mixture.

[0165] In some embodiments, the solvent used in the method of preparing the salt is an organic solvent miscible with water.

[0166] In other embodiments of the invention, the solvent used in the method of preparing the salt is selected from the group consisting of acetone, acetonitrile, 1-butanol, cyclohexane, dichloromethane, diisopropyl ether, dimethylacetamide, dimethyl sulfoxide, dioxane, ethanol, ethyl acetate, heptane, isopropyl acetate, methyl tert-butyl ether, methyl ethyl ketone, methyl isobutyl ketone, methanol, 2-propanol, toluene, tetrahydrofuran, water, and combinations of these.

[0167] The salt of Compound A having a kinetically favored crystalline form will be converted to a thermodynamically more stable crystalline form under appropriate conditions.

[0168] Compound A can be prepared according to the procedure described in Bioorg. Med. Chem. Lett. 2015, 25, 236 (NPL 26) as Compound 40 on a gram scale (< 100 g). A smaller scale preparation is also set forth in U.S. Patent Number 8,653,063 (PL 1) as Example 23.

[0169] Examples

The present invention is explained in more detail in the following by referring to Reference Example and Examples, which are not to be construed as limitative but just typical examples.

Abbreviations

The following abbreviations are used in the Examples:

AAT-730:
2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol (Compound A)

μL: microliter

μM: micromolar

^{1}H NMR: proton nuclear magnetic resonance spectroscopy

ACN: acetonitrile

API: active pharmaceutical ingredient, i.e. AAT-730

aq.: aqueous

A_w: water activity

DCM: dichloromethane

DIPE: diisopropyl ether

DMAc: N,N-dimethylacetamide

DMSO: dimethyl sulfoxide

DMSO-d_6: dimethyl sulfoxide-d_6

DSC: differential scanning calorimetry

EDSA: ethane-1,2-disulfonic acid

eq.: equivalent

EtOAc: ethyl acetate

EtOH: ethanol

evap: evaporation

g: gram

H_2SO_4: sulfuric acid

HCl: hydrochloric acid

HPLC: high performance liquid chromatography

IPA: isopropyl alcohol, 2-propanol

i-PrOAc: isopropyl acetate

IR: infrared

KF: karl fischer

kg: kilogram

L: liter

M: molar

MEK: methyl ethyl ketone
MeOH: methanol
MeOH-d_4: methanol-d_4 (CD_3OD)
mg: milligram
MHz: megahertz
MIBK: methyl isobutyl ketone
min: minute
mL: milliliter
mm: millimeter
MSA: methanesulfonic acid
MTBE: methyl tert-butyl ether
N/A: not available
N_2: nitrogen
No.: number
pH: power of hydrogen, potential of hydrogen, hydrogen-ion exponent
pK_a: acid dissociation constant, acidity constant
PO: preferred orientation
pptn: precipitation
PS: peak shifting
PSD: position sensitive detector
PTFE: polytetrafluoroethylene
p-TSA: p-toluenesulfonic acid
RH: relative humidity
rpm: revolutions per minute
T, Temp: temperature
TFA: trifluoroacetic acid
TG/DTA: thermogravimetric differential thermal analysis
TGA: thermal gravimetric analysis
THF: tetrahydrofuran
UV: ultraviolet
XRPD: X-ray powder diffraction

[0170] Experimental techniques

X-ray Powder Diffraction (XRPD)

XRPD analyses were performed using a Panalytical Xpert Pro diffractometer equipped with a Cu X-ray tube and a Pixcel detector system. The isothermal samples were analyzed in transmission mode and held between low density polyethylene films. The default XRPD program was used (range 3-40 degrees 2-Theta, step size 0.013 degree, counting time 22 sec, at most 5 min run time). XRPD patterns were sorted

using HighScore Plus 2.2c software.

[0171] Differential Scanning Calorimetry (DSC)

DSC analyses were carried out on a Perkin Elmer Jade Differential Scanning Calorimeter. Accurately weighed samples were placed in crimped aluminum pans. Each sample was heated under nitrogen at a rate of 10 °C/minute to a maximum of 150 °C. Temperatures were reported at the transition onset to the nearest 0.01 degree. Note that DSC traces within this report may contain automated peak integrations which calculate Delta H (OH) of fusion. Where multiple thermal events are observed at similar temperatures, these Delta H values are prone to significant error.

[0172] Thermogravimetric Differential Thermal Analysis (TG/DTA)

Thermogravimetric analyses were carried out on a Mettler Toledo TGA/DSC1 STARe instrument. Samples were accurately weighed in an aluminum sample pan on an analytical balance and inserted into the TG furnace. The heat flow signal was stabilized for one minute at 30 °C, prior to heating to 300 °C in a stream of nitrogen at a rate of 10 °C/minute.

[0173] ^{1}I-I Nuclear Magnetic Resonance spectroscopy (^{1}H NMR)

^{1}I-I NMR analysis was carried out on a Bruker 400 or 500 MHz instrument in CD_3OD (MeOH-d_4) or DMSO-d_6. Instrumental parameters are listed on the relevant spectrum plots.

[0174] Optical and hot stage microscopy

Microscopy analyses were carried out using an Olympus BX51 stereomicroscope with crosspolarized light and a 1st order red compensator plate. Photomicrographic images were captured using a ColorView™ IIIu digital camera and SynchronizIR basic V5.0 imaging software with objective lens magnification of x10. Hot stage microscopy analyses were performed using a Linkam hot stage accessory. Solid samples were heated using pre-set temperature programs which included the selected ramp rate, final temperature and interval hold times if required for individual samples.

[0175] Volumetric Karl Fischer (KF) analysis for water content

Volumetric KF analysis was performed using a Mettler Toledo V30 KF titrator. A weighed amount of solid sample was added directly to the KF cell. The solution was stirred, and the water content of the sample was then determined by automatic titration against standard KF reagent titrant.

[0176] Reference Example, Preparation of AAT-730 (Compound A) 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yll sulfonyl)azetidin-l-yllethan-l-ol (AAT-730) was prepared according to the procedure described in the Non Patent Literature 25 (Bioorg. Med. Chem. Lett. 2015, 25: 236-240). The solid reaction product was further purified by the following preparative HPLC procedure.

The solids (22.8 g) were dissolved in 10% ACN containing 0.1% TFA in water (460 mL) and purified by HPLC using ODS silica (Daiso SP-120-40/60 ODS-B, 110 × 1000 mm, 10 L volume, OSAKA SODA CO.,LTD., Osaka, Japan), gradient elution with 0.1% TFA/ACN system (ascending mode of ACN from 9% to 15%) at a flow rate of 200 mL/min, and UV detection at 220 nm. The collected fractions (24 L) were evaporated to remove ACN under 30 °C. Then, to the concentrated aqueous mixture was added 0.5% aq. Ammonia (2 L) and chloroform (1 L), and the organic layer was separated. The aqueous layer was extracted with chloroform (1 L). The combined organic layers were washed with water and brine, dried with sodium sulfate, and concentrated to give a residue. The residue was dried under reduced pressure at room temperature overnight to afford 12.4 g of AAT-730 (Lot No. 033-190725-1) as a colorless oil.

The product (12.4 g) was recrystallized from a mixture of isopropyl acetate (15 mL) and n-heptane (30 mL) to provide 10.79 g of AAT-730 (Lot No. 33-13) as white solids.

[0177] Example 1, Free base form of AAT-730 (Compound A)

Free base form of AAT-730 was characterized by XRPD, polarized light microscopy, TG/DTA, DSC, and ^{1}H NMR. The stability was also tested at a range of elevated relative humidity conditions for 7 days. The solubility of AAT-730 free base was estimated in various solvent systems.

[0178] Example 1-1, Characterization of AAT-730 (Compound A)

The XRPD pattern obtained for AAT-730 is shown in Figure 2-1. The XRPD pattern is indicative of a crystalline material.

[0179] Thermogravimetric/Differential Thermal Analysis (TG/DTA) was performed to determine the thermal profile and associated % weight changes of AAT-730 (Figure 2-2).

[0180] Weight loss of 0.05% was noted from 30 °C to 225 °C suggesting minimal moisture or solvent content, indicating AAT-730 to be an anhydrous material. A second weight loss at temperatures greater than approximately 250 °C may correspond to the initiation of decomposition of the material. A melting endotherm was observed at onset temperature 102.23 °C.

[0181] The DSC thermogram obtained for AAT-730 at 10 °C/min is shown in Figure 2-3 and the melting onset is 100.67 °C.

[0182] The ^{1}H NMR spectrum of AAT-730 analyzed (Figure 2-4 and Figure 2-5) conformed to the molecular structure and solvent was not detected.

[0183] Polarized light microscopy of AAT-730 showed that the material is composed of crystalline particles of varying particle size distribution. The crystal habit appears to be laths, as shown in the photomicrograph (Figure 2-6).

[0184] AAT-730 free base was stressed at elevated relative humidity and temperature as

shown in Table 1-2. XRPD analysis of the post-stressed samples (Figure 2-7) showed a change in form to the hydrate at 40 °C/75% RH and at 70 °C/75% RH. The material remained as an anhydrate at 25 °C/60% RH. ^{1}H NMR analysis (Figure 2-8, Figure 2-9, and Figure 2-10) showed no change.

[0185] Table of humidity stressing experiments

[Table 1-2]

Sample No. (CAT-0001E-)	Conditions
023-07	25 °C/60% RH
023-08	40 °C/75% RH
023-09	70 °C/75% RH

[0186] Conclusions from characterization

1) XRPD analysis indicated that AAT-730 was a crystalline material and polarized light microscopy concurred with this.

2) TG/DTA data showed negligible weight loss from 30-225 °C, suggesting minimal moisture or residual solvent content, and shows that AAT-730 remains thermally stable up to 250 °C.

3) Heat rate studies by DSC indicated a melting onset of 100.7 °C.

4) ^{1}H NMR spectroscopy conformed to molecular structure and no solvent was detected.

5) XRPD and ^{1}H NMR analyses of AAT-730 free base samples after elevated relative humidity and temperature stressing suggested that the anhydrate had converted to a hydrate at 40 °C/75% RH and 70 °C/75% RH.

[0187] Example 1-2, Solubility estimation

Aliquots of the test solvent were added to an accurately weighed sample (at most 25 mg) of AAT-730 at ambient temperature. The aliquot volumes were typically 20-200 μL. Complete dissolution of the test material was determined by visual inspection. The solubility was estimated from these experiments based on the total solvent used to provide complete dissolution. It should be noted that the actual solubility may be greater than that calculated because of the use of solvent aliquots that were too large or due to a slow rate of dissolution.

If dissolution did not occur after the last aliquot of solvent was added (typically at most 40 volumes of solvent), the sample was subjected to two cycles of the following temperature cycling regime on the Clarity crystallization station:

Heating from 20 °C to within 3 °C of solvent boiling point (or 100 °C, whichever was lower) at 0.5 °C/minute.

Cooling to 20 °C at 0.2 °C/minute.

Stirrering speed 800 rpm.

From the infrared (IR) transmission data of the sample vials, dissolution and precipitation events were recorded as the point of complete transmission of IR and the onset of turbidity by IR respectively.

(Note: IR probe was not functioning correctly throughout; did not give the dissolution temperature of MIBK)

Samples were held at ambient temperature for at least 18 hours to maximize the chance of precipitation. Any recoverable solids were analyzed by XRPD. The solubility values for AAT-730 were expressed as a range and rounded to the nearest whole number.

[0188] Estimated solubility of AAT-730 (Compound A)

The solubility of AAT-730 was estimated in 20 solvent systems using the aliquot addition method. These included 4 aqueous/organic mixtures at compositions. AAT-730 had a solubility of >25 mg/mL in 11 of the solvents and 4 of the aqueous mixtures at ambient temperature. The solubility data obtained is shown in Table 1-3. AAT-730 had an aqueous solubility of approximately 367-514 mg/mL.

[0189] Solubility estimates of AAT-730 at 20 °C

[Table 1-3]

Solvent	Acronym	Solubility range (mg/mL)
acetone	-	118-157
acetonitrile	ACN	145-164
anisole	-	58-60
cyclohexane	-	<24
dichloromethane	DCM	360-504
dimethyl sulfoxide	DMSO	242-303
dioxane	-	117-129
ethanol	EtOH	213-256
ethyl acetate	EtOAc	27-28
methanol	MeOH	>510
methyl isobutyl ketone	MIBK	<26
methyl *tert*-butyl ether	MTBE	<26
2-propanol, isopropyl alcohol	IPA	81-87
tetrahydrofuran	THF	246-492
toluene	-	<25
water	-	367-514
acetone/water (50/50, A_w at most 0.91)	-	618-1235
EtOH/water (96/4, A_w at most 0.25)	-	313-417
MeOH/water (84/16, A_w at most 0.44)	-	638-1275
THF/water (96/4, A_w at most 0.74)	-	410-615

[0190] Conclusions from solvent screening

AAT-730 had a solubility greater than or equal to 25 mg/mL in 15 of the solvents and aqueous mixtures tested. It had an aqueous solubility of approximately 367-514 mg/mL.

[0191] Example 2, Polymorph screening of AAT-730 (Compound A) freebase

A focused polymorph screen has been performed on AAT-730 freebase, the objective of which was to investigate the polymorphic landscape of AAT-730 free base. The approach was to generate solids under a wide and diverse range of nucleation conditions, designed to mimic the process conditions and solvents used during development and formulation. The starting material used in this study was AAT-730 (Lot No. 33-13).

[0192] All solids from the crystallization experiments were analyzed by XRPD and the resulting patterns compared to that exhibited by the starting material. Novel XRPD patterns were assigned an alphabetical descriptor in order of discovery (Pattern A, Pattern B etc.). Where sufficient material was available, further analysis (e.g. ^{1}H NMR

or TGA) was conducted on solids with novel XRPD patterns to allow tentative assignment of the novel pattern as a polymorph, solvate, hydrate, degradant or mixture thereof.

[0193] Polymorph screening methods of Example 2

Method 2-1, Slow evaporation

A solution of AAT-730 was prepared in each solvent and filtered through a 0.2 μm PTFE filter. The filtered solution was evaporated in a fume hood at ambient temperature in a vial covered with perforated aluminum foil. High boiling solvents (boiling point >100 °C) were evaporated under a flow of nitrogen. The resulting solids were analyzed by XRPD.

[0194] Method 2-2, Crash precipitation

AAT-730 (20 mg) was dissolved in solvent (100-400 μL) and added into a vial containing antisolvent (2.5-10 volumes) at ambient temperature and the mixture stirred overnight. In some cases, an oil was generated, and the samples were heated up to 40 °C and/or further anti-solvent was added. Where precipitation was not observed overnight, samples were cooled to 5 °C to encourage precipitation.

[0195] Method 2-3, Slurry experiments

Sufficient AAT-730 (Lot No. 33-13 or gels from previous experiments) was added to a given solvent until undissolved solids remained at the desired temperature (5, 20, or 40 °C). The vial was sealed, and the slurry was maintained at the selected temperature and agitated by magnetic stirring for 4-7 days or approximately 2 hours for gels. Solids were isolated by centrifugation and air dried prior to analysis by XRPD.

[0196] Method 2-4, Slow cooling

AAT-730 (Lot No. 33-13, at most 20 mg) and solvent (100-1000 μL) were added to a vial and stirred to form an almost saturated solution at 60 °C (the solvent was added in aliquots). The solutions were cooled without agitation at 0.2 °C/min to a final temperature of 5 °C. Experiments that precipitated solids were filtered and air dried before analysis by XRPD.

[0197] Method 2-5, Vapor stress

Approximately 20 mg of amorphous AAT-730 was prepared by melt quench as detailed in Example 2-1. Each vial was placed unsealed inside a larger sealed vessel containing 500 μL of the selected solvent. After up to 7 days, the samples were removed and analyzed by XRPD.

[0198] Method 2-6, Humidity stress

Approximately 20 mg of amorphous AAT-730 was prepared by melt quench as detailed in Example 2-1. Each vial was placed unsealed inside the following relative humidity chambers (sealed cabinets with relative humidity conditions controlled by super-saturated salt solutions) for 7 days prior to analysis by XRPD:

Chamber 1 - 23% RH
Chamber 2 - 59% RH
Chamber 3 - 76% RH
Chamber 4 - 98% RH

[0199] Method 2-7, Temperature cycling

The test solvent (100 μL) was added to a sample of AAT-730 (at most 20 mg) at ambient temperature and 10 cycles of the following temperature program was performed using the Clarity crystallization station:

Heating from 20 °C to 60-80 °C at 1 °C/min (depending on boiling point of solvent)
Cooling to 20 °C at 1 °C/min
Stirrering speed - 600 rpm

[0200] Method 2-8, Sonication of pastes

AAT-730 (at most 20 mg) was added to a vial with 10 μL of the selected solvent to form a paste. The mixture was sonicated at 50% intensity using a Cole-Parmer 130 Watt ultrasonic processor using a pulsed program (3 cycles - 30 seconds on and 30 seconds off). In cases where the solids dissolved at ambient temperature, the sample was left uncapped to evaporate. The wet pastes recovered from these experiments were analyzed using XRPD.

[0201] Method 2-9, Thermal stressing

Approximately 20 mg of various forms of AAT-730 was added to a vial, flushed with nitrogen, sealed and placed into a heater block at 40, 60, or 80 °C for varying times prior to analysis by XRPD.

[0202] Method 2-10, Vapor diffusion

A solution of AAT-730 was prepared and the vial was placed unsealed inside larger vials, which contained an aliquot of anti-solvent. The larger vials were sealed and left undisturbed under ambient conditions for up to 7 days. Solids were isolated by centrifugation and air dried prior to analysis by XRPD. Cyclohexane (500 μL) was added to vials which contained solutions, and these were stirred for 16 hours prior to isolation of solids and analysis by XRPD.

[0203] Example 2-1, Generation of amorphous AAT-730 (Compound A, Melt quench)

Amorphous AAT-730 was generated from melt quench for screening. AAT-730 (20 mg) was added to a HPLC vial and flushed with N_2. This was heated to 120 °C for up to 5 minutes and was quickly immersed in a liquid nitrogen/acetone mixture to form amorphous AAT-730. The resulting amorphous material was confirmed visually by microscopy.

[0204] Example 2-2, Slow evaporation

Slow evaporation of AAT-730 solutions were conducted as described in Method 2-1. The results are shown in Table 2-1. Solids were isolated from four evaporation ex-

periments. Pattern A material was isolated from DCM and EtOAc and Pattern C material was isolated from acetone. Pattern B material was isolated from water, although some amorphous content was noted. All other experiments afforded gels and were slurried in cyclohexane (Table 2-3). Unique materials were further characterized and are discussed further in Examples 2-11 to 2-14.

[0205] Screening results from slow evaporation experiments

[Table 2-1]

Sample (TW-0011E-)	Solvent	Result	XRPD
001-01	acetone	solid	Pattern C
001-02	ACN	gel	N/A
001-03	DCM	solid	Pattern A (PO)
001-04	EtOH	gel	N/A
001-05	EtOAc	solid	Pattern A
001-06	MeOH	gel	N/A
001-07	IPA	gel	N/A
001-08	water	solid	Pattern B + amorphous (minor)
001-09	THF	gel	N/A

PO = preferred orientation

[0206] Example 2-3, Crash precipitation experiments

Crash precipitation experiments were carried out as detailed in Method 2-2. Solvents and chemically diverse anti-solvents were selected, and the results are shown in Table 2-2. In four cases, precipitation was not observed. Experiments which afforded solids were confirmed as Pattern A, Pattern B and Pattern C material by XRPD and these are discussed further in Examples 2-11 to 2-14.

[0207] Precipitation of saturated AAT-730 solutions with anti-solvents

[Table 2-2]

Sample No. (TW-0011E-)	Solvent	Anti-solvent	Result	XRPD
003-01	acetone	cyclohexane	solid	Pattern C
003-02	EtOAc	cyclohexane	solid	Pattern B
003-03	EtOH	cyclohexane	solution	N/A
003-04	THF	cyclohexane	solid	Pattern A
003-05	water	toluene	solid	Pattern B
003-06	acetone	MTBE	solution	N/A
003-07	ACN	MTBE	solution	N/A
003-08	dioxane	MTBE	solid	Pattern B
003-09	DCM	MTBE	solid	Pattern C
003-10	EtOH	MTBE	solution	N/A

[0208] Example 2-4, Slurry experiments

Suspensions of AAT-730 in various solvents were held at 5, 20 and 40 °C for 5-7 days prior to isolation and analysis by XRPD (Table 2-3) as detailed in Method 2-3. Pattern B and Pattern C materials were isolated from a range of solvents and temperatures in pure form with Pattern B + C also isolated from a few experiments. A unique form, Pattern D was isolated from the recycling of a gel in cyclohexane however, this was isolated as a mixture with Pattern A material. No further analysis was performed on this mixture.

[0209] Screening results from slurry experiments

[Table 2-3]

Sample No (TW-0011E-)	Input material	Solvent	Temp (°C)	Result	XRPD
002-01	Lot No. 33-13	acetone	5	solution	N/A
002-02	Lot No. 33-13	ACN/cyclohexane (20/80)	5	solution	N/A
002-03	Lot No. 33-13	EtOAc	5	solid	Pattern B
002-04	Lot No. 33-13	MIBK	5	solid	Pattern B + C
002-05	Lot No. 33-13	MTBE	5	solid	Pattern C + B
002-06	Lot No. 33-13	IPA	5	solid	Pattern C
002-07	Lot No. 33-13	toluene	5	solid	Pattern C
013-01	Lot No. 33-13	MeOH/water (84/16, A_w at most 0.44)	5	solution	N/A
013-02	Lot No. 33-13	THF/water (96/4, A_w at most 0.74)	5	solid	Pattern B
013-03	Lot No. 33-13	acetone/water (20/1, A_w at most 0.6)	5	solid	Pattern B
005-01	Lot No. 33-13	EtOAc	20	solid	Pattern B
005-02	Lot No. 33-13	acetone/cyclohexane (20/80)	20	solid	Pattern C
005-03	Lot No. 33-13	IPA/cyclohexane (20/80)	20	solid	Pattern C
005-04	Lot No. 33-13	ACN/cyclohexane (10/90)	20	solid	Pattern C
005-05	Lot No. 33-13	dioxane/cyclohexane (10/90)	20	solid	Pattern C + B
004-01	Lot No. 33-13	cyclohexane	40	solid	Pattern C
004-02	Lot No. 33-13	MTBE	40	solid	Pattern C
004-03	Lot No. 33-13	MIBK	40	solid	Pattern C
004-04	Lot No. 33-13	toluene	40	solid	Pattern C
012-01	001-02	cyclohexane	40	solid	Pattern B
012-02	001-04	cyclohexane	40	solid	Pattern B + C
012-03	001-06	cyclohexane	40	solid	Pattern B + C
012-04	001-07	cyclohexane	40	solid	Pattern B + C
012-05	001-09	cyclohexane	40	solid	Pattern D + A

[0210] Example 2-5, Slow cooling

The slow increase in supersaturation allows more stable forms to nucleate. A sub-

ambient final temperature also probes for stable solvates at temperatures typically accessed during cooling crystallization at plant scale. Experiments were carried out as detailed in Method 2-4. Table 2-4 shows the screening results from slow cooling experiments. Pattern C material was isolated from most experiments. A mixture of Pattern C + A with preferred orientation was isolated from EtOAc. Crystallization was not observed from an experiment with MIBK.

[0211] Screening results from slow cooling experiments

[Table 2-4]

Sample No. (TW-0011E-)	Solvent	Result	XRPD
006-01	acetone	solid	Pattern C (PO)
006-02	EtOAc	solid	Pattern C + A (PO)
006-03	MIBK	solution	N/A
006-04	MTBE	solid	Pattern C
006-05	toluene	solid	Pattern C

PO= preferred orientation

[0212] Example 2-6, Vapor and humidity stress

X-ray amorphous material generated from melt quench was exposed to air saturated in solvent vapor and various controlled humidity conditions for up to 7 days before analysis by XRPD as detailed in Method 2-5 and Method 2-6. The results are shown in Table 2-5. As amorphous material has lost long range order, it is in a high energy state. Exposure to vapor plasticizes the solid, allowing limited molecular mobility and is therefore an excellent method of generating metastable solvates and hydrates. Several mixtures of forms were isolated from these experiments (Patterns A+B, A+C and B+C). Phase pure Pattern C material was isolated from the majority of these stress experiments. Pattern B material was isolated from stressing at 98% relative humidity. Pattern A material was isolated from three experiments but with some amorphous content present from stressing in cyclohexane, with peak shifting from stressing in MTBE and with an extra peak present from stressing in toluene.

[0213] Results from vapor stressing and humidity experiments

[Table 2-5]

Sample No. (TW-0011E-)	Solvent	Result	XRPD
008-01	acetone	solid	Pattern C (PO)
008-02	ACN	solid	Pattern C (PO)
008-03	cyclohexane	solid	Pattern A (slight amorphous character)
008-04	DCM	solid	Pattern C + A + peak at 6.56
008-05	EtOH	gel	Pattern A + B
008-06	EtOAc	solid	Pattern C
008-07	MIBK	solid	Pattern C (PO)
008-08	MTBE	solid	Pattern A (PS)
008-09	IPA	solid (after cyclohexane added)	Pattern B + C
008-10	THF	solid	Pattern C
008-11	toluene	solid	Pattern A + peak at 7.33
009-01	23% RH stress	gel (solid after cyclohexane added)	Pattern B + C
009-02	59% RH stress	solid	Pattern C
009-03	75% RH stress	solid	Pattern C
009-04	98% RH stress	gel (solid after cyclohexane added)	Pattern B

PO = preferred orientation, PS = peak shifting

[0214] Example 2-7, Temperature cycling

Samples were subjected to the temperature cycling program outlined in Method 2-7 and the results are shown in Table 2-6. Pattern C material was isolated from most experiments. A mixture of Pattern A + C was isolated from cycling IPA.

[0215] Screening results from temperature cycling experiments

[Table 2-6]

Sample No. (TW-0011E-)	Solvent	Result	XRPD
010-01	anisole	solid	Pattern C
010-02	cyclohexane	solid	Pattern C
010-03	EtOAc	solid	Pattern B + C
010-04	MIBK	solid	Pattern C
010-05	MTBE	solid	Pattern C
010-06	IPA	solid	Pattern A + C
010-07	toluene	solid	Pattern C

[0216] Example 2-8, Sonication

Sonication experiments were carried out as detailed in Method 2-8. The results are shown in Table 2-7. Most experiments afforded Pattern C material. Pattern B material was isolated from an experiment with water. A mixture of forms, Pattern A + C was isolated from an experiment with MTBE. Solutions were isolated from four ex-

periments and no further work was performed on these samples.

[0217] Screening results from sonication experiments

[Table 2-7]

Sample No. (TW-0011E-)	Solvent	Result	XRPD
011-01	acetone	solid	Pattern C
011-02	ACN	solid	Pattern C
011-03	anisole	solid	Pattern C
011-04	DCM	solid	Pattern C
011-05	dioxane	solution	N/A
011-06	EtOH	solution	N/A
011-07	EtOAc	solid	Pattern C
011-08	MeOH	solution	N/A
011-09	MIBK	solid	Pattern C
011-10	MTBE	solid	Pattern A + C
011-11	IPA	solution	N/A
011-12	toluene	solid	Pattern C
011-13	water	solid	Pattern B

[0218] Example 2-9, Thermal stress

AAT-730 was thermally stressed at 40 or 60 °C for several days in a sealed vial and analyzed by XRPD as detailed in Method 2-9. The results are shown in Table 2-8. AAT-730 (Lot No. 33-13), Pattern A (isolated during screening) and Pattern B were physically unstable to stressing at the temperatures tested. Pattern C remained physically stable to stressing at 40 °C. Pattern B material was also stressed at 80 °C.

[0219] Screening results from thermal stress experiments

[Table 2-8]

Input	Sample No. (TW-0011E-)	Temp (°C)	Result	XRPD	Comments/ Time
Lot No. 33-13	014-01	40	solid	Pattern A + Pattern C	increase in the amount of Pattern C
Lot No. 33-13	014-02	60	solid	Pattern A + Pattern C	-
Pattern B	014-03	40	solid	Pattern C	-
Pattern C	014-04	40	solid	Pattern C	-
Pattern A	014-05	40	solid	Pattern A + Pattern C	-
Pattern B	014-06	60	solid	Pattern A	-
Pattern B	016-01	80	solid	Pattern A (very weak sample)	20 minutes
Pattern B	016-02	80	solid	Pattern A (disordered/weak sample)	120 minutes

[0220] Example 2-10, Vapor diffusion

Vapor diffusion experiments were carried out as detailed in Method 2-10. The results are shown in Table 2-9. No novel patterns were isolated.

[0221] Screening results from vapor diffusion experiments

[Table 2-9]

Sample No. (TW-0011E-)	Solvent	Anti-solvent	Result	XRPD
015-01	acetone	cyclohexane	solid	Pattern C
015-02	EtOH	cyclohexane	solid (after trituration)	Pattern B + C
015-03	EtOAc	cyclohexane	solid	Pattern C
015-04	IPA	cyclohexane	solid (after trituration)	Pattern B
015-05	THF	cyclohexane	solid	Pattern A

[0222] Conclusions from polymorph screening

Approximately 100 experiments were carried out using solvent and non-solvent based techniques. Four crystalline solids (Table 2-10) were observed during this study, including AAT-730 (Lot No. 33-13). Amorphous material was also generated from melt quench of AAT-730.

[0223] Summary of the physical forms observed during this study

[Table 2-10]

Pattern	Comment
A	Novel polymorph, suspected anhydrate
B	Novel polymorph, suspected monohydrate
C	Novel polymorph, suspected anhydrate
D	Unique pattern, only isolated as a mixture with Pattern A
Amorphous	Isolated by melt quench up to 130 °C

[0224] Example 2-11, Preparation and characterization of AAT-730 (Compound A), Pattern A

AAT-730 Pattern A material was isolated from a range of screening experiments, as shown in Table 2-11. Pattern A material is a crystalline solid and the XRPD diffractogram is shown in Figure 3-1. TG/DTA analysis (Figure 3-2) suggests that Pattern A material is an anhydrate with a melting onset up to 99.5 °C. Thermally stressing Pattern A material at 40 °C gave a mixture of Pattern A + Pattern C suggesting that Pattern A is thermally unstable and converts to Pattern C.

[0225] Screening experiments which yielded Pattern A solids

[Table 2-11]

Input	Sample No. (TW-0011E-)	Solvent	Antisolvent	Screen method	Result	XRPD
Lot No. 33-13	001-03	DCM	none	slow evap	solid	Pattern A
Lot No. 33-13	001-05	EtOAc	none	slow evap	solid	Pattern A
Lot No. 33-13	003-04	THF	cyclohexane	crash pptn	solid	Pattern A
amorphous	008-03	cyclohexane	none	vapor stress	solid	Pattern A (slight amorphous character)
amorphous	008-08	MTBE	none	vapor stress	solid	Pattern A (PS)
Pattern B	014-06	N/A	N/A	thermal stress (60 °C)	solid	Pattern A
Lot No. 33-13	015-05	THF	cyclohexane	vapor diffusion	solid	Pattern A
Pattern B	016-02	N/A	N/A	thermal stress (80 °C)	solid	Pattern A

PS = peak shifting

[0226] Example 2-12, Preparation and characterization of AAT-730 (Compound A) Pattern B

AAT-730 Pattern B material was isolated from a range of experiments using various solvents and techniques as shown in Table 2-12. The XRPD trace is shown in Figure 3-3 and the material was crystalline. TG/DTA (Figure 3-4) showed a weight loss of at most 4.2% w/w between approximately 40 and 120 °C which corresponded to at most 1 mole of water, suggesting Pattern B was a monohydrate. Pattern B material was physically unstable to stressing at 40 and 60 °C, converting to Pattern C and Pattern A respectively as shown in Figure 3-5.

[0227] Screening experiments which yielded Pattern B solids

[Table 2-12]

Input	Sample No. (TW-001E-)	Solvent	Anti-solvent	Screen method	Result	XRPD
Lot No. 33-13	001-08	water	none	slow evap	solid	Pattern B
Lot No. 33-13	002-03	EtOAc	none	slurry (5 °C)	solid	Pattern B
Lot No. 33-13	003-02	EtOAc	cyclohexane	crash pptn	solid	Pattern B
Lot No. 33-13	003-05	water	toluene	crash pptn	solid	Pattern B
Lot No. 33-13	003-08	dioxane	MTBE	crash pptn	solid	Pattern B
Lot No. 33-13	005-01	EtOAc	none	slurry (20 °C)	solid	Pattern B
amorphous	009-04	none	none	98% RH stress	gel	Pattern B
Lot No. 33-13	011-13	water	none	sonication	solid	Pattern B
gel (001-02)	012-01	cyclohexane	none	slurry (40 °C)	solid	Pattern B
Lot No. 33-13	013-03	Acetone/water, A_w at most 0.6	none	slurry (5 °C)	solid	Pattern B

[0228] Example 2-13, Preparation and characterization of AAT-730 (Compound A) Pattern C

AAT-730 Pattern C material was isolated from a range of experiments using various solvents and techniques as shown in Table 2-13. The XRPD trace is shown in Figure 3-6 and the material was crystalline. Pattern C solids were analyzed by ^{1}H NMR (Figure 3-8) and TG/DTA (Figure 3-7) analyses. TG/DTA analysis showed at most 0.4% weight loss between approximately 30 and 200 °C which was likely due to a small amount of residual solvent. The ^{1}H NMR spectrum concurred with the molecular structure and a small amount of cyclohexane was present in the spectrum suggesting Pattern C material was an anhydrate with a very similar melting point to Pattern A material. The melting onset of Pattern C material, determined by TG/DTA is up to 100.8 °C.

[0229] Screening experiments which yielded Pattern C solids

[Table 2-13]

Input	Sample No. (TW0011E-)	Solvent	Anti-solvent	Screen method	XRPD
Lot No. 33-13	001-01	acetone	none	slow evap	Pattern C
Lot No. 33-13	002-06	IPA	none	slurry (5 °C)	Pattern C
Lot No. 33-13	002-07	toluene	none	slurry (5 °C)	Pattern C
Lot No. 33-13	003-01	acetone	cyclohexane	crash pptn	Pattern C
Lot No. 33-13	003-09	DCM	MTBE	crash pptn	Pattern C
Lot No. 33-13	004-01	cyclohexane	none	slurry (40 °C)	Pattern C
Lot No. 33-13	004-02	MTBE	none	slurry (40 °C)	Pattern C
Lot No. 33-13	004-03	MIBK	none	slurry (40 °C)	Pattern C
Lot No. 33-13	004-04	toluene	none	slurry (40 °C)	Pattern C
Lot No. 33-13	005-02	acetone/cyclohexane (20/80)	none	slurry (20 °C)	Pattern C
Lot No. 33-13	005-03	IPA/cyclohexane (20/80)	none	slurry (20 °C)	Pattern C
Lot No. 33-13	005-04	ACN/cyclohexane (10/90)	none	slurry (20 °C)	Pattern C
Lot No. 33-13	006-01	acetone	none	slow cool	Pattern C
Lot No. 33-13	006-05	toluene	none	slow cool	Pattern C
amorphous	008-01	acetone	none	vapor stress	Pattern C (PO)
amorphous	008-02	ACN	none	vapor stress	Pattern C (PO)
amorphous	008-06	EtOAc	none	vapor stress	Pattern C
amorphous	008-07	MIBK	none	vapor stress	Pattern C (PO)
amorphous	009-02	none	none	59% RH stress	Pattern C
amorphous	009-03	none	none	75% RH stress	Pattern C
Lot No. 33-13	010-02	cyclohexane	none	temp cycle	Pattern C
Lot No. 33-13	010-04	MIBK	none	temp cycle	Pattern C
Lot No. 33-13	010-05	MTBE	none	temp cycle	Pattern C
Lot No. 33-13	010-07	toluene	none	temp cycle	Pattern C
Lot No. 33-13	011-01	acetone	none	sonication	Pattern C
Lot No. 33-13	011-02	ACN	none	sonication	Pattern C
Lot No. 33-13	011-03	anisole	none	sonication	Pattern C
Lot No. 33-13	011-04	DCM	none	sonication	Pattern C
Lot No. 33-13	011-07	EtOAc	none	sonication	Pattern C
Lot No. 33-13	011-09	MIBK	none	sonication	Pattern C
Lot No. 33-13	011-12	toluene	none	sonication	Pattern C
Pattern C	014-04	none	none	thermal stress 40 °C	Pattern C

PO= preferred orientation

[0230] Example 2-14, Preparation and characterization of AAT-730 (Compound A) Pattern D

Pattern D material was isolated from one slurry experiment (40 °C) in cyclohexane as a mixture with Pattern A. The diffractogram is shown in Figure 3-9 and was crystalline. As Pattern D was isolated as a mixture, no further analysis was performed.

[0231] Conclusions

1) XRPD analysis indicated that AAT-730 (Lot No. 33-13) was a mixture of two

crystalline forms, Pattern A and Pattern C.

2) Approximately 100 experiments were carried out using solvent and non-solvent based techniques. Four crystalline XRPD patterns (Table 2-10) were observed during this study, including AAT-730 (Lot No. 33-13). Amorphous material was also generated from melt quench of AAT-730.

3) Patterns A and C materials appear to be crystalline anhydrates with similar melting points. Pattern C appears to be the most stable of these forms as it was isolated from most of the slurry experiments starting with AAT-730 (Lot No. 33-13).

4) AAT-730 Pattern B material is a monohydrate which dehydrates on heating to either Pattern A or Pattern C material.

[0232] Example 3, Salt screening

The starting material used in this study was AAT-730 (Lot No. 33-13). Table 3-1 shows details of the materials and reagents used in the salt screen. The list has been chosen based on the following factors:

pK_a - AAT-730 has pK_a values of 7.1 and 2.1, and the counterions were chosen with a pK_a difference of >2 pK_a units for salt formation.

Acids which are pharmaceutically acceptable, generally Class 1 but some Class 2 salt formers have also been included as these may give good salt properties and have been used previously in marketed drugs.

At the screening stage, a range of different types of counterion: mineral acids, carboxylic acids, aromatic acids, mono, di and tri-acids, different carbon chain lengths, cyclic acids, chiral and non-chiral acids as the properties of the counterion affect the properties of the salts were chosen.

Generally a low molecular weight counterion is preferred, however, in this case the increase in molecular weight may be a benefit due to the low melting point of the API.

[0233] Details of acids used in screening

[Table 3-1]

Acid	MW	pK_a	Class	ADI/GRAS*
acetic acid	60.05	4.76	1	No limit/yes
L-ascorbic acid	176.13	4.17, 11.57	1	No limit/yes
L-aspartic acid	133.11	1.88, 3.65, 9.6	1	No limit/yes
benzenesulfonic acid	158.18	0.7	2	
citric acid	192.13	3.13, 4.76, 6.4	1	No limit/yes
ethane-1,2-disulfonic acid (EDSA)	190.2	-2.06, -1.5	2	
fumaric acid	116.02	3.03, 4.38	1	6 mg/kg
2,5-dihydroxybenzoic acid (gentisic acid)	154.12	2.93	2	
D-gluconic acid	196.16	3.76	1	No limit/yes
D-glucuronic acid	194.14	3.18	1	
L-glutamic acid	147.13	2.19, 4.25, 9.67	1	No limit/yes
glutaric acid	132.12	4.34, 5.22	1	
glycolic acid	76.05	3.83	1	
hippuric acid	179.17	3.55	1	
hydrochloric acid (HCl)	36.46	-6	1	No limit/yes
L-lactic acid	90.08	3.86	1	
maleic acid	116.08	1.92, 6.23	1	
L-malic acid	134.09	3.46, 5.1	1	Acceptable/yes
methanesulfonic acid (MSA)	96.1	-1.2	2	
phosphoric acid	98.0	1.96, 7.12, 12.32	1	70 mg/kg/yes
p-toluenesulfonic acid (*p*-TSA)	172.2	-1.34	2	
succinic acid	118.09	4.21, 5.64	1	No limit/yes
sulfuric acid (H_2SO_4)	98.08	-3, 1.92	1	No limit/yes
L-tartaric acid	150.09	3.02, 4.36	1	30 mg/kg/yes

* ADI: Acceptable Daily Intake, GRAS: Generally Recognized As Safe

[0234] The salt screening approach was to generate salts from precipitation experiments with 24 acids and test the stability of any salts to elevated relative humidity. TG/DTA analysis was also carried out on any stable salts to determine the melting point.

All solids from the salt formation experiments were analyzed by XRPD and the resulting patterns compared to that exhibited by the starting material. Where sufficient material was available, further analysis (e.g. ^{1}H NMR or TGA) was conducted on solids with novel XRPD patterns to allow tentative assignment of the novel pattern as a salt.

[0235] Salt screening methods of Example 3

Experiments were carried out at a scale of at most 30 mg with 1:1, 1:0.5 and 1:2 stoichiometry (free base of AAT-730:salt former). Solutions of the free base in the chosen solvent were added to either solutions of the salt former, or if the salt was not soluble in the solvent, slurries of the salt formers. Any solids which precipitated were

recovered and analyzed by XRPD analysis to determine if the solid was crystalline.

[0236] Method 3-1, Preparation of stock solution of AAT-730 (Compound A) in THF

AAT-730 (1.059 g) was added to a 5 mL volumetric flask, dissolved in THF and diluted to volume with THF. The concentration of the stock solution was up to 1 M.

[0237] Method 3-2, Preparation of stock solution of AAT-730 (Compound A) in THF/water

AAT-730 (1.058 g) was added to a 5 mL volumetric flask, dissolved in THF/water (9/1) and diluted to volume with THF/water (9/1). The concentration of the stock solution was up to 1 M.

[0238] Method 3-3, Precipitation experiments

The required acid (1 molar equivalent) was added to each HPLC vial and the API stock solution (containing 30 mg of API) was added. The mixtures were stirred at 300 rpm (ambient temperature) for up to 16 hours. Any solids which precipitated were isolated by centrifugation, solvent decanted and solids dried with thin strips of filter paper prior to analysis by XRPD. Any solutions were evaporated to dryness and solids analyzed by XRPD. Gels were either triturated or temperature cycled in MTBE.

[0239] Method 3-4, Slurry/precipitation experiments

API (30 mg), acid co-former (1 mol. eq.) and ethanol (300 μL) were added to HPLC vials and stirred at 40 °C for up to16 hours. Solids were recovered by centrifugation, solvent decanted and dried with thin strips of filter paper prior to analysis by XRPD. Solutions were evaporated to dryness.

[0240] Method 3-5, Trituration of gels in MTBE or EtOAc

Gels isolated from the screening experiments were triturated in either MTBE or EtOAc to induce precipitation. MTBE or EtOAc (200 μL) was added to the gel and stirred at 40 °C for up to 3 hours prior to cooling to ambient and stirring for up to 48 hours. Any solids were isolated by centrifugation, solvent decanted and solids dried with thin strips of filter paper prior to analysis by XRPD. Any solutions were evaporated to dryness.

[0241] Method 3-6, Temperature cycling of gels in MTBE

Gels isolated from screening experiments were temperature cycled in MTBE according to the following program:

Heating from 20 °C to 40 °C at 0.2 °C/minute.

Coolling to 20 °C at 0.1 °C/minute.

Stirrering speed 400 rpm.

Solids were recovered by centrifugation, solvent decanted and solids dried with thin strips of filter paper prior to analysis by XRPD.

[0242] Method 3-7, Planetary Milling

AAT-730 (at most 30 mg), acid co-former (1 mol. eq.) and isopropyl acetate (i-PrOAc, 20 μL) were added to vials with 3 steel milling balls. The vials were sealed

and the contents milled using a Fritsch Pulverisette 5 planetary mill (30 repetitions of 20 minutes milling at 400 rpm and 20 minutes pause). The resultant material was analyzed using XRPD.

[0243] Method 3-8, Humidity stress of possible salts

Samples of the suspected salts were added to HPLC vials (if sufficient material was available the weight was recorded). The samples were place in a RH chamber at 40 °C. The relative humidity of the chamber was controlled by a supersaturated salt solution. The samples were removed after 1 week and any deliquescence was recorded.

[0244] Method 3-9, Aqueous solubility

Aliquots of the water were added to an accurately weighed sample (at most 5 mg) of AAT-730 at ambient temperature. The aliquot volumes were typically 10-20 μL. Complete dissolution of the test material was determined by visual inspection. The solubility was estimated from these experiments based on the total solvent used to provide complete dissolution.

[0245] Example 3-1, Precipitations experiments in THF

Precipitation experiments in THF were carried out as described in Method 3-3 and the results are shown in Table 3-2. Most of the experiments yielded gels after evaporation. Solids/gels isolated from experiments with citric, L-malic and L-tartaric acids were amorphous by XRPD. These samples were triturated in MTBE to try to induce crystallization (Method 3-5 and Example 3-3). Solids isolated from the experiments with L-aspartic acid and L-glutamic acid were composed of acid co-former and salt formation had not occurred. Solids displaying novel XRPD patterns were isolated from the experiments with fumaric acid, EDSA, maleic acid and MSA and these are possible salts. These solids were further analyzed and are discussed in Examples 3.8 to 3.18.

[0246] Results from salt formation experiments in THF

[Table 3-2]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	008-01	precipitation	solution	N/A
L-ascorbic acid	008-02	precipitation→evap.	gel	N/A
L-aspartic acid	008-03	precipitation	haze	L-aspartic acid
benzenesulfonic acid	008-04	precipitation→evap.	gel	N/A
citric acid	008-05	precipitation→evap.	gel*	Amorphous
EDSA	008-06	precipitation	solid	AAT-730 EDSA salt
fumaric acid	008-07	precipitation	solid	AAT-730 fumarate
gentisic acid	008-08	precipitation→evap.	gel	N/A
D-gluconic acid	008-09	precipitation→evap.	gel	N/A
D-glucuronic acid	008-10	precipitation→evap.	gel	N/A
L-glutamic acid	008-11	precipitation	solid	L-glutamic acid
glutaric acid	008-12	precipitation→evap.	gel	N/A
glycolic acid	008-13	precipitation	solution	N/A
hippuric acid	008-14	precipitation	gel	N/A
HCl	008-15	precipitation	solution	N/A
L-lactic acid	008-16	precipitation	gel	N/A
maleic acid	008-17	precipitation	solid	AAT-730 maleate
L-malic acid	008-18	precipitation	gel*	Amorphous
MSA	008-19	precipitation	solid	AAT-730 MSA salt
phosphoric acid	008-20	precipitation→evap.	gel	N/A
p-TSA	008-21	precipitation→evap.	gel	N/A
succinic acid	008-22	precipitation→evap.	gel	N/A
H_2SO_4	008-23	precipitation→evap.	gel	N/A
L-tartaric acid	008-24	precipitation	solid	Amorphous

* these initially appeared to contain solids but on preparation of the XRPD sample were determined to be gels

[0247] Example 3-2, Precipitation experiments in THF/water

Precipitation experiments in THF/water were carried out as detailed in Method 3-3 and the results are shown in Table 3-3. Gels were isolated from almost all screening experiments and this may be due to the presence of water. As salt formation may have occurred these gels were temperature cycled in MTBE to try to induce crystallization (Method 3-6 and Example 3-4).

Solids displaying novel XRPD patterns were isolated from the experiments with L-lactic acid, maleic acid, MSA and succinic acid and these are possible salts. These were further analyzed and are discussed in Examples 3.8 to 3.18.

[0248] Results from salt formation experiments in THF

[Table 3-3]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	009-01	precipitation→evap.	gel	N/A
L-ascorbic acid	009-02	precipitation→evap.	gel	N/A
L-aspartic acid	009-03	precipitation→evap.	gel	N/A
benzenesulfonic acid	009-04	precipitation→evap.	gel	N/A
citric acid	009-05	precipitation→evap.	gel	N/A
EDSA	009-06	precipitation→evap.	gel	N/A
fumaric acid	009-07	precipitation→evap.	gel	N/A
gentisic acid	009-08	precipitation→evap.	gel	N/A
D-gluconic acid	009-09	precipitation→evap.	gel	N/A
D-glucuronic acid	009-10	precipitation→evap.	gel	N/A
L-glutamic acid	009-11	precipitation→evap.	gel	N/A
glutaric acid	009-12	precipitation→evap.	gel	N/A
glycolic acid	009-13	precipitation→evap.	gel	N/A
hippuric acid	009-14	precipitation→evap.	gel	N/A
HCl	009-15	precipitation→evap.	gel	N/A
L-lactic acid	009-16	precipitation→evap.	solid	AAT-730 L-lactate
maleic acid	009-17	precipitation	solid	AAT-730 maleate
L-malic acid	009-18	precipitation→evap.	gel	N/A
MSA	009-19	precipitation→evap.	solid	AAT-730 MSA salt
phosphoric acid	009-20	precipitation→evap.	gel	N/A
p-TSA	009-21	precipitation→evap.	gel	N/A
succinic acid	009-22	precipitation→evap.	solid	AAT-730 succinate
H_2SO_4	009-23	precipitation→evap.	gel	N/A
L-tartaric acid	009-24	precipitation→evap.	gel	N/A

[0249] Example 3-3, Trituration of gels in MTBE

The gels isolated from the precipitation experiments in THF were triturated in MTBE as described in Method 3-5 and the results are shown in Table 3-4. Solids were isolated from glutaric acid, L-lactic acid, sulfuric acid and L-tartaric acid and these were analyzed by XRPD analysis. Solids displaying crystalline XRPD patterns were further analyzed (Examples 3.8 to 3.18). Gels or amorphous solids were isolated from the remaining experiments and as these could not be easily crystallized, they were not expected to be useful for further scale up and characterization within this project.

[0250] Screening results from temperature cycling of gels isolated from THF

[Table 3-4]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	010-02	trituration	gel	N/A
citric acid	010-05	trituration	solution	N/A
gentisic acid	010-08	trituration	gel	N/A
D-gluconic acid	010-09	trituration	gel	N/A
D-glucuronic acid	010-10	trituration	gel	N/A
glutaric acid	010-12	trituration	solid	AAT-730 glutarate
hippuric acid	010-14	trituration	gel	N/A
L-lactic acid	010-16	trituration	solid	AAT-730 L-lactate
L-malic acid	010-18	trituration	gel	N/A
phosphoric acid	010-20	trituration	gel	N/A
p-TSA	010-21	trituration	gel	N/A
succinic acid	010-22	trituration	gel	N/A
H_2SO_4	010-23	trituration	solid	AAT-730 sulfate
L-tartaric acid	010-24	trituration	solid	amorphous

[0251] Example 3-4, Temperature cycling of gels

The gels isolated from screening experiments in THF/water were temperature cycled in MTBE as shown in Method 3-6 and the results are shown in Table 3-5. Any solids with novel crystalline XRPD patterns were further analyzed and this is shown in Examples 3.8 to 3.18. Salt formation had not occurred with L-aspartic or L-glutamic acids. Gels or amorphous solids were isolated from the remaining experiments and as these could not be easily crystallized, they were not expected to be useful for further scale up and characterization within this project.

[0252] Screening results from temperature cycling of gels isolated from THF/water

[Table 3-5]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	011-01	trituration	gel	AAT-730 acetate
L-ascorbic acid	011-02	trituration	gel	N/A
L-aspartic acid	011-03	trituration	solid	Free base Pattern A
benzenesulfonic acid	011-04	trituration	gel	N/A
citric acid	011-05	trituration	gel	N/A
EDSA	011-06	trituration	gel	N/A
fumaric acid	011-07	trituration	gel	N/A
gentisic acid	011-08	trituration	gel	N/A
D-gluconic acid	011-09	trituration	gel	N/A
D-glucuronic acid	011-10	trituration	gel	N/A
L-glutamic acid	011-11	trituration	solid	L-glutamic acid + API
glutaric acid	011-12	trituration	solid	AAT-730 glutarate
glycolic acid	011-13	trituration	solid	AAT-730 glycolate
hippuric acid	011-14	trituration	gel	N/A
HCl	011-15	trituration	solid	AAT-730 HCl salt
L-malic acid	011-18	trituration	gel	N/A
phosphoric acid	011-20	trituration	gel	N/A
p-TSA	011-21	trituration	gel	N/A
H_2SO_4	011-23	trituration	gel	N/A
L-tartaric acid	011-24	trituration	gel	N/A

[0253] Example 3-5, Screening experiments in ethanol or dioxane

Screening experiments were carried out in EtOH or dioxane as described in Method 3-3 and the results are shown in Table 3-6 and Table 3-7. These experiments were carried out using acid co-formers which had not resulted in crystalline salt formation from the precipitation reactions in THF or THF/water (Example 3-1 and Example 3-2). Dioxane was used for the experiments with sulfonic acids. Possible glycolate, HCl and L-lactate salts of AAT-730 were isolated. Experiments which yielded gels were triturated in EtOAc and the results are shown in Table 3-8, acetate and succinate salts were isolated. Any suspected salts which were isolated are further analyzed in Examples 3.8 to 3.18.

[0254] Results from salt formation experiments in EtOH

[Table 3-6]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	012-01	precipitation→evap.	gel	N/A
L-ascorbic acid	012-02	precipitation→evap.	gel	N/A
L-aspartic acid	012-03	precipitation→evap.	gel	L-aspartic acid
citric acid	012-05	precipitation→evap.	gel	N/A
gentisic acid	012-08	precipitation→evap.	gel	N/A
D-gluconic acid	012-09	precipitation→evap.	gel	N/A
D-glucuronic acid	012-10	precipitation→evap.	solid	IS*
L-glutamic acid	012-11	precipitation→evap.	solid	L-glutamic acid
glycolic acid	012-13	precipitation→evap.	solid	AAT-730 glycolate
hippuric acid	012-14	precipitation→evap.	gel	N/A
HCl	012-15	precipitation→evap.	solid	AAT-730 HCl salt
L-lactic acid	012-16	precipitation→evap.	solid	AAT-730 L-lactate
L-malic acid	012-18	precipitation→evap.	gel	N/A
phosphoric acid	012-20	precipitation→evap.	gel	N/A
succinic acid	012-22	precipitation→evap.	gel	N/A
L-tartaric acid	012-24	precipitation→evap.	gel	N/A

*Insufficient sample for XRPD analysis

[0255] Results from salt formation experiments in dioxane

[Table 3-7]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
benzenesulfonic acid	013-04	precipitation→evap.	gel	N/A
p-TSA	013-21	precipitation→evap.	gel	N/A

[0256] Results from trituration of gels in EtOAc

[Table 3-8]

Acid	Sample No. (CAT-0001E-)	Screen method	Result	XRPD Result
acetic acid	015-01	trituration	solid	AAT-730 acetate
L-ascorbic acid	015-02	trituration	gel	N/A
citric acid	015-05	trituration	gel	N/A
gentisic acid	015-08	trituration	gel	N/A
D-gluconic acid	015-09	trituration	gel	N/A
D-glucuronic acid	015-10	trituration	gel	N/A
hippuric acid	015-14	trituration	gel	N/A
L-malic acid	015-18	trituration	gel	N/A
phosphoric acid	015-20	trituration	gel	N/A
succinic acid	015-22	trituration	solid	AAT-730 succinate
L-tartaric acid	015-24	trituration	gel	N/A
benzenesulfonic acid	016-04	trituration	gel	N/A
p-TSA	016-21	trituration	gel	N/A

[0257] Example 3-6, Planetary milling

Screening experiments were carried out using the planetary mill (Method 3-7) and these results are shown in Table 3-9. This method was chosen to try to eliminate formation of gels as only a small amount of solvent was used. Salt formation was not observed by this technique and the milling appeared to cause AAT-730 to become slightly disordered as peak broadening was noted in the diffractogram (Figure 4-1).

[0258] Results from screening by planetary milling

[Table 3-9]

Acid	Sample No. (CAT-0001E-)	Result	XRPD Result
acetic acid	018-01	solid	AAT-730 – disordered XRPD pattern
L-ascorbic acid	018-02	solid	AAT-730 – disordered XRPD pattern
L-aspartic acid	018-03	solid	AAT-730 (disordered) + L-aspartic acid
benzenesulfonic acid	018-04	gel	N/A
citric acid	018-05	solid	AAT-730 – disordered XRPD pattern
gentisic acid	018-08	gel	N/A
D-gluconic acid	018-09	gel	N/A
D-glucuronic acid	018-10	solid	AAT-730 (disordered) + D-glucuronic acid
L-glutamic acid	018-11	solid	AAT-730 – disordered XRPD pattern
hippuric acid	018-14	solid	AAT-730 (disordered) + hippuric acid + possible salt
L-malic acid	018-18	solid	AAT-730 – disordered XRPD pattern
phosphoric acid	018-20	solid	AAT-730 – disordered XRPD pattern
p-TSA	018-21	solution	N/A
L-tartaric acid	018-24	solid	AAT-730 – disordered XRPD pattern

[0259] Example 3-7, Experiments with altered stoichiometry

Some of the acid co-formers had pK_a values which were suitable for forming either hemi or bis-salts and experiments were carried out using these acids. The molar equivalents used are shown in Table 3-10. Crystalline solids were isolated from the experiments using 0.5 mol. eq. of EDSA but these appeared to be composed of polymorphs of the free base and salt formation hadn't occurred with 0.5 mol. eq. of EDSA. The EDSA salt formed with 2 mol. eq. of EDSA yielded solids with the same XRPD pattern as the mono-EDSA salt. Two different crystalline salts were isolated from the reactions with HCl and these may be the mono and bis-HCl salts, however stoichiometry cannot be determined by ^{1}H NMR. The salt formation with MSA yielded the bis-MSA salt and this is discussed in Example 3-16. The salt isolated with glutaric acid has the same XRPD pattern as the salt isolated with 1 mol. eq. of glutaric acid and is a mono-glutarate salt (Example 3-17). A solid was isolated from the experiment with 2 mol. eq. of sulfuric acid and this may be a sulfate.

[0260] Screening experiments with alternative stoichiometry

[Table 3-10]

Acid	Sample No. (CAT0001E-)	Solvent	Acid (mol. eq.)	Result	XRPD Result
EDSA	019-01	THF	0.5	solid	free base polymorph + free base Pattern A
EDSA	019-01B	EtOH	0.5	solid	crystalline, not salt formation
EDSA	019-01C	THF	0.5	solid	free base polymorph + free base Pattern A
H_2SO_4	019-02	THF	0.5	haze	N/A
benzenesulfonic acid	019-03	THF	2	gel	N/A
EDSA	019-04	THF	2	solid	AAT-730 EDSA
HCl	019-05	THF	2	solid	AAT-730 HCl Pattern A**
HCl	019-05B	EtOH	2	solid	AAT-730 HCl Pattern B
MSA	019-06	THF	2	solid	AAT-730 MSA Pattern B
p-TSA	019-07	THF	2	haze	N/A
H_2SO_4	019-08	THF	2	haze	possible sulfate Pattern B
L-aspartic acid	019-09	THF	0.5	solid	API
citric acid	019-10	THF	0.5	solid	IS*
L-glutamic acid	019-11	THF	0.5	solid	API
glutaric acid	019-12	THF	0.5	solid	AAT-730 glutarate
L-malic acid	019-13	THF	0.5	gel	N/A
succinic acid	019-14	THF	0.5	solution	N/A
L-tartaric acid	019-15	THF	0.5	gel	N/A

* IS = insufficient sample for XRPD analysis

** The XRPD pattern of AAT-730 HCl salt Pattern A is referred as to Pattern 1 in Examples 5 and 6.

[0261] Conclusions from salt screening

1) Approximately 175 salt screening experiments were carried out. Fourteen possible salts from 11 different salt formers were isolated as listed in Table 3-11.

2) These were stressed at 40 °C/75% RH for 1 week and visually checked for deliquescence. Further analysis by ^{1}H NMR, TGA and aqueous solubility was carried out where sufficient material was available.

[0262] Summary of the salts observed during this study

[Table 3-11]

Salt	Pattern	Comment
acetate	A	crystalline solid, non-stoichiometric, gained at most 18.4% weight on stressing at 40 °C
EDSA salt	A	1:1 salt, unstable to 40 °C/75% RH stressing
fumarate	A	crystalline 1:1 salt, unstable to 40 °C/75% RH stressing
glutarate	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 163-245 mg/mL
glycolate	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 179-238 mg/mL
HCl salt	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 164-205 mg/mL
	B	crystalline salt (stoichiometry 1:2 AAT-730:HCl) physically stable to 40 °C/75% RH stressing
L-lactate	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 320-640 mg/mL
maleate	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 280-560 mg/mL
MSA salt	A	crystalline 1:1 salt, physically stable to 40 °C/75% RH stressing, aqueous solubility approximately 228-260 mg/mL
	B	crystalline salt (stoichiometry 1:2 AAT-730:MSA), unstable to 40 °C/75% RH stressing
sulfate	A	crystalline salt, stoichiometry of salt not determined, physically stable to 40 °C/75% RH stressing, aqueous solubility up to approximately 500 mg/mL
	B	crystalline, possible salt, stoichiometry not determined, deliquesced on stressing at 40 °C/75% RH
succinate	A	crystalline 1:1 salt, unstable to 40 °C/75% RH stressing

[0263] Example 3-8, Characterization of AAT-730 (Compound A) acetate

A possible acetate (acetic acid salt) of AAT-730 was isolated after trituration in MTBE of the gel isolated from the reaction of AAT-730 and acetic acid in THF/water or from trituration in EtOAc after reaction in ethanol. The solids were analyzed by XRPD (Figure 4-2) and ^{1}H NMR analyses (Figure 4-3) and shown to be crystalline by XRPD analysis. The ^{1}H NMR spectrum suggested that the material was a non-stoichiometric salt. The salt gained at most 18% w/w on stressing at 40 °C/75% RH.

[0264] Example 3-9, Characterization of AAT-730 (Compound A) EDSA salt

AAT-730 mono-EDSA salt was isolated from a precipitation reaction of AAT-730 and EDSA (1 or 2 mol. eq.) in THF. The solids were isolated and analyzed by XRPD (Figure 4-4). Although the sample was weak, the material was crystalline. ^{1}H NMR analysis (Figure 4-5) confirmed a 1:1 ratio of API:acid. The salt deliquesced on stressing at 40 °C/75% RH.

[0265] Solids isolated from the reaction of AAT-730 and EDSA (0.5 mol eq.) in EtOH yielded solids with a novel XRPD pattern (Figure 4-6). This was labelled AAT-730 EDSA Pattern C. ^{1}H NMR (Figure 4-7) analysis suggested that salt formation may not have occurred.

[0266] Example 3-10, Characterization of AAT-730 fumarate

Solids precipitated from the reaction of AAT-730 and fumaric acid in THF. XRPD analysis of the solids showed they were crystalline with a novel XRPD pattern (Figure 4-8). The material was analyzed by ^{1}H NMR analysis (Figure 4-9) which suggested formation of a mono-fumarate. The material was stressed at 40 °C/75% RH for 7 days and the solid deliquesced.

[0267] Example 3-11, Characterization of AAT-730 (Compound A) glutarate

AAT-730 glutarate (glutaric acid salt) was isolated from screening experiments of AAT-730 and glutaric acid in THF and THF/water. Gels were isolated from the experiments with 1 molar equivalent of acid and these were triturated/temperature cycled in MTBE to yield solids which were crystalline by XRPD (Figure 4-10). Analysis by ^{1}H NMR (Figure 4-11) showed formation of a mono-glutarate (at most 5.4% w/w of MTBE was also noted). The approximate aqueous solubility was 163-245 mg/mL. TG/DTA of the salt showed 3 endothermic events which may be due to either melting of the material or loss of solvent or acid on heating (Figure 4-12).

[0268] Example 3-12, Characterization of AAT-730 (Compound A) glycolate

A suspected salt was isolated from a screening experiment of AAT-730 and glycolic acid in EtOH and was analyzed by XRPD analysis (Figure 4-13). The solid was crystalline and this was analyzed by ^{1}H NMR analysis (Figure 4-14) which suggested formation of a mono-glycolate.

TG/DTA analysis (Figure 4-15) showed a small weight loss between 30 and 160 °C which is likely to be due to residual solvent. An endotherm at onset up to 133 °C is probably due to melting of the material. The material was physically stable to stressing at 40 °C/75% RH for 1 week.

[0269] Example 3-13, Characterization of AAT-730 (Compound A) HCl salt Pattern A

A suspected HCl salt was isolated from a precipitation experiment of AAT-730 and HCl (1 mol. eq.) in ethanol. The solids were analyzed by XRPD (Figure 4-16), TG/DTA (Figure 4-18) and ^{1}H NMR (Figure 4-17) analyses. The XRPD diffractogram was

consistent with a crystalline solid and the TG/DTA showed a possible melting endotherm at onset up to 184 °C. No weight loss is observed which suggests an anhydrous material. A second endotherm at onset up to 234 °C may be due to melting of another crystalline form. The ^{1}H NMR spectrum shows peak shifting consistent with salt formation and the solids were stable to stressing at 40 °C/75% RH. The solubility of the suspected salt was approximately 164-205 mg/mL.

[0270] A second possible HCl salt (AAT-730 HCl salt Pattern B) was isolated from a screening experiment of AAT-730 with 2 moles of HCl in ethanol. This may be a 1:2 salt (API:acid), however stoichiometry cannot be determined by ^{1}H NMR analysis (Figure 4-20). XRPD analysis (Figure 4-19) showed that the material was crystalline with some amorphous content and ^{1}H NMR analysis showed peak shifting consistent with salt formation. TG/DTA analysis showed an endotherm at onset 161.6 °C and a second endotherm followed immediately by an exotherm (Figure 4-21). The solids were stable to stressing at 40 °C/75% RH for 1 week.

[0271] Example 3-14, Characterization of AAT-730 (Compound A) L-lactate

AAT-730 L-lactate (L-lactic acid salt) was isolated from a precipitation experiment of AAT-730 and L-lactic acid (1 mol. eq.) in either ethanol or THF/water. XRPD analysis (Figure 4-22) showed that the material was composed of a crystalline solid.^{1}H NMR analysis (Figure 4-23) suggested formation of a mono-lactate salt. The TG/DTA thermogram (Figure 4-24) showed a probable melting onset at up to 117 °C and minimal weight loss between 30 and 150 °C due to residual solvent. The material had a solubility of approximately 320-640 mg/mL in water and was stable to stressing at 40 °C/75% RH for 1 week.

[0272] Example 3-15, Characterization of AAT-730 (Compound A) maleate

A suspected AAT-730 maleate (maleic acid salt) was isolated from precipitation experiments in THF and THF/water. The solid was crystalline by XRPD analysis (Figure 4-25) and ^{1}H NMR analysis (Figure 4-26) suggested formation of a mono-maleate. TG/DTA (Figure 4-27) showed a probable melting endotherm at onset up to 153 °C. Weight loss observed in the thermogram is likely to be due to residual THF which was also noted in the ^{1}H NMR spectrum. The salt had an aqueous solubility of approximately 280-560 mg/mL and it was stable to stressing at 40 °C/75% RH for 1 week.

[0273] Example 3-16, Characterization of AAT-730 (Compound A) MSA salt

A suspected AAT-730 MSA salt was isolated from precipitation experiments in THF and

THF/water. The solid was crystalline by XRPD analysis (Figure 4-28) and ^{1}H NMR analysis (Figure 4-29) suggested formation of a mono-MSA salt of AAT-730. TG/DTA analysis (Figure 4-30) showed minimal weight loss between 30 and 150 °C

suggesting an anhydrous form. A probable melting endotherm was observed at onset up to 155 °C. An exotherm immediately after melting may be due to recrystallisation or decomposition. The salt had a solubility of approximately 228-260 mg/mL in water and was stable to stressing at 40 °C/75% RH for 1 week.

[0274] A second possible MSA salt was isolated from a screening experiment of AAT-730 with 2 moles of MSA in THF. ^{1}H NMR analysis (Figure 4-32) suggests that this may be a 1:2 salt (API:acid). The material was crystalline by XRPD analysis (Figure 4-31) and it deliquesced on stressing at 40 °C/75% RH.

[0275] Example 3-17, Characterization of AAT-730 (Compound A) succinate

The succinate (succinic acid salt) of AAT-730 was isolated from salt formation experiments in THF/water or ethanol to form gels which were then triturated in either MTBE or EtOAc to form a solid which was crystalline by XRPD analysis (Figure 4-33). ^{1}H NMR analysis (Figure 4-34) suggested formation of a mono-succinate which deliquesced on stressing at 40 °C/75% RH.

[0276] Example 3-18, Characterization of AAT-730 (Compound A) sulfate

AAT-730 sulfate was isolated from a salt formation experiment in THF which was evaporated to yield a gel. The gel was triturated in MTBE to yield the salt as a solid which was crystalline by XRPD analysis (Figure 4-35). ^{1}H NMR analysis suggested formation of a salt as peak shifting was observed in the ^{1}H NMR spectrum (Figure 4-36). Stoichiometry could not be determined by ^{1}H NMR analysis and the solids did not deliquesce on stressing at 40 °C/75% RH.

Another possible sulfate was isolated from the screening experiment with 2 mol. eq. of H_2SO_4 and analyzed by XRPD (Figure 4-37). This deliquesced on stressing at 40 °C/75% RH.

[0277] Example 4, AAT-730 (Compound A) HCl salt and maleate

The preparation of the HCl salt and maleate (maleic acid salt) of AAT-730 was scaled up to 250 mg. Both salts were characterized using a range of techniques including XRPD, DSC, TG/DTA, ^{1}H NMR, and microscopy. The stability was also tested at a range of elevated relative humidity conditions for 7 days. The solubility of AAT-730 HCl salt Pattern A was estimated in various solvent systems.

[0278] Method 4-1, Solubility estimation method

Aliquots of the test solvent were added to an accurately weighed sample (at most 20 mg) of AAT-730 HCl salt at ambient temperature. The aliquot volumes were typically 25-100 μL. Complete dissolution of the test material was determined by visual inspection. The solubility was estimated from these experiments based on the total solvent used to provide complete dissolution. It should be noted that the actual solubility may be greater than that calculated because of the use of solvent aliquots that were too large or due to a slow rate of dissolution.

[0279] If dissolution did not occur after the last aliquot of solvent was added (typically up to 50 volumes of solvent), the sample was subjected to two cycles of the following temperature cycling regime on the Clarity crystallization station:

Heating from 20 °C to within 3 °C of solvent boiling point (or 100 °C, whichever was lower) at 0.5 °C/minute.

Cooling to 20 °C at 0.2 °C/minute.

Stirrering speed 600 rpm.

From the infrared (IR) transmission data of the sample vials, dissolution and precipitation events were recorded as the point of complete transmission of IR and the onset of turbidity by IR respectively.

[0280] Samples were held at ambient temperature for 18 hours to maximize the chance of precipitation. Any recoverable solids were analyzed by XRPD. The solubility values for AAT-730 HCl salt were expressed as a range and rounded to the nearest whole number. From this data, the solvents were grouped in the following manner to guide the screening experiments:

Solvents (A): AAT-730 HCl salt was soluble in less than or equal to 50 volumes (greater than or equal to 20 mg/mL) at ambient temperature.

Soluble with heating (B): AAT-730 HCl salt was not soluble in 50 volumes at ambient but dissolved at higher temperatures. These solvents could be regarded as possible solvents for cooling crystallizations.

Anti-solvents (C): AAT-730 HCl salt was not soluble in 50 volumes at all temperatures studied.

[0281] Example 4-1, Preparation of AAT-730 (Compound A) HCl salt Pattern A

AAT-730 (250 mg) and THF (1.25 mL) were stirred in a vial and a solution of HCl in dioxane (4 M, 177.5 μL) was added dropwise. This was stirred at 400 rpm for up to 16 hours. A gel had formed on the surface and a further portion of THF (1 mL) was added. The crust was broken with a pipette and the mixture instantly became cloudy and a thick white precipitate formed. The mixture was centrifuged, and the supernatant was removed. THF (at most 1 mL) was added and the mixture was agitated, centrifuged and solvent decanted. This was repeated and the solids were dried under N_2 overnight to yield the product as a white solid (185 mg, 68% yield).

[0282] Example 4-2, Characterization of AAT-730 (Compound A) HCl salt Pattern A

AAT-730 HCl salt Pattern A was prepared on at most 185 mg scale from a precipitation experiment of AAT-730 and HCl (1 mol. eq.) in THF. The solids were characterized, and the results are detailed below. The XRPD diffractogram (Figure 5-1) was consistent with a crystalline solid and was composed of the same form as the previously prepared AAT-730 HCl salt Pattern A material.

[0283] Thermogravimetric/Differential Thermal Analysis (TG/DTA) was performed to

determine the thermal profile and associated % weight changes of AAT-730 HCl salt Pattern A (Figure 5-2). The TG/DTA data showed a melting endotherm at onset up to 200 °C. Weight loss of at most 0.25% w/w was observed between approximately 30 and 190 °C which suggests an anhydrous material with a small amount of residual solvent. An exotherm at onset up to 212 °C may be due to crystallization to another form or decomposition.

[0284] The DSC thermogram obtained for AAT-730 HCl salt Pattern A at 10 °C/min is shown in Figure 5-3 and the melting onset is 192.46 °C.

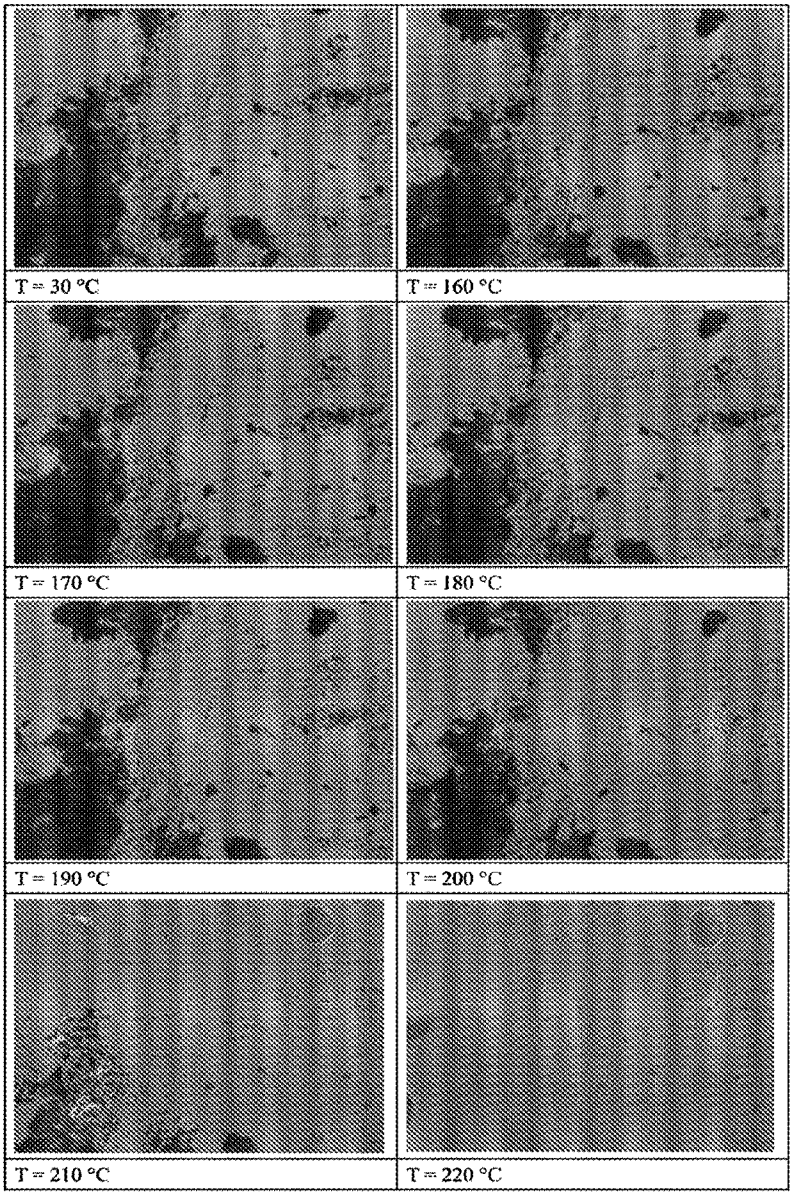
[0285] The ^{1}H NMR spectrum of AAT-730 HCl salt Pattern A analyzed in CD_3OD (Figure 5-4) conformed to the molecular structure and a small amount of residual THF was observed in the spectrum. This concurs with the TG/DTA data.

[0286] Polarized light microscopy of AAT-730 HCl salt Pattern A solids (Figure 5-5) showed that the material is composed of fine acicular particles and some aggregation and/or agglomeration is observed.

[0287] Hot-stage microscopy was carried out using a Linkam hot-stage accessory and the photomicrographs are shown in Table 4-1. The material remains mostly unchanged on heating until approximately 190 °C. Between 190 °C and 200 °C some changes in the bulk density can be observed as the solids begin to melt. The bulk density has further reduced by 210 °C and the material has completely liquefied by 220 °C.

[0288] Hot-stage photomicrographs of AAT-730 HCl salt Pattern A

[Table 4-1]



[0289] Example 4-3, Humidity stress of AAT-730 (Compound A) HCl salt

Sample of AAT-730 HCl salt was added to HPLC vials. The vials were placed, uncapped, into RH chambers as shown in Table 4-2.

The relative humidity of the chambers was controlled by supersaturated salt solutions. The samples were removed after 1 week and the XRPD patterns were acquired.

AAT-730 HCl salt (at most 20 mg) was added to each of the humidity chambers as described above. The XRPD patterns of the post stress samples are shown in Figure 5-6. ^{1}H NMR analysis (Figure 5-7, Figure 5-8, and Figure 5-9) of the post-stressed

samples showed no change.

[0290] Table of humidity stressing experiments

[Table 4-2]

Sample No. (CAT-0001E-)	Conditions
023-01	25 °C/60% RH
023-02	40 °C/75% RH
023-03	70 °C/75% RH

[0291] Example 4-4, Aqueous equilibrium solubility of AAT-730 (Compound A) HCl salt

AAT-730 HCl salt (50 mg) was added to a vial and water (100 μL) was added. The mixture was stirred and after 30 minutes a thick suspension was formed. Further aliquots (20 μL) of water were added until a fine suspension was formed. This was stirred at 25 °C overnight and filtered to yield a clear solution. The solution was weighed and evaporated to constant weight to determine the solubility.

According to the above method, solubility of AAT-730 HCl salt was determined and was approximately 220 mg/mL in water at pH 6.6 to 7.0.

[0292] Example 4-5, Estimated solubility of AAT-730 (Compound A) HCl salt

The solubility of AAT-730 HCl salt was estimated in 10 solvent systems using the aliquot addition method. These included 4 aqueous/organic mixtures. The compound had a solubility of >20 mg/mL in 2 of the aqueous mixtures at ambient temperature. The solubility data obtained is shown in Table 4-3. Those experiments which did not show dissolution in at most 50 volumes were temperature cycled as described in Method 4-1. From this data and the solubility screen, the solvents were sorted into three groups outlined in Table 4-4 to define the scope of the screening experiments.

[0293] The solubility of AAT-730 HCl salt was assessed by aliquot addition and was found to have solubility greater than or equal to 20 mg/mL in DMSO/water and EtOH/water.

[0294] Solubility estimates of AAT-730 HCl salt at 20 °C

[Table 4-3]

Solvent	Acronym	Solubility at 20 °C (mg/mL)	T dissolution (°C)
acetone	-	<20	-
acetonitrile	ACN	<21	-
dichloromethane	DCM	<20	-
ethanol	EtOH	<21	-
methanol	MeOH	<20	40
tetrahydrofuran	THF	<20	-
DMSO/water (80/20, A_w at most 0.27)	-	22-25	-
acetone/water (20/1, A_w at most 0.6)	-	<20	-
THF/water (13/1, A_w at most 0.9)	-	<20	38
EtOH/water (50/50)	-	205-273	-

[0295] Solvent systems grouped into categories

[Table 4-4]

(A) - Solvents	(B) - Soluble with heating	(C) - Anti-solvents
DMSO/water (80/20, A_w at most 0.27)	MeOH	acetone
EtOH/water (50:50)	THF/water (13/1, A_w at most 0.9)	acetone/water (20/1, A_w at most 0.6)
-	-	ACN
-	-	DCM
-	-	EtOH
-	-	THF

[0296] Example 4-6, Determination of chloride content

AAT-730 HCl salt (6 mg) was added to a vial and water (1 mL) was added. A chloride test strip was added, and the solution allowed to travel up the strip. The level was recorded, and the chloride content calculated.

According to the above method, the strip read 2.8 which corresponded to a chloride content of 393 ppm. The theoretical concentration for a mono-HCl salt was 428 ppm. These results suggest that AAT-730 Pattern A is a mono-HCl salt (mono-hydrochloride).

[0297] Conclusions from characterization of AAT-730 HCl salt

1) XRPD analysis indicated that AAT-730 HCl was a crystalline material and polarized light microscopy concurred with this.

2) TG/DTA data showed 0.25% weight loss from 30-190 °C, suggesting minimal moisture or residual solvent content, and shows that AAT-730 HCl salt remains thermally stable up to 220 °C.

3) Heat rate studies by DSC indicated a melting onset of 192.46 °C.

4) ^{1}H NMR spectroscopy conformed to molecular structure and a small amount of residual THF was detected.

5) AAT-730 HC1 salt was stressed for 7 days at 25 °C/60% RH, 40 °C/75% RH and 70 °C/75% RH. 6) The post-stressed samples were analyzed by XRPD and ^{1}H NMR analyses. No change in physical form was observed in all samples and ^{1}H NMR suggested that it was chemically stable.

7) The solubility of AAT-730 HC1 salt Pattern A was assessed by aliquot addition and was found to have solubility greater than or equal to 20 mg/mL in DMSO/water and EtOH/water. AAT-730 HC1 salt had a solubility or up to approximately 220 mg/mL in water at pH 6.6 to 7.0.

8) Chloride analysis suggests that AAT-730 HC1 Pattern A is a mono-HC1 salt.

[0298] Example 4-7, Preparation of AAT-730 (Compound A) maleate

AAT-730 (250 mg) and THF (1.25 mL) were stirred in a vial and a solution of maleic acid (69 mg) in THF (500 µL) was added dropwise. This was stirred at 400 rpm for up to16 hours. A thick white precipitate formed immediately and a further portion (1 mL) of THF was added to assist stirring. The mixture was centrifuged, and the supernatant was removed. THF (at most 1 mL) was added and the mixture was agitated, centrifuged and solvent decanted. This was repeated and the solids were dried under N_2 overnight to yield the product as a white solid (198.7 mg, 62% yield).

[0299] Example 4-8, Characterization of AAT-730 (Compound A) maleate

AAT-730 maleate was isolated from a precipitation experiment in THF as described in Example 4-7. The solids were characterized as detailed below. The solids were crystalline by XRPD analysis (Figure 5-10) and it was composed of the desired form which was previously isolated from the screening experiments.

[0300] KF analysis was carried out as described and the maleate had a water content of 0.77% w/w. The maleate is not a hydrate.

[0301] Thermogravimetric/Differential Thermal Analysis (TG/DTA) was performed to determine the thermal profile and associated % weight changes of AAT-730 maleate (Figure 5-11). The TG/DTA data showed a melting endotherm at onset up to 138 °C. Weight loss of at most 1.8% w/w was observed between approximately 30 and 130 °C which is probably due to residual solvent or moisture. A second endotherm at onset up to 179 °C may be due to melting of another form. Weight loss of at most 5.45% w/w between approximately 130 and 175 °C may be due to loss of maleic acid which thermally decomposes at 135 °C.

[0302] The DSC thermogram obtained for AAT-730 maleate at 10 °C/min is shown in Figure 5-12 and the melting onset is 132.91 °C. Further thermal events are observed, an exotherm at onset up to 167 °C and another endotherm at onset up to 184 °C. The

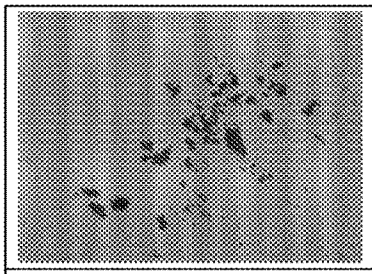
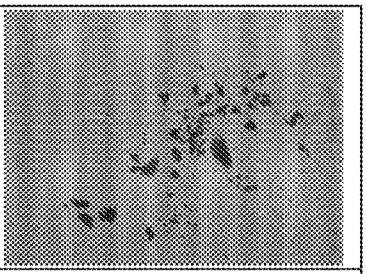
exotherm may be due to recrystallisation of another form and then subsequent melting. This concurs with the hot-stage microscopy images (Table 4-5).

[0303] ^{1}I-I NMR analysis was carried out in CD_3OD and the spectrum is shown in Figure 5-13. It suggests formation of a mono-maleate. Residual solvent is detected in the spectrum.

[0304] A photomicrograph of AAT-730 maleate is shown in Figure 5-14 and the material is composed of small irregular particles. Aggregation and/or agglomeration is also observed.

[0305] Hot-stage microscopy was carried out using a Linkam hot-stage accessory and the photomicrographs are shown in Table 4-5. The material remains mostly unchanged on heating up to 110 °C. Between 110 °C and 130 °C some changes in the bulk density can be observed as the solids begin to melt. At 140 °C the material has liquefied and some recrystallisation is observed. Between 150 °C and 180 °C further recrystallisation is observed and the material has liquified by 190 °C.

[Table 4-5]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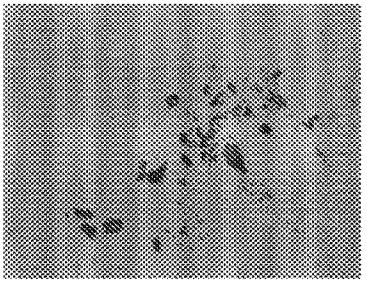	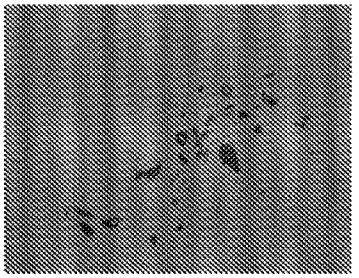
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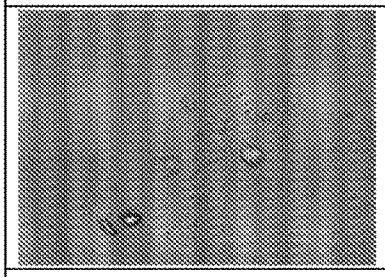	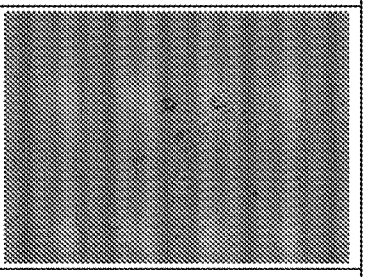
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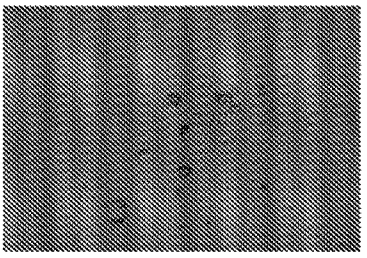
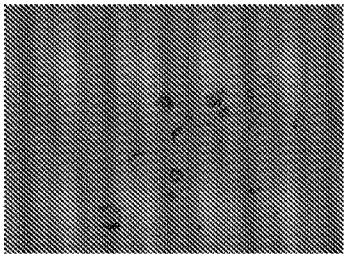
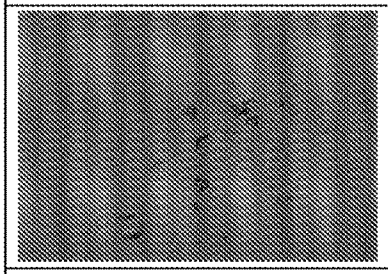
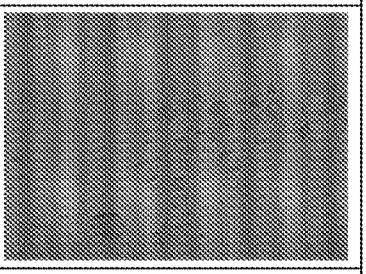
	
T = 160 °C	T = 170 °C
	
180 °C	T = 190 °C

[0307] Example 4-9, Humidity stress of AAT-730 (Compound A) maleate (maleic acid salt)

Sample of AAT-730 maleate was added to HPLC vials. The vials were placed, uncapped, into RH chambers as shown in Table 4-6.

The relative humidity of the chambers was controlled by supersaturated salt solutions. The samples were removed after 1 week and the XRPD patterns were acquired.

[0308] AAT-730 maleate (at most 20 mg) was added to each of the humidity chambers as described above. The XRPD patterns of the post stress samples are shown in Figure 5-15. At 70 °C/75% RH, the material deliquesced. The XRPD diffractograms of the samples suggest changes in the physical form and ^{1}H NMR analyses of the post-stressed samples shows that the ratio of maleic acid to API has changed (Figure 5-16 and Figure 5-17). These results would suggest that AAT-730 maleate is unstable to stressing at elevated relative humidity and would not be suitable for further development.

[0309] Table of humidity stressing experiments

[Table 4-6]

Sample No. (CAT-0001E-)	Conditions
023-01	25 °C/60% RH
023-02	40 °C/75% RH
023-03	70 °C/75% RH

[0310] Example 4-10, Attempted aqueous equilibrium solubility of AAT-730 (Compound A) maleate

AAT-730 maleate (50 mg) was added to a vial and water (100 µL) was added. A clear solution resulted and a further portion of AAT-730 maleate (20 mg) was added. This dissolved immediately.

AAT-730 maleate had a solubility or >700 mg/mL in water at pH 6 to 7.

[0311] Conclusions from characterization of AAT-730 (Compound A) maleate

1) XRPD analysis indicated that AAT-730 maleate was a crystalline material and polarized light microscopy concurred with this.

2) TG/DTA data showed 1.8% weight loss from 30-130 °C, suggesting some residual solvent content. Further weight loss is observed from up to 130 °C and shows that AAT-730 maleate may be thermally unstable.

3) Heat rate studies by DSC indicated a melting onset of 132.91 °C.

4) ^{1}H NMR spectroscopy conformed to molecular structure and suggested formation of a mono-maleate. Residual THF was detected.

5) AAT-730 maleate salt was stressed for 7 days at 25 °C/60% RH, 40 °C/75% RH and 70 °C/75% RH. The post-stressed samples were analyzed by XRPD and ^{1}H NMR

analyses. Change in physical form was observed in all samples by XRPD analysis and ^{1}H NMR analysis also suggested that AAT-730 maleate was unstable to stressing.
6) AAT-730 maleate salt had a solubility or >700 mg/mL in water at pH 6 to 7.

[0312] Example 5, Polymorph screening of AAT-730 (Compound A) HCl salt

A focused polymorph screen has been performed on AAT-730 HCl salt, the objective of which was to investigate the polymorphic landscape of AAT-730 HCl salt. The approach was to generate solids under a wide and diverse range of nucleation conditions, designed to mimic the process conditions and solvents used during development and formulation.

The XRPD pattern of AAT-730 HCl salt Pattern A is hereafter referred as to Pattern 1.

All solids from the crystallization experiments were analyzed by XRPD and the resulting patterns compared to that exhibited by the starting material. Novel XRPD patterns were assigned a descriptor in order of discovery (Pattern 2, Pattern 3, etc.). Where sufficient material was available, further analysis (e.g. ^{1}H NMR or TGA) was conducted on solids with novel XRPD patterns to allow tentative assignment of the novel pattern as a polymorph, solvate, hydrate, degradant or mixture thereof. The starting material used in this study was AAT-730 HCl salt as prepared in Example 5-1.

[0313] Polymorph screening methods of Example 5

Method 5-1, Temperature cycling

The test solvent (1 mL) was added to a sample of AAT-730 HCl salt (at most 20 mg) at ambient temperature and 15 cycles of the following temperature program was performed using the Clarity crystallization station:

Heating from 5 °C to 60 °C at 0.5 °C/min (depending on boiling point of solvent)
Cooling to 5 °C at 0.5 °C/min
Stirrering speed - 300 rpm

[0314] Method 5-2, Slow evaporation

A solution of AAT-730 HCl salt was prepared in each solvent and evaporated in a fume hood at ambient temperature in a vial covered with perforated aluminum foil. After 2 weeks any samples which were still solutions were evaporated under a flow of nitrogen. The resulting solids were analyzed by XRPD.

[0315] Method 5-3, Crash precipitation

AAT-730 HCl (at most 20 mg) salt was dissolved in water (100 μL) and filtered into anti-solvent (1 mL) with stirring. Experiments which did not result in precipitation were placed in the refrigerator for up to 7 days, then uncapped and left to evaporate in a fume hood at ambient temperature until solids were observed. The resulting solids were analyzed by XRPD.

[0316] Method 5-4, Slow cooling

Sufficient solvent was added to AAT-730 HCl salt (20 mg) until dissolution at 60 °C. The solutions were cooled with agitation at 0.2 °C/min to a final temperature of 5 °C and any solids recovered by centrifugation and air dried prior to analysis by XRPD.

[0317] Method 5-5, Slurry experiments

Sufficient AAT-730 HCl salt was added to a given solvent until undissolved solids remained at the desired temperature (5, 20, 40, and 50 °C). The vial was sealed and the slurry was maintained at the selected temperature and agitated by magnetic stirring for 5 to 7 days. Solids were isolated by centrifugation and air dried prior to analysis by XRPD.

[0318] Method 5-6, Sonication of pastes

AAT-730 HCl salt (at most 20 mg) was added to a vial with 80 μL of the selected solvent to form a paste. The mixture was sonicated at 70% intensity using a Cole-Parmer 130 Watt ultrasonic processor using a pulsed program. In cases where the solids dissolved at ambient temperature, the sample was left uncapped to evaporate. The wet pastes recovered from these experiments were analyzed using XRPD.

[0319] Method 5-7, Crystalline Vapor stress

Approximately 20 mg of crystalline AAT-730 HCl salt was added to a vial and placed unsealed inside a larger sealed vessel containing 1 mL of the selected solvent. After 7 days, the samples were removed and analyzed by XRPD.

[0320] Method 5-8, Amorphous Vapor stress

Amorphous AAT-730 HCl salt was generated from evaporation of AAT-730 HCl salt from aqueous solution under a steady stream of N2. The resulting solids were placed unsealed inside a larger sealed vessel containing 1 mL of the selected solvent. After 7 days, the samples were removed and analyzed by XRPD.

[0321] Method 5-9, Humidity stress

Approximately 20 mg of Pattern 1 AAT-730 HCl salt was added to three individual vials and placed unsealed into the following relative humidity chambers (sealed cabinets with relative humidity conditions controlled by super-saturated salt solutions) for 7 days prior to analysis by XRPD:

Chamber 1 - 23% RH

Chamber 2 - 76% RH

Chamber 3 - 98% RH

[0322] Method 5-10, Planetary milling

Approximately 20 mg of AAT-730 HCl salt was added to vials with steel milling balls. Vials were sealed and contents milled using a Fritsch Pulverisette 5 planetary mill and the following cycle:

Mill for 60 minutes at a rotation speed of 400 rpm.

Rest for 15 minutes.

Total time 18 hours

Solvent (30 μL) was added and the contents were milled again using the following cycle:

Mill for 60 minutes at a rotation speed of 400 rpm.

Rest for 15 minutes.

Total time 18 hours

[0323] Example 5-1, Preparation of AAT-730 (Compound A) HCl salt Pattern 1

AAT-730 (2 g) and THF (10 mL) were added to a round bottom flask and stirred. Dissolution was incomplete after up to 10 minutes and a further portion (1 mL) of THF was added. The mixture was stirred to dissolution and HCl in dioxane (4 M, 1.5 mL) was added dropwise. A crust formed on the top and this was broken up with a pipette. Gumball formation was noted and a further portion (3 mL) of THF was added and the mixture was stirred to break up the solids. The solids were isolated by filtration, washed with THF (3 mL) and air dried in the Buchner funnel. The solids were transferred to a vial and dried to constant weight, under a flow of N_2, to yield the salt as a white solid (2.128 g, up to 98% yield).

[0324] Example 5-2, Generation of amorphous AAT-730 (Compound A) HCl salt

Freeze drying

AAT-730 HCl salt (25 mg) was dissolved in water (1 mL), filtered through a 0.45 μm filter into a HPLC vial. This was frozen in liquid nitrogen and lyophilized under vacuum (0.08 milibar) for 18 hours. The amorphous material was not obtained.

[0325] Melt quench

AAT-730 HCl salt (at most 20 mg) was added to a HPLC vial and flushed with N2. This was heated to 200 °C and was quickly immersed in an ice/water bath. A dark brown solid was formed which had degraded. AAT-730 HCl salt (at most 20 mg) was added to a HPLC vial and flushed with N2. This was heated up to 180 °C and was quickly immersed in an ice/water bath. A brown solid was formed which had degraded.

[0326] Evaporation

AAT-730 HCl salt (at most 20 mg) was added to a HPLC vial and water (1 mL) was added to form a solution. This was evaporated under a flow of nitrogen to yield amorphous material.

[0327] Example 5-3, Temperature cycling

Samples were subjected to the temperature cycling program outlined in Method 5-1 and the results are shown in Table 5-1. Pattern 1 or Pattern 2 materials were isolated from the screening experiments and are discussed further in Example 5-12 and Example 5-13.

[0328] Screening results from temperature cycling experiments

[Table 5-1]

Sample No. (TW-0012E-)	Solvent	Result	XRPD
003-01	acetone	solid	Pattern 1
003-02	ACN	solid	Pattern 1
003-04	EtOH	solid	Pattern 1
003-05	THF	solid	Pattern 1
003-06	acetone/water (20/1, A_w at most 0.6)	solid	Pattern 1
003-07	THF/water (13/1, A_w at most 0.9)	solid	Pattern 1
003-08	EtOH/water (50/50)	solid	Pattern 1
015-01	1-Butanol	solid	Pattern 2
015-02	cyclohexane	solid	Pattern 2
015-03	DIPE	solid	Pattern 2
015-04	DMAc	solid	Pattern 2
015-05	MEK	solid	Pattern 2
015-06	MIBK	solid	Pattern 2
015-07	MeOH	solution	N/A
015-08	IPA	solid	Pattern 2
015-09	Dioxane	solid	Pattern 2
015-10	*i*-PrOAc	solid	Pattern 2
015-11	toluene	solid	Pattern 2
015-12	heptane	solid	Pattern 2

[0329] Example 5-4, Slow evaporation

Slow evaporation of AAT-730 HCl salt solutions were conducted as described in Method 5-2 and the results are shown in Table 5-2. Pattern 4 was isolated from the EtOH/water evaporation and this material was not further characterized but it was included in the interconversion and water activity experiments as detailed in Example 5-16. Amorphous material was isolated from the evaporation in water and this method was then used to prepare amorphous material for vapor stressing.

[0330] Screening results from evaporations in vials

[Table 5-2]

Sample No. (TW-0012E-)	Solvent	Result	XRPD
008-01	water	solid	amorphous
008-02	DMSO/water (80/20, A_w at most 0.27)	solid	Pattern 3 + 2
008-03	EtOH/water (50/50)	solid	Pattern 4

[0331] Example 5-5, Crash precipitation

Crash precipitation experiments were carried out as detailed in Method 5-3 and the results are shown in Table 5-3. Most of the solids isolated contained amorphous material. Patterns 3 and 4 were isolated and these are discussed in Example 5-14 and

Example 5-15.

[0332] Screening results from crash precipitation experiments

[Table 5-3]

Sample No. (TW-0012E-)	Solvent	Anti-solvent	Result	XRPD
009-01	water	acetone	solid (after evap)	Amorphous + Pattern 4
009-02	water	ACN	solid (after evap)	Amorphous
009-03	water	ethanol	gel (after evap)	N/A
009-04	water	MeOH	solid (after evap)	Pattern 4
009-05	water	IPA	solid (after evap)	Pattern 3
009-06	water	THF	solid (after evap)	Amorphous
009-07	water	dioxane	solid (after evap)	Amorphous + Pattern 1

[0333] Example 5-6, Slow cooling

The slow increase in supersaturation allows more stable forms to nucleate. A sub-ambient final temperature also probes for stable solvates at temperatures typically accessed during cooling crystallization at plant scale. Table 5-4 shows the screening results from slow cooling experiments and Pattern 1 material was isolated from all experiments.

[0334] Screening results from slow cooling experiments

[Table 5-4]

Sample No. (TW-0012E-)	Solvent	Result	XRPD
016-01	MeOH	solid	Pattern 1
016-02	DMSO/water (80/20, A_w at most 0.27)	solid	Pattern 1 + amorphous
016-03	THF/water (13/1, A_w at most 0.9)	solid	Pattern 1

[0335] Example 5-7, Slurry experiments

Suspensions of AAT-730 HCl salt Pattern 1 in various solvents were held at 5, 20 °C and 50 °C for 5-7 days prior to isolation and analysis by XRPD (Table 5-5). Pattern 1 or 2 materials were isolated from each experiment. Pattern 1 was isolated from most of the experiments at 5 °C. Pattern 2 solids were isolated from the slurry experiments at 20 and 50 °C except for in aqueous solvents where either Pattern 1 or 2 was isolated.

[0336] Screening results from slurry experiments

[Table 5-5]

Sample No. (TW-0012E-)	Solvent	Temp. (°C)	Days	Result	XRPD
003-03	DCM	40	5	solid	Pattern 1
004-01	acetone	5	5	solid	Pattern 1
004-02	ACN	5	5	solid	Pattern 1
004-03	DCM	5	5	solid	Pattern 1
004-04	EtOH	5	5	solid	Pattern 1
004-05	THF	5	5	solid	Pattern 2
004-06	DMSO/water (80/20, A_w at most 0.27)	5	5	solid	Pattern 1
004-07	acetone/water (20/1, A_w at most 0.6)	5	5	solid	Pattern 2
004-08	THF/water (13/1, A_w at most 0.9)	5	5	solid	Pattern 1
005-01	acetone	20	5	solid	Pattern 2
005-02	ACN	20	5	solid	Pattern 2
005-03	DCM	20	5	solid	Pattern 2
005-04	EtOH	20	5	solid	Pattern 2
005-05	THF	20	5	solid	Pattern 2
005-06	DMSO/water (80/20, A_w at most 0.27)	20	5	solid	Pattern 1
005-07	acetone/water (20/1, A_w at most 0.6)	20	5	solid	Pattern 2
005-08	THF/water (13/1, A_w at most 0.9)	20	5	solid	Pattern 1
006-01	acetone	50	7	solid	Pattern 2
006-02	ACN	50	7	solid	Pattern 2
006-04	EtOH	50	7	solid	Pattern 2
006-05	THF	50	7	solid	Pattern 2

[0337] Example 5-8, Sonication of pastes

Sonication experiments were carried out as detailed in Method 5-6 and the results are displayed in Table 5-6. Pattern 2 solids were isolated from the majority of the screening experiments and these are discussed in Example 5-13. Pattern 1 material was isolated from the sonication experiments in aqueous solvents and in MeOH.

[0338] Screening results from sonication experiments

[Table 5-6]

Sample No. (TW-0012E-)	Solvent	Result	XRPD
010-01	acetone	solid	Pattern 2
010-02	ACN	solid	Pattern 2
010-03	DCM	solid	Pattern 2
010-04	EtOH	solid	Pattern 2
010-05	THF	solid	Pattern 2
010-06	DMSO/water (80/20, A_w at most 0.27)	solid	Pattern 1 + amorphous
010-07	acetone/water (20/1, A_w at most 0.6)	solid	Pattern 1
010-08	MeOH	solid	Pattern 1

[0339] Example 5-9, Vapor and humidity stress

X-ray amorphous material generated from evaporation in water was exposed to air saturated in solvent vapor before analysis by XRPD. As amorphous material has lost long range order, it is in a high energy state. Exposure to vapor plasticizes the solid, allowing limited molecular mobility and is therefore an excellent method of generating metastable solvates and hydrates. Amorphous material crystallized to Pattern 1 material in all experiments. This may be aided by the residual water present in the amorphous material. Additional vapor and humidity stress experiments were setup using Pattern 1 material and the results are all shown in Table 5-7. In almost all cases Pattern 1 material converted to Pattern 2 on vapor stressing. Pattern 1 solids converted to Pattern 2 on stressing at less than or equal to 75% RH but remained as Pattern 1 at 98% RH.

[0340] Results from vapor stressing and humidity experiments

[Table 5-7]

Input	Sample No. (TW-0012E-)	Solvent	Screen method	Result	XRPD
Pattern 1	012-01	acetone	vapor stress	solid	Pattern 2
Pattern 1	012-02	ACN	vapor stress	solid	Pattern 2
Pattern 1	012-03	cyclohexane	vapor stress	solid	Pattern 2
Pattern 1	012-04	DIPE	vapor stress	solid	Pattern 2
Pattern 1	012-05	EtOH	vapor stress	solid	Pattern 2
Pattern 1	012-06	EtOAc	vapor stress	solid	Pattern 2
Pattern 1	012-07	MeOH	vapor stress	solid	Pattern 2
Pattern 1	012-08	MTBE	vapor stress	solid	Pattern 2
Pattern 1	012-09	MIBK	vapor stress	solid	Pattern 2
Pattern 1	012-10	IPA	vapor stress	solid	Pattern 2
Pattern 1	012-11	*i*-PrOAc	vapor stress	solid	Pattern 2
Pattern 1	012-12	Heptane	vapor stress	solid	Pattern 2
Pattern 1	013-01	none	23% RH stress	solid	Pattern 2
Pattern 1	013-02	none	75% RH stress	solid	Pattern 2
Pattern 1	013-03	none	98% RH stress	solid	Pattern 1
amorphous	018-01	acetone	vapor stress	solid	Pattern 1
amorphous	018-02	ACN	vapor stress	solid	Pattern 1
amorphous	018-03	DCM	vapor stress	solid	Pattern 1
amorphous	018-04	EtOH	vapor stress	solid	Pattern 1
amorphous	018-05	THF	vapor stress	solid	Pattern 1

[0341] Example 5-10, Planetary milling

Planetary milling experiments were carried out as detailed in Method 5-10 and the results are shown in Table 5-8. Pattern 1 was isolated from most of these experiments.

[0342] Screening results from planetary milling experiments

[Table 5-8]

Input	Sample No. (TW0012E-)	Solvent	Result	XRPD
Pattern 1	017-01	acetone	solid	Disordered Pattern 1
Pattern 1	017-02	ACN	solid	Pattern 1 + very minor pattern 2
Pattern 1	017-04	Cyclohexane	solid	Disordered Pattern 1
Pattern 1	017-05	DCM	solid	Pattern 1
Pattern 1	017-06	dioxane	solid	Pattern 1
Pattern 1	017-07	DIPE	solid	Disordered Pattern 1
Pattern 1	017-08	EtOH	solid	Pattern 1
Pattern 1	017-09	EtOAc	solid	Pattern 1
Pattern 1	017-10	heptane	solid	Pattern 1
Pattern 1	017-12	MIBK	solid	Pattern 1
Pattern 1	017-13	IPA	solid	Pattern 1
Pattern 1	017-14	i-PrOAc	solid	Pattern 1
Pattern 1	017-15	toluene	solid	Pattern 1
Pattern 1	017-16	none	solid	Disordered Pattern 1

[0343] Conclusions from polymorph screening

1) Approximately 100 experiments were carried out using solvent and non-solvent based techniques. 2) Four crystalline XRPD patterns (Table 5-9) were observed during this study. Amorphous material was also generated from evaporation of a solution of AAT-730 HCl salt in water.

[0344] Summary of the physical forms observed during this study

[Table 5-9]

Pattern	Comment
1	Isolated from preparation of AAT-730 HCl salt in THF
2	Novel polymorph, XRPD is similar to Pattern 1
3	Novel polymorph, possible solvate or hydrate
4	Novel polymorph, isolated from water or water mixtures, possible hydrate
amorphous	Isolated from evaporation of AAT-730 HCl salt in water

[0345] Example 5-11, Preparation and characterization of AAT-730 (Compound A) HCl salt amorphous form

X-ray amorphous AAT-730 HCl salt was generated from evaporation of an aqueous solution of AAT-730 HCl salt under a steady stream of N_2. XRPD analysis displayed a halo pattern indicative of X-ray amorphous material (Figure 6-1).

[0346] Physical stability of amorphous material was assessed by exposure to selected organic vapors and the material crystallized under organic vapor stress to Pattern 1 material.

[0347] Example 5-12, Preparation and characterization of AAT-730 (Compound A) HCl salt Pattern 1

AAT-730 HCl salt Pattern 1 was isolated from the salt formation reaction and was frequently isolated throughout the polymorph screen (Table 5-10). XRPD analysis showed the material to be crystalline (Figure 6-2). Proton NMR analysis performed on a sample isolated from the salt screen conformed to the molecular structure of the compound and no residual solvent was detected (Figure 6-3). The TG/DTA data showed a melting endotherm at onset up to 200 °C (Figure 6-4). Weight loss of at most 0.25% w/w was observed between approximately 30 and 190 °C which suggests an anhydrous material with a small amount of residual solvent/water, interconversion and water activity experiments disagree with this and suggest that Pattern 1 is a hydrate (Example 5-16). An exotherm at onset up to 212 °C may be due to crystallization to another form or decomposition.

[0348] Screening experiments which yielded Pattern 1 material

[Table 5-10]

Input	Sample No. (TW0012E-)	Solvent	Screen method	Result	XRPD
amorphous	001-01	THF	salt formation	solid	Pattern 1
Lot No. 33-13	002-01	THF	salt formation	solid	Pattern 1
Pattern 1	003-01	acetone	temp cycle	solid	Pattern 1
Pattern 1	003-02	ACN	temp cycle	solid	Pattern 1
Pattern 1	003-03	DCM	slurry (40 °C)	solid	Pattern 1
Pattern 1	003-04	EtOH	temp cycle	solid	Pattern 1
Pattern 1	003-05	THF	temp cycle	solid	Pattern 1
Pattern 1	003-06	acetone/water (20/1, A_w at most 0.6)	temp cycle	solid	Pattern 1
Pattern 1	003-07	THF/water (13/1, A_w at most 0.9)	temp cycle	solid (after evap)	Pattern 1
Pattern 1	003-08	EtOH/water (50/50)	temp cycle	solid (after evap)	Pattern 1
Pattern 1	004-01	acetone	slurry (5 °C)	solid	Pattern 1
Pattern 1	004-02	ACN	slurry (5 °C)	solid	Pattern 1
Pattern 1	004-03	DCM	slurry (5 °C)	solid	Pattern 1
Pattern 1	004-04	EtOH	slurry (5 °C)	solid	Pattern 1
Pattern 1	004-06	DMSO/water (80/20, A_w at most 0.27)	slurry (5 °C)	solid	Pattern 1
Pattern 1	004-08	THF/water (13/1, A_w at most 0.9)	slurry (5 °C)	solid	Pattern 1
Pattern 1	005-06	DMSO/water (80/20, A_w at most 0.27)	slurry (20 °C)	solid	Pattern 1
Pattern 1	005-08	THF/water (13/1, A_w at most 0.9)	slurry (20 °C)	solid	Pattern 1
Pattern 1	010-07	acetone/water (20/1, A_w at most 0.6)	sonication	solid	Pattern 1
Pattern 1	010-08	MeOH	sonication	solid	Pattern 1
Pattern 1	013-03	none	98% RH stress	solid	Pattern 1
Pattern 1	016-01	MeOH	slow cool	solid	Pattern 1
Pattern 1	016-03	THF/water (13/1, Aw at most 0.9)	slow cool	solid	Pattern 1
Pattern 1	017-05	DCM	Planetary milling	solid	Pattern 1
Pattern 1	017-06	dioxane	Planetary milling	solid	Pattern 1
Pattern 1	017-08	EtOH	Planetary milling	solid	Pattern 1
Pattern 1	017-09	EtOAc	Planetary milling	solid	Pattern 1
Pattern 1	017-10	heptane	Planetary milling	solid	Pattern 1
Pattern 1	017-12	MIBK	Planetary milling	solid	Pattern 1
Pattern 1	017-13	IPA	Planetary milling	solid	Pattern 1
Pattern 1	017-14	*i*-PrOAc	Planetary milling	solid	Pattern 1
Pattern 1	017-15	toluene	Planetary milling	solid	Pattern 1
amorphous	018-01	acetone	Vapor stress	solid	Pattern 1
amorphous	018-02	ACN	Vapor stress	solid	Pattern 1
amorphous	018-03	DCM	Vapor stress	solid	Pattern 1
amorphous	018-04	EtOH	Vapor stress	solid	Pattern 1
amorphous	018-05	THF	Vapor stress	solid	Pattern 1
Pattern 2	020-03	EtOH/water (86/14, A_w at most 0.6)	Water Activity experiments	solid	Pattern 1
Pattern 2	020-04	EtOH/water (68/32, A_w at most 0.8)	Water Activity experiments	solid	Pattern 1

[0349] Example 5-13, Preparation and characterization of AAT-730 (Compound A) HCl salt

Pattern 2

AAT-730 HCl salt Pattern 2 was isolated from a large number of screening experiments (Table 5-11). XRPD analysis showed the material to be crystalline (Figure 6-5). Proton NMR analysis (Figure 6-6) conformed to the molecular structure of the compound and no residual solvent was detected. TG/DTA analysis (Figure 6-7) performed on AAT-730 HCl salt Pattern 2 showed a melting endotherm at onset up to 192 °C. Weight loss of at most 0.85% w/w was observed between approximately 30 and 180 °C which suggests an anhydrous material with a small amount of residual solvent/water. XRPD comparison of AAT-730 HCl salt Pattern 1 with Pattern 2 is shown in Figure 6-8.

[0350] Screening experiments which yielded Pattern 2 material

[Table 5-11]

Input	Sample No. (TW-0012F-)	Solvent	Screen method	Result	XRPD
Pattern 1	004-05	THF	slurry (5 °C)	solid	Pattern 2
Pattern 1	004-07	acetone/water (20/1, A_w at most 0.6)	slurry (5 °C)	solid	Pattern 2
Pattern 1	005-01	acetone	slurry (20 °C)	solid	Pattern 2
Pattern 1	005-02	ACN	slurry (20 °C)	solid	Pattern 2
Pattern 1	005-03	DCM	slurry (20 °C)	solid	Pattern 2
Pattern 1	005-04	EtOH	slurry (20 °C)	solid	Pattern 2
Pattern 1	005-05	THF	slurry (20 °C)	solid	Pattern 2
Pattern 1	005-07	acetone/water (20/1, A_w at most 0.6)	slurry (20 °C)	solid	Pattern 2
Pattern 1	006-01	acetone	slurry (50 °C)	solid	Pattern 2
Pattern 1	006-02	ACN	slurry (50 °C)	solid	Pattern 2
Pattern 1	006-04	EtOH	slurry (50 °C)	solid	Pattern 2
Pattern 1	006-05	THF	slurry (50 °C)	solid	Pattern 2
Pattern 1	010-01	acetone	sonication	solid	Pattern 2
Pattern 1	010-02	ACN	sonication	solid	Pattern 2
Pattern 1	010-03	DCM	sonication	solid	Pattern 2
Pattern 1	010-04	EtOH	sonication	solid	Pattern 2
Pattern 1	010-05	THF	sonication	solid	Pattern 2
Pattern 1	012-01	acetone	vapor stress	solid	Pattern 2
Pattern 1	012-02	ACN	vapor stress	solid	Pattern 2
Pattern 1	012-03	cyclohexane	vapor stress	solid	Pattern 2
Pattern 1	012-04	DIPE	vapor stress	solid	Pattern 2
Pattern 1	012-05	EtOH	vapor stress	solid	Pattern 2
Pattern 1	012-06	EtOAc	vapor stress	solid	Pattern 2
Pattern 1	012-07	MeOH	vapor stress	solid	Pattern 2
Pattern 1	012-08	MTBE	vapor stress	solid	Pattern 2
Pattern 1	012-09	MIBK	vapor stress	solid	Pattern 2
Pattern 1	012-10	IPA	vapor stress	solid	Pattern 2
Pattern 1	012-11	*i*-PrOAc	vapor stress	solid	Pattern 2
Pattern 1	012-12	heptane	vapor stress	solid	Pattern 2
Pattern 1	013-01	none	23% RH stress	solid	Pattern 2
Pattern 1	013-02	none	75% RH stress	solid	Pattern 2
Pattern 1	015-01	1-Butanol	temp cycle	solid	Pattern 2
Pattern 1	015-02	cyclohexane	temp cycle	solid	Pattern 2
Pattern 1	015-03	DIPE	temp cycle	solid	Pattern 2
Pattern 1	015-05	MEK	temp cycle	solid	Pattern 2
Pattern 1	015-06	MIBK	temp cycle	solid	Pattern 2
Pattern 1	015-08	IPA	temp cycle	solid	Pattern 2
Pattern 1	015-09	dioxane	temp cycle	solid	Pattern 2
Pattern 1	015-10	*i*-PrOAc	temp cycle	solid	Pattern 2
Pattern 1	015-11	toluene	temp cycle	solid	Pattern 2
Pattern 1	015-12	heptane	temp cycle	solid	Pattern 2
Pattern 2	019-01	THF	competitive slurry	solid	Pattern 2
Pattern 2	019-02	THF	competitive slurry	solid	Pattern 2
Pattern 2	019-03	THF	competitive slurry	solid	Pattern 2
Pattern 2	020-01	EtOH/water (97/3, A_w at most 0.2)	water activity experiments	solid	Pattern 2

[0351] Example 5-14, Preparation and characterization of AAT-730 (Compound A) HCl salt Pattern 3

AAT-730 HCl salt Pattern 3 material was isolated from the experiments shown in Table 5-12. XRPD analysis (Figure 6-9) showed the material to be crystalline. Proton NMR analysis of the sample isolated from the water/IPA crash precipitation experiment (Figure 6-10) conformed to the molecular structure of the compound and IPA (at most 7.6% w/w) was detected. TG/DTA performed on the same sample of AAT-730 HCl salt Pattern 3 showed a weight loss of at most 2.7% w/w between approximately 30 and 145 °C and a further weight loss of 3.6% between approximately 145 and 180 °C (Figure 6-11). The weight loss may be due to loss of IPA and/or water and suggests the compound may be a solvate/hydrate. The other Pattern 3 solids may be either hydrates or isostructural solvates.

[0352] Experiments which yielded Pattern 3 solids

[Table 5-12]

Input	Sample No. (TW-0012E-)	Solvent	Anti-solvent	Screen method	Result	XRPD
Pattern 1	008-02	DMSO/water (80/20, A_w at most 0.27)	none	slow evap	solid	Pattern 3 (PS) + 2
Pattern 1	009-05	water	IPA	crash pptn	solid (after evap)	Pattern 3
Pattern 1	015-04	DMAc	none	temp cycle	solid	Pattern 3 + peak

[0353] Example 5-15, Preparation and characterization of AAT-730 (Compound A) HCl salt Pattern 4

AAT-730 HCl salt Pattern 4 was isolated from the screening experiments shown in Table 5-13. The XRPD diffractogram is shown in Figure 6-12 and is concordant with a crystalline material. Pattern 4 solids were not further analyzed as there was a very small amount of material, but it may be a hydrate. However, it was included in interconversion experiments (Example 5-16).

[0354] Screening experiments which yielded Pattern 4 material

[Table 5-13]

Input	Sample No. (TW-0012E-)	Solvent	Screen method	Result	XRPD
Pattern 1	008-03	EtOH/water (50/50)	slow evap	solid-after evap	Pattern 4
Pattern 1	009-04	water	crash pptn	solid-after evap	Pattern 4
Pattern 1	011-01	water	freeze drying	solid	Pattern 4

Example 5-16, Determination of most stable form

The most robust method for determining the thermodynamically most stable Form at a given temperature involves suspension of all observed forms in a saturated solution, as the system will naturally gravitate to the lowest free energy form. In solvent mediated conversions, seeds of all forms are present and there is no activation energy barrier to interconversion. This technique is used to identify the 'true' transition temperature and the thermodynamic relationship between the forms.

[0355] Interconversion slurries of AAT-730 (Compound A) HCl salt

Saturated slurries of Pattern 2 AAT-730 HCl salt were prepared in THF and stirred overnight. The slurry was seeded with Patterns 1, 2, 3, and 4 AAT-730 HCl salt and stirred for up to 10 days prior to isolation and analysis by XRPD (Figure 6-13). The results are shown in Table 5-14 and suggest that Pattern 2 material is the most stable form in anhydrous solvent in the temperature range 5 to 50 °C.

[0356] Results from interconversion slurry experiments

[Table 5-14]

Sample No. (TW-0012E-)	Solvent	Temp (°C)	Seeds added	Result	XRPD
019-01	THF	5	Patterns 1,2,3 and 4	solid	Pattern 2
019-02	THF	25	Patterns 1,2,3 and 4	solid	Pattern 2
019-03	THF	50	Patterns 1,2,3 and 4	solid	Pattern 2

[0357] Water activity experiments of AAT-730 (Compound A) HCl salt

Water activity experiments were carried out to determine if the water activity of the solvent influenced which form was isolated. The results are shown in Table 5-15 and Figure 6-14. At A_w at most 0.2, Pattern 2 was the most stable form. A mixture was isolated at A_w at most 0.4 and this may be close to the critical water activity. At A_w greater than or equal to 0.6, Pattern 1 was the more stable form. These results suggest that Pattern 1 may be a hydrate as its formation is influenced by water activity.

[0358] Results from water activity experiments

[Table 5-15]

Sample No. (TW-0012E-)	Solvent	A_w	Seeds added	Result	XRPD
020-01	EtOH/water (97/3)	0.2	Patterns 1,2,3 and 4	solid	Pattern 2
020-02	EtOH/water (93/7)	0.4	Patterns 1,2,3 and 4	solid	Pattern 1 + small amount of Pattern 2
020-03	EtOH/water (86/14)	0.6	Patterns 1,2,3 and 4	solid	Pattern 1
020-04	EtOH/water (68/32)	0.8	Patterns 1,2,3 and 4	solid	Pattern 1

[0359] Example 5-17, Further characterization of AAT-730 (Compound A) HCl salt Pattern 2

AAT-730 HCl salt Pattern 2 was further characterized by DSC and humidity

stressing. The aqueous solubility was also determined by aliquot addition.

[0360] The DSC thermogram obtained for AAT-730 HCl salt Pattern 2 at 10 °C/min is shown in Figure 6-15 and shows a melting endotherm at onset 190.84 °C which is concordant with TG/DTA data.

[0361] AAT-730 HCl salt Pattern 2 was stressed at a range of relative humidity conditions for 7 days, as shown in Table 5-16. The salt was added to HPLC vials and placed, uncapped, into the relative humidity conditions shown in Table 5-16. The materials remained as Pattern 2 under the conditions tested (Figure 6-16). ^{1}H NMR analysis (Figure 6-17, Figure 6-18 and Figure 6-19) of the post-stressed samples showed no change.

[0362] Results from RH screening experiments

[Table 5-16]

Input	Sample No (TW0012E-)	Conditions	XRPD
Pattern 2	021-01	25 °C/60% RH	Pattern 2
Pattern 2	021-02	40 °C/75% RH	Pattern 2
Pattern 2	021-03	70 °C/75% RH	Pattern 2

[0363] The aqueous solubility was determined as detailed in Method 4-1 by aliquot addition. The solubility of AAT-730 HCl salt Pattern 2 in water was 197-263 mg/mL at pH 6-7.

[0364] Conclusions

1) Four novel solids were isolated from the screening experiments. The XRPD diffractograms were all very similar suggesting that the solids all have a very similar crystal structure.

2) Interconversion slurries in dry solvent at 5, 25 and 50 °C yielded Pattern 2 material suggesting that this was the stable form in dry solvent between 5 and 50 °C.

3) Water activity experiments yielded AAT-730 Pattern 1 at A_w greater than or equal to 0.6. Pattern 2 was stable at A_w at most 0.2 and at A_w at most 0.4, a mixture was isolated which suggests that the critical water activity is at most 0.4.

4) AAT-730 HCl salt Pattern 2 was a crystalline anhydrate with a melting onset of 190.84 °C.

5) AAT-730 HCl salt Pattern 2 was stressed for 7 days at 25 °C/60% RH, 40 °C/75% RH and at 70 °C/75% RH. The post-stressed samples were analyzed by XRPD and ^{1}H NMR analyses. No change in physical form was observed in all samples and ^{1}H NMR suggested that it was chemically stable.

6) The solubility of AAT-730 HCl salt Pattern 2 was 197-263 mg/mL (pH 6-7).

[0365] Example 6, Isolation of AAT-730 (Compound A) HCl salt Pattern 2

AAT-730 (2 g) and THF (10 mL) were added to a round bottom flask and stirred. Dissolution was incomplete after up to 10 minutes and a further portion (1 mL) of THF was added. The mixture was stirred to dissolution and HCl in dioxane (4 M, 1.5 mL) was added dropwise. A crust formed on the top and this was broken up with a pipette. Gumball formation was noted and a further portion (3 mL) of THF was added and the mixture was stirred to break up the solids. The solids were isolated by filtration, washed with THF (3 mL) and air dried in the Buchner funnel. The solids were transferred to a vial and dried to constant weight, under a flow of N_2, to yield the salt as a white solid (2.128 g, up to 98% yield). XRPD analysis confirmed formation of AAT-730 HCl salt Pattern 1.

[0366] AAT-730 HCl salt Pattern 1 was added to THF (10-20 volumes) and stirred for 5 days at 20 °C (temperatures between 5 and 50 °C were also suitable). The samples were isolated and air dried prior to analysis by XRPD (Figure 7). AAT-730 HCl salt Pattern 2 was isolated. Pattern 2 material may be produced quicker by seeding the slurry.

Claims

1. A crystalline form Pattern 2 of HCl salt of the compound, 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, wherein said crystalline form Pattern 2 is characterized by at least one of the following:
(i) a powder X-ray diffraction (XRPD) pattern comprising peaks in terms of 2-Theta, at 5.9, 6.6, 8.9, 11.8, 13.2, 14.5, 15.6, 16.0, 17.4, 18.3, 19.5, 20.2, 22.0, 26.6, and 27.0 degrees 2-Theta +/- 0.2 degrees 2-Theta; or
(ii) an XRPD pattern substantially in accordance with the pattern shown by Fig. 1-1.

2. The crystalline form Pattern 2 according to claim 1, having a melting endotherm at onset 191 °C in differential scanning calorimetry (DSC).

3. The crystalline form Pattern 2 according to claim 1 or 2, having a melting endotherm at onset 192°C in thermogravimetry/differential thermal analysis (TG/DTA).

4. The crystalline form Pattern 2 according to any one of claims 1 to 3, wherein the crystalline form Pattern 2 is at least 90 weight % based on weight of HCl salt.

5. A crystalline form Pattern 1 of HCl salt of the compound, 2-[3-({1-[2-(dimethylamino)ethyl]-2-(2,2-dimethylpropyl)-1H-1,3-benzodiazol-5-yl}sulfonyl)azetidin-1-yl]ethan-1-ol, wherein said crystalline form Pattern 1 is characterized by at least one of the following:
(i) an XRPD pattern comprising peaks in terms of 2-Theta at 6.6, 13.2, 15.6, 16.0, 17.2, 17.4, 17.9, 18.9, 20.1, 22.1, 23.4, 26.6, and 27.0 degrees 2-Theta +/- 0.2 degrees 2-Theta; or
(ii) an XRPD pattern substantially in accordance with the pattern shown by Fig. 1-4.

6. The crystalline form Pattern 1 according to claim 5, having a melting endotherm at onset 192 °C in differential scanning calorimetry (DSC).

7. The crystalline form Pattern 1 according to claim 5 or 6, having a melting endotherm at onset 200°C in thermogravimetry/differential thermal analysis (TG/DTA).

8. The crystalline form Pattern 1 according to any one of claims 5 to 7, wherein the crystalline form Pattern 1 is at least 90 weight % based on weight of HCl salt.

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9. A pharmaceutical composition comprising the crystalline form Pattern 2 as defined in any one of claims 1 to 4 and/or the crystalline form Pattern 1 as defined in any one of claims 5 to 8 and a pharmaceutically acceptable excipient, diluent, or carrier.

10. Use of the crystalline form Pattern 2 as defined in any one of claims 1 to 4, and/or the crystalline form Pattern 1 as defined in any one of claims 5 to 8 for preventing or treating a disease or condition selected from pain, inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgia,, trigeminal neuralgia, multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhea, functional gastrointestinal disorder, arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis, cutaneous T cell lymphoma, pancreatic cancer, systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars, acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis, glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome, glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy, hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH), myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack, diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL), attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome, malaria, and pyrexia.

11. The use according to claim 10, wherein the disease is pain.

12. The use according to claim 10, wherein the disease is inflammatory pain.

13. The use according to claim 10, wherein the disease is irritable bowel syndrome (IBS).

14. The use according to claim 10, wherein the disease is inflammatory bowel disease (IBD).

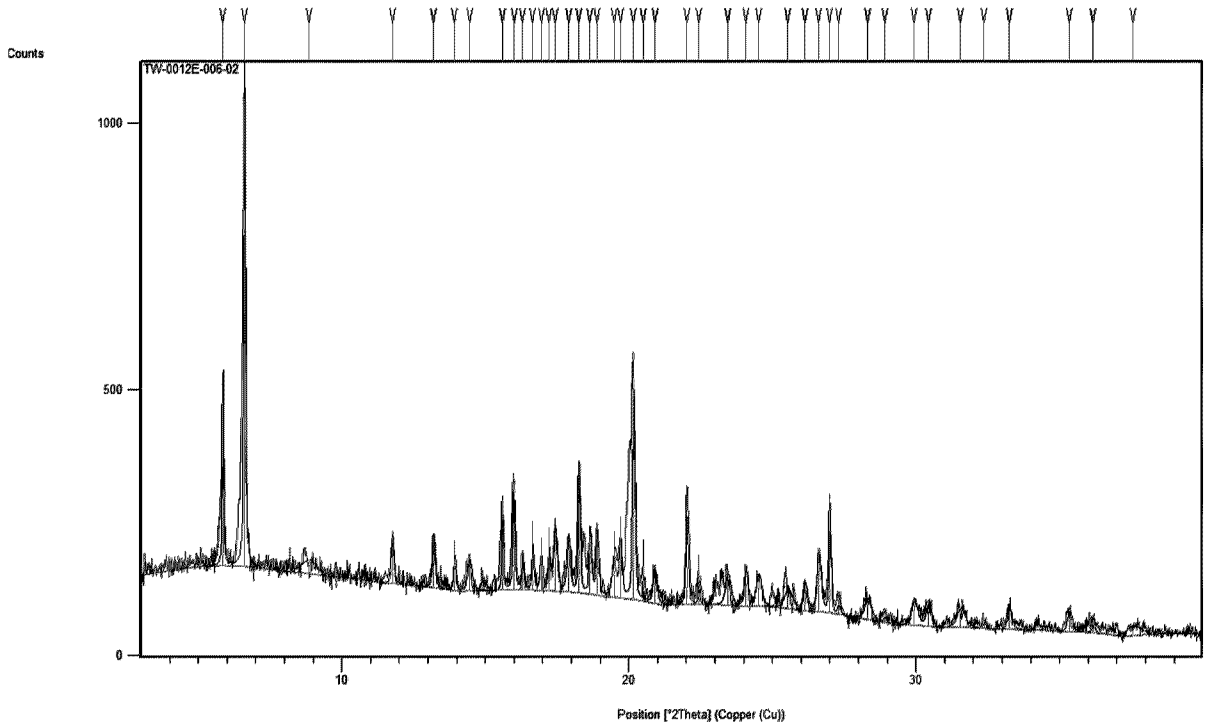
15. The use according to claim 10, wherein the disease is ulcerative colitis.

16. A process of producing the crystalline form Pattern 2 as defined in any one of claims 1 to 4, and/or the crystalline form Pattern 1 as defined in any one of claims 5 to 8, wherein the process comprises suspending the compound of claim 1 or claim 5 in a suitable solvent; contacting the compound with hydrochloric acid or hydrogen chloride gas to provide a mixture; heating the mixture at a temperature of from 20 °C to 100 °C; cooling the mixture at a temperature of from -20 °C to 40 °C; and isolating the HCl salt.

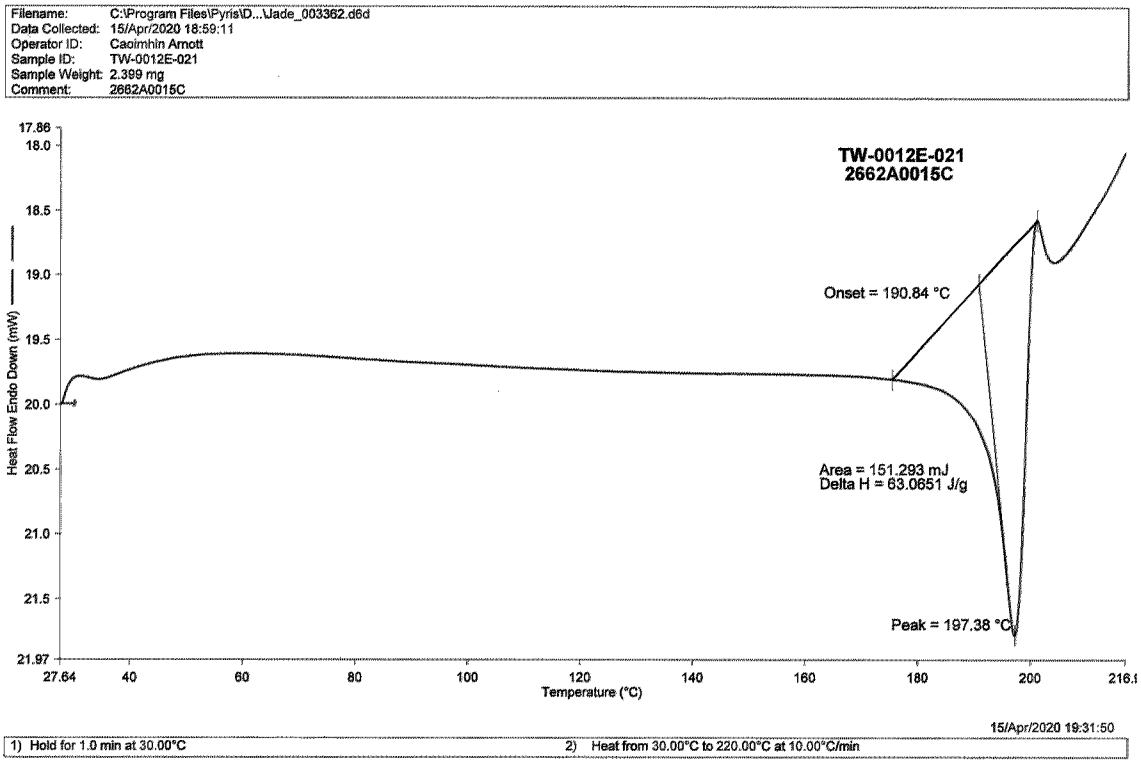
17. The process according to claim 16, wherein the suitable solvent is selected from the group consisting of acetone, acetonitrile, 1-butanol, cyclohexane, dichloromethane, diisopropyl ether, dimethylacetamide, dimethyl sulfoxide, dioxane, ethanol, ethyl acetate, heptane, isopropyl acetate, methyl tert-butyl ether, methyl ethyl ketone, methyl isobutyl ketone, methanol, 2-propanol, toluene, tetrahydrofuran, water, and a mixture of the solvents thereof.

{DRAWINGS}

{Fig. 1-1}



{Fig. 1-2}



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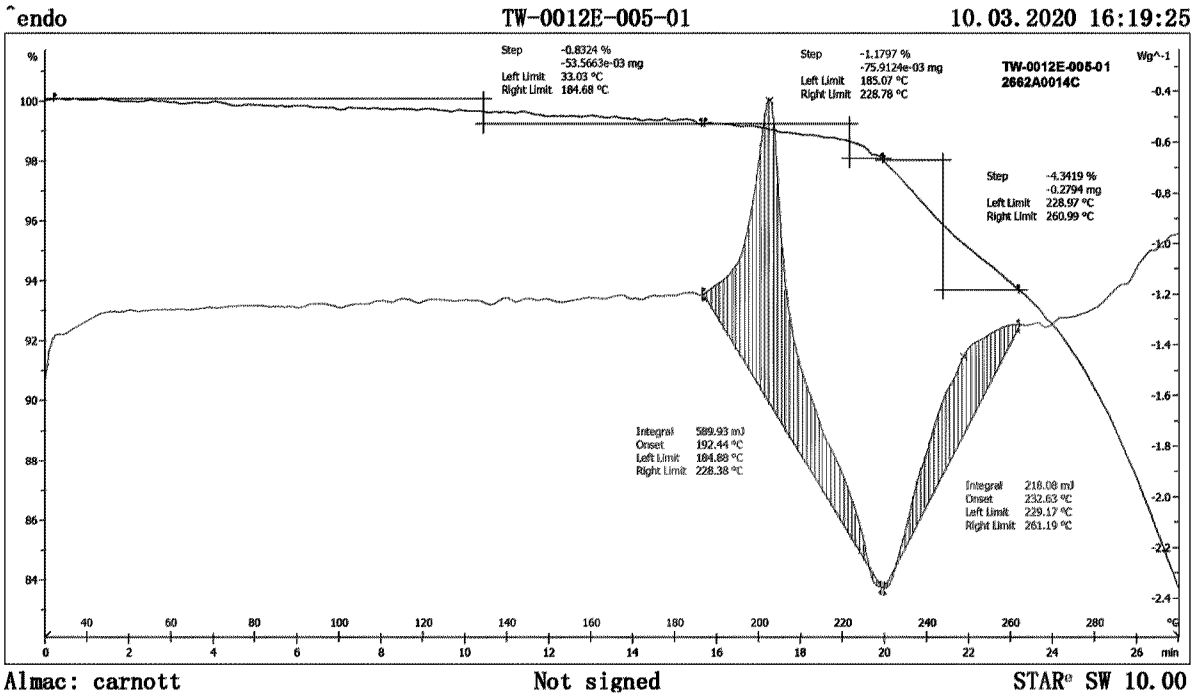
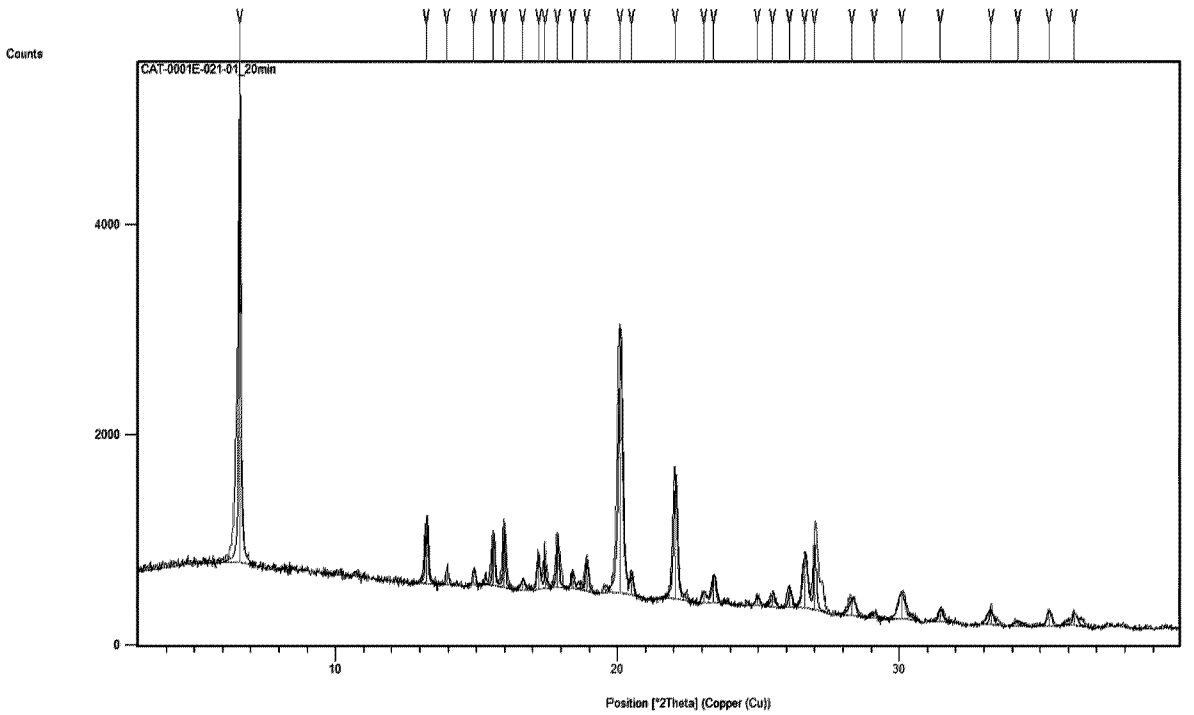
{Fig. 1-3}



{Fig. 1-4}



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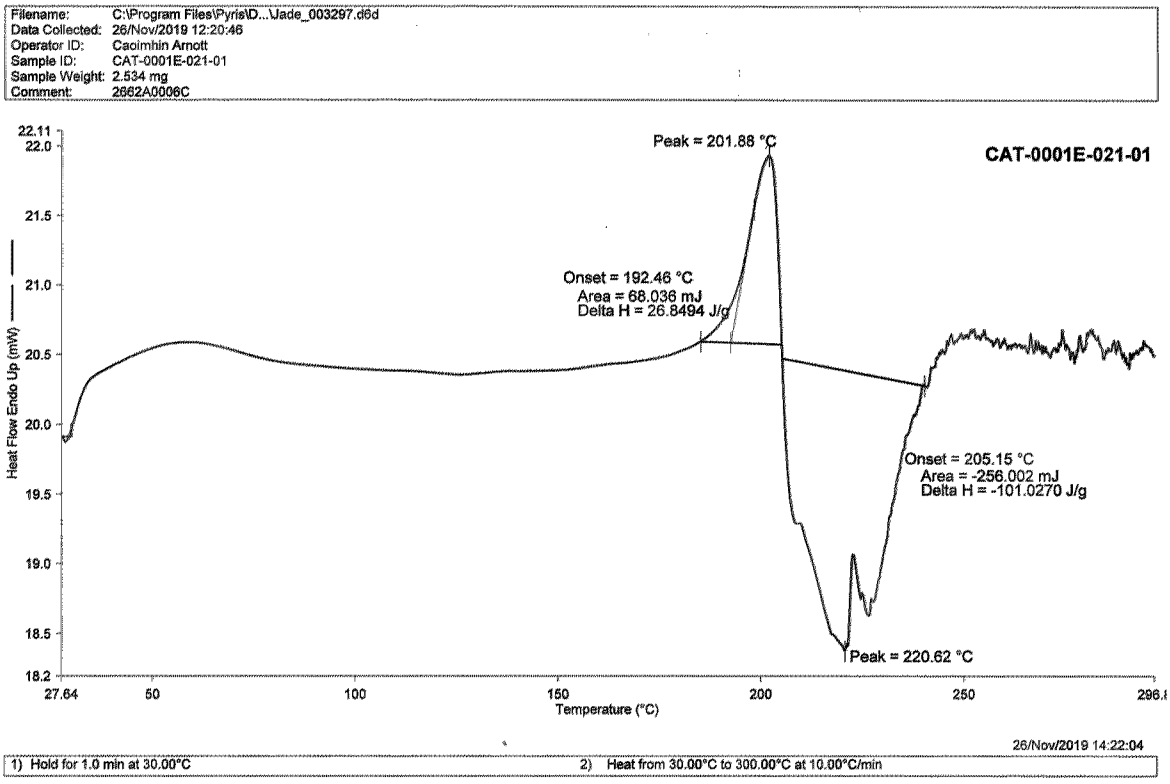
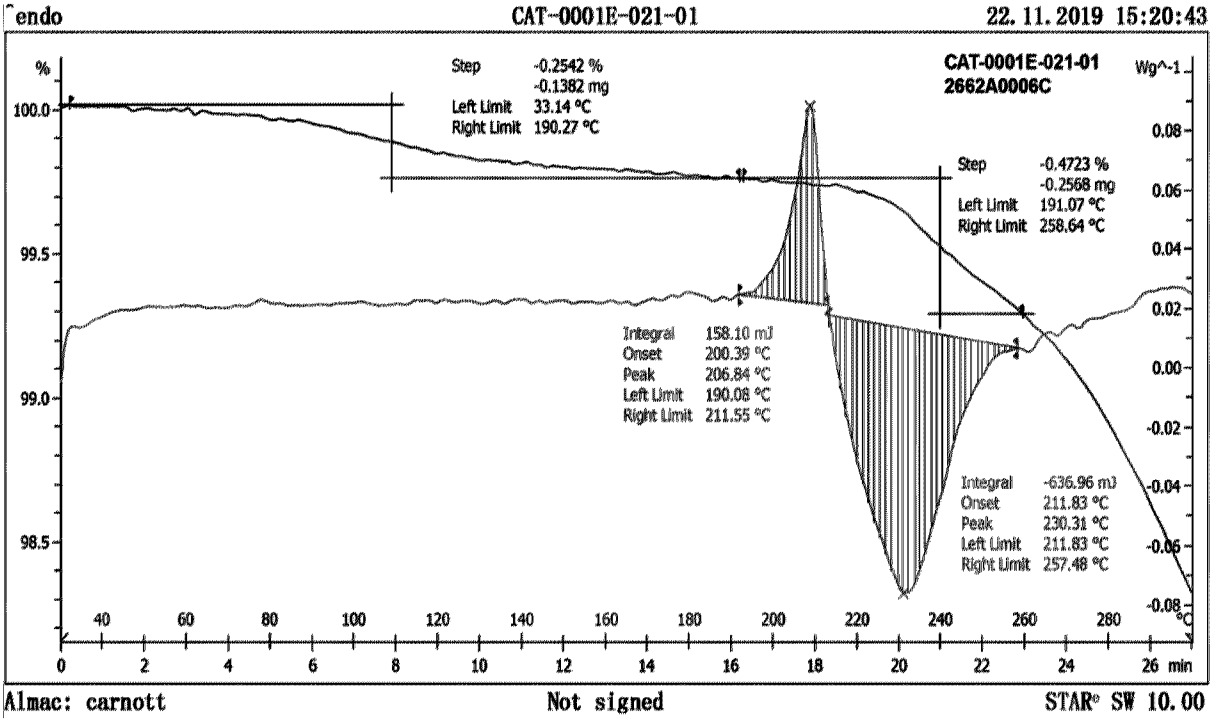
{Fig. 1-5}



{Fig. 1-6}



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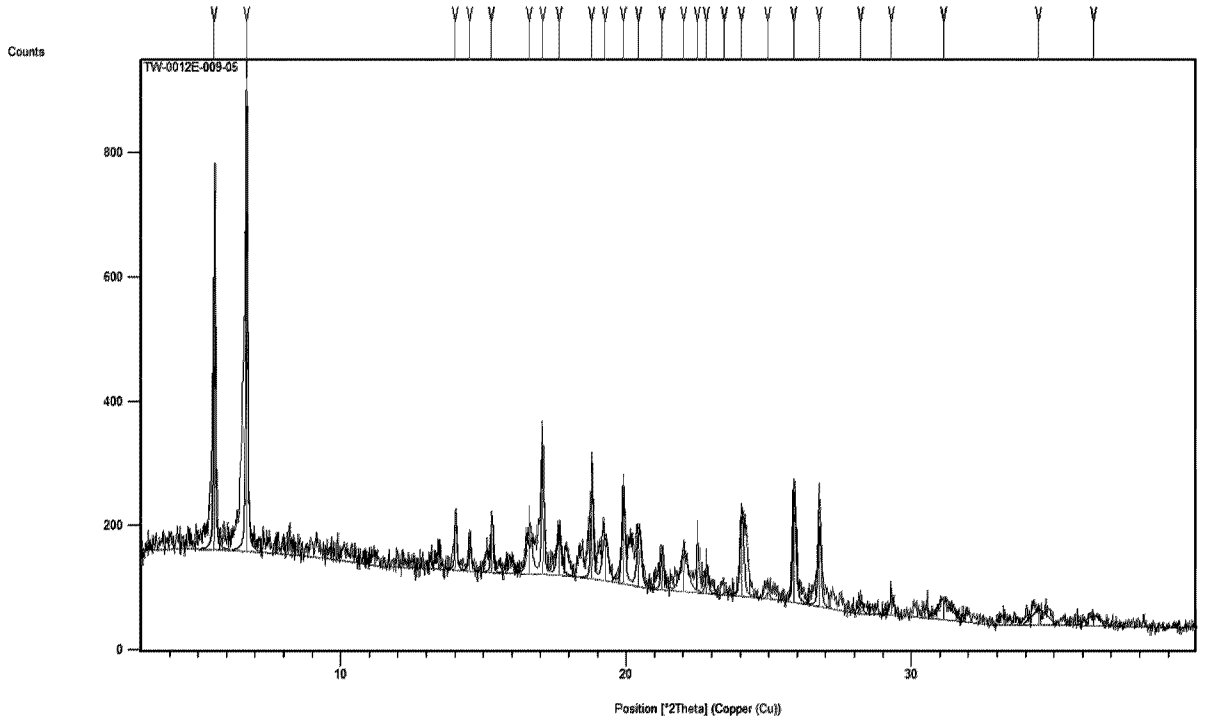
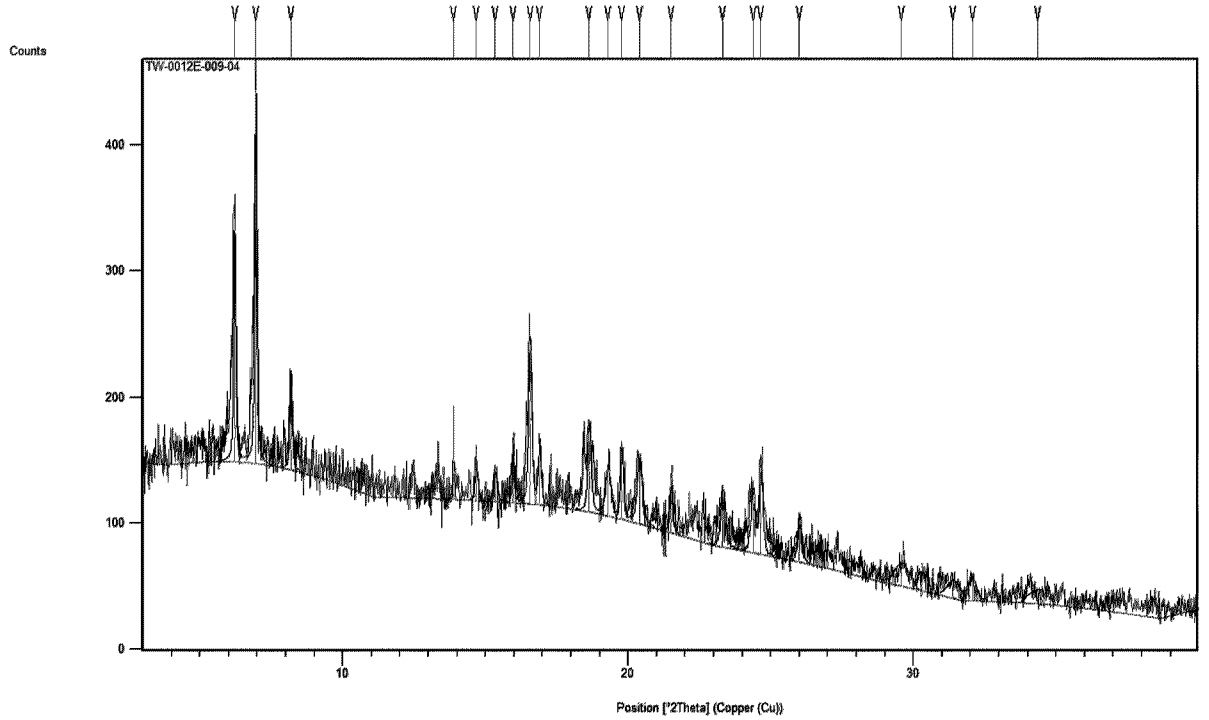
{Fig. 1-7}



{Fig. 1-8}



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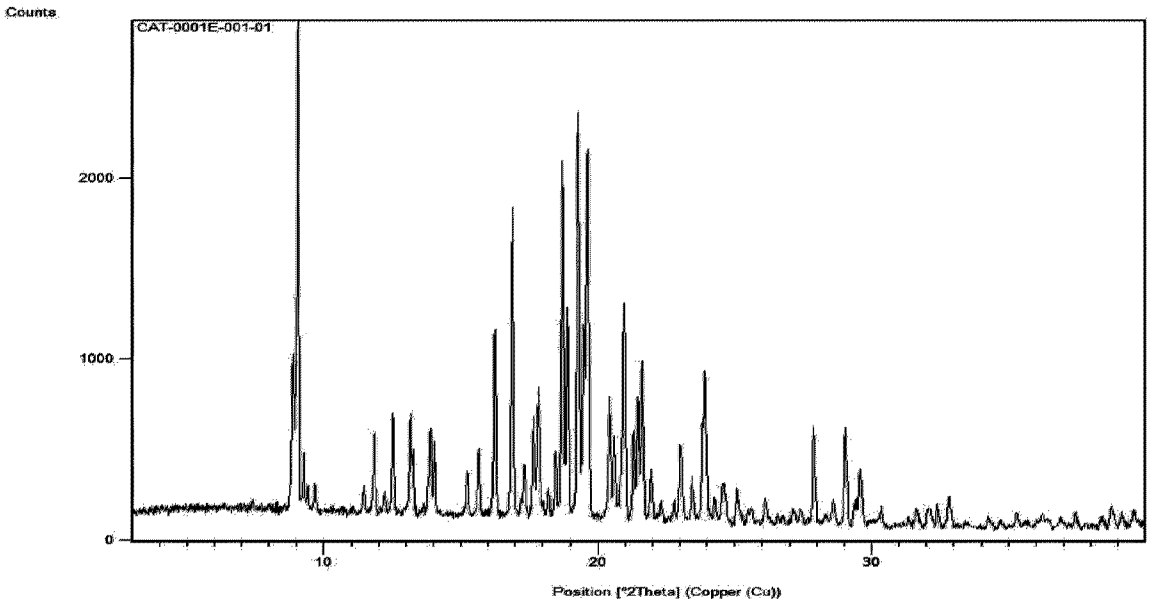
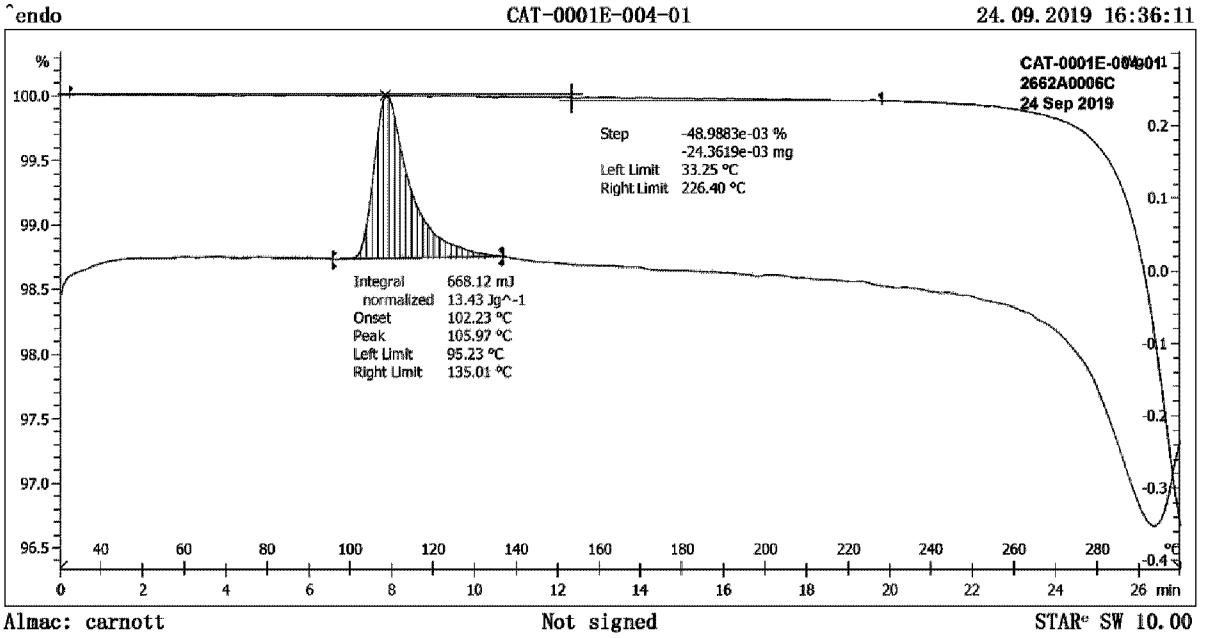
{Fig. 2-1}



{Fig. 2-2}



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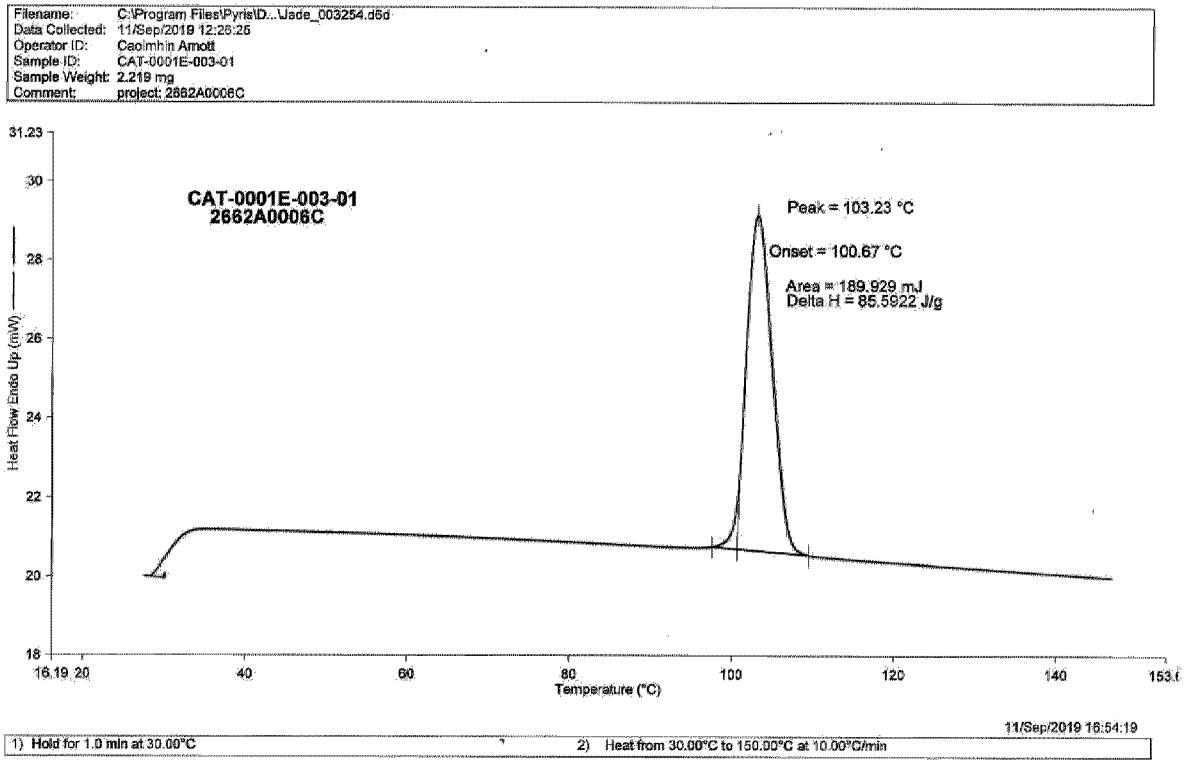
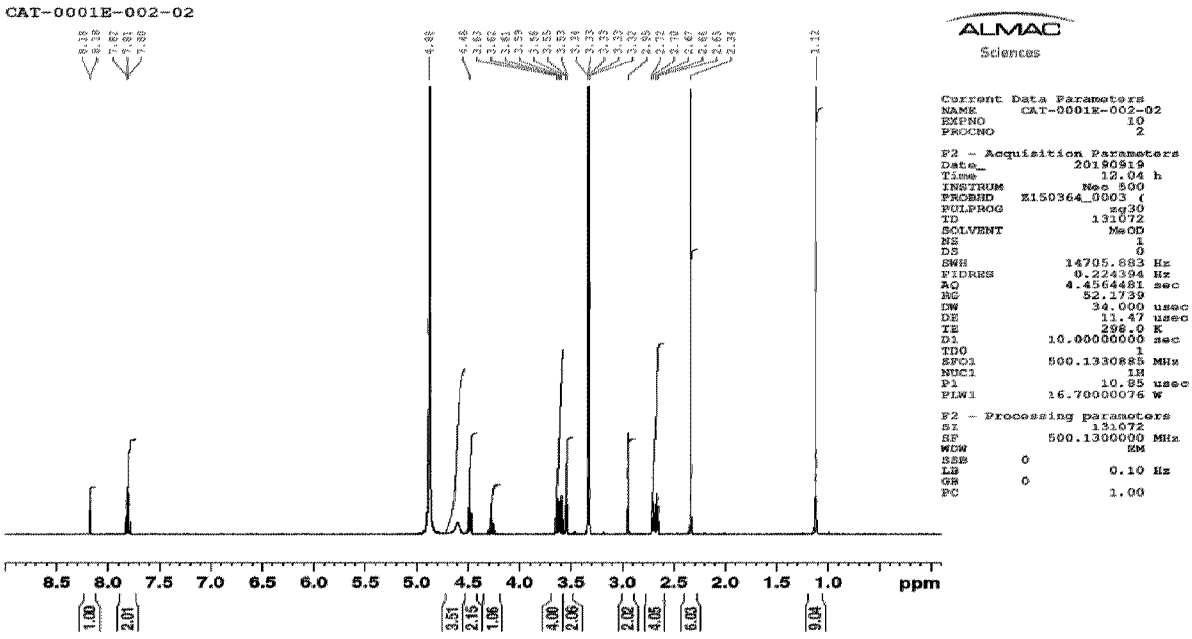
{Fig. 2-3}



{Fig. 2-4}



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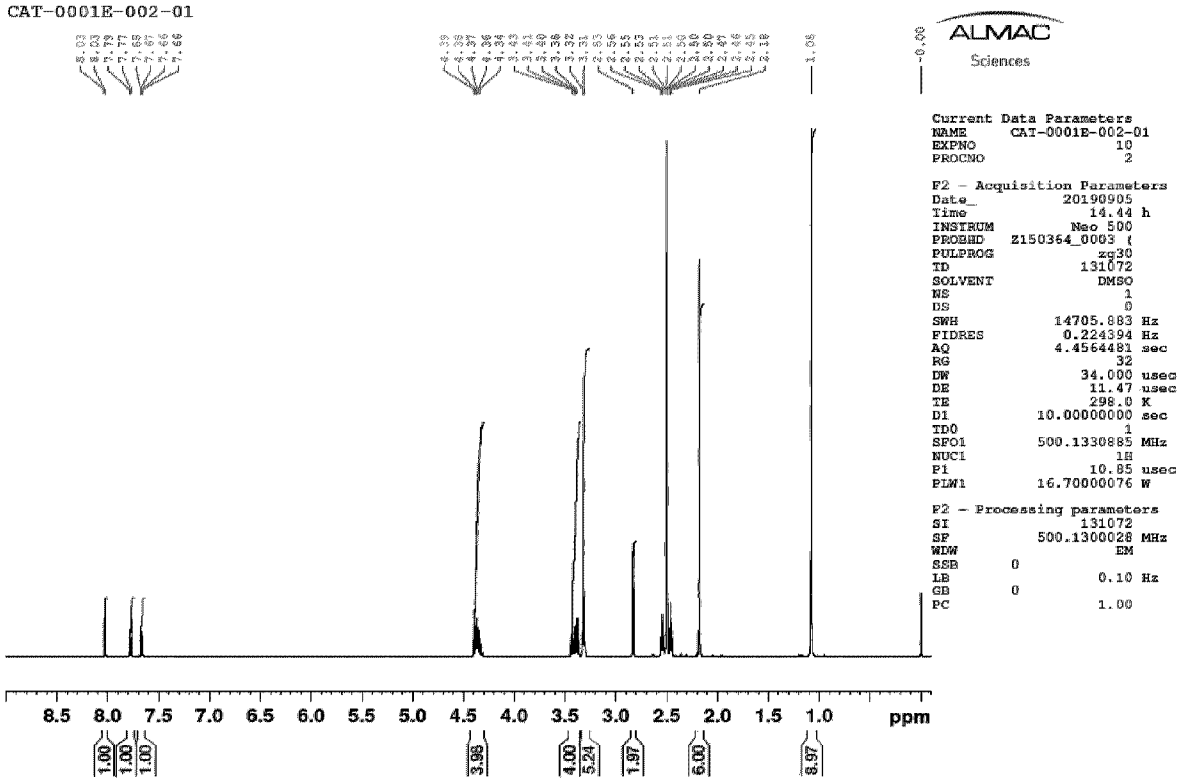
{Fig. 2-5}



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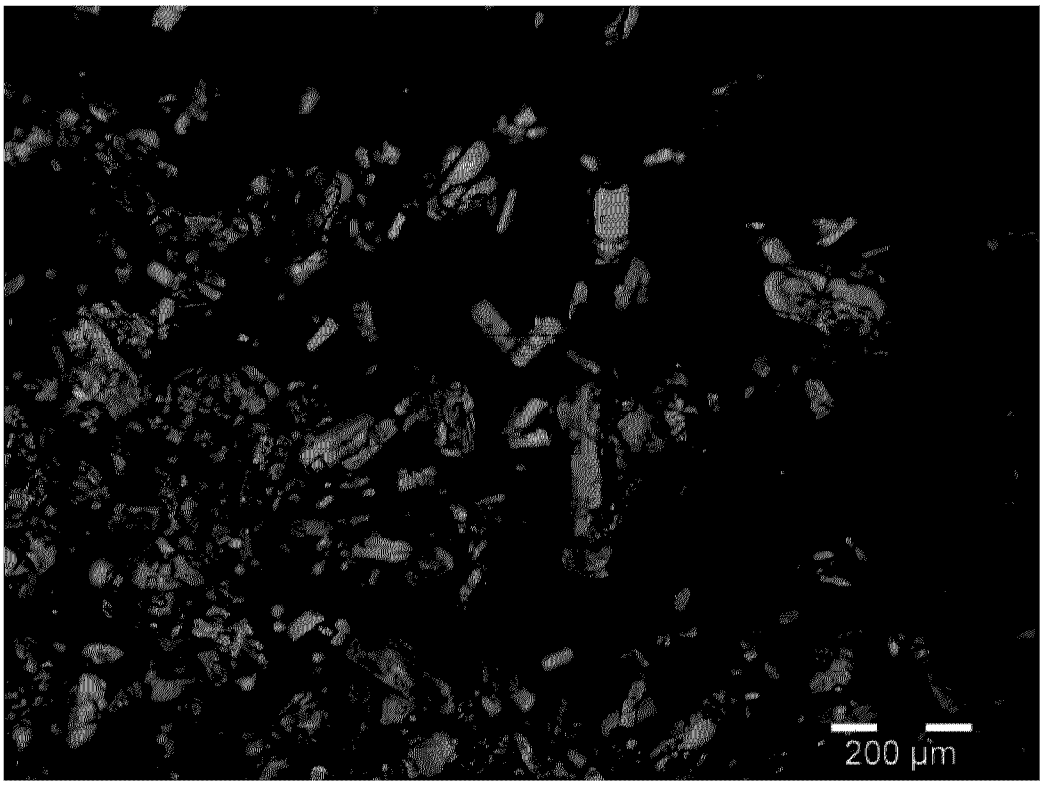

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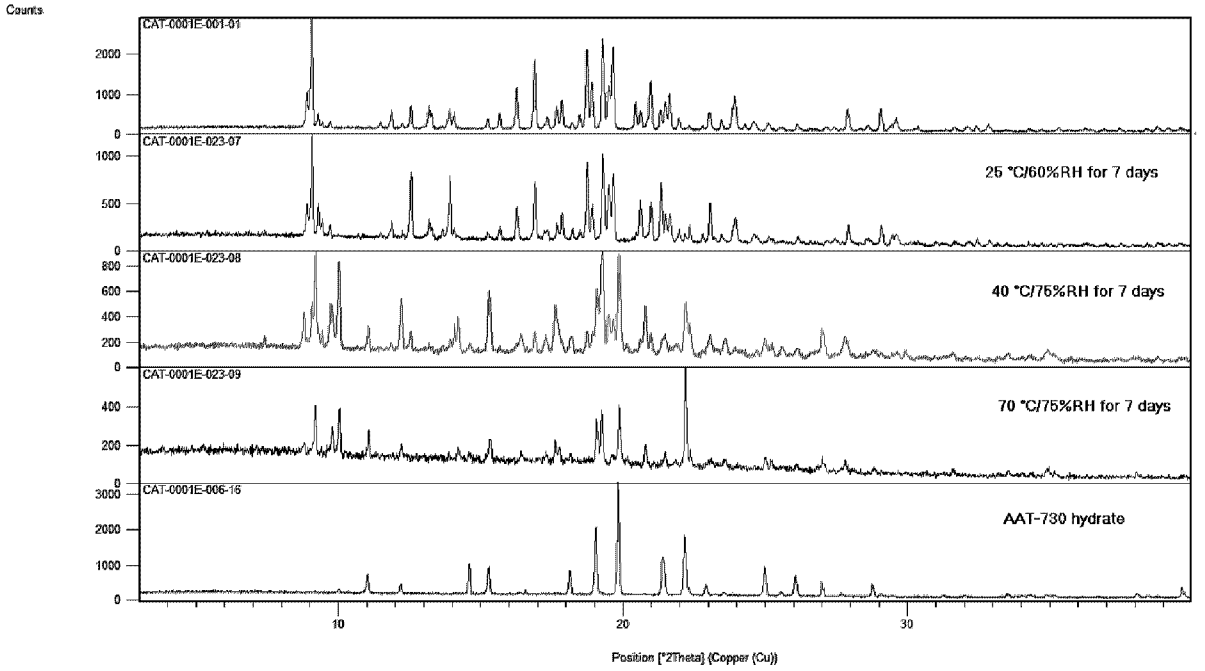
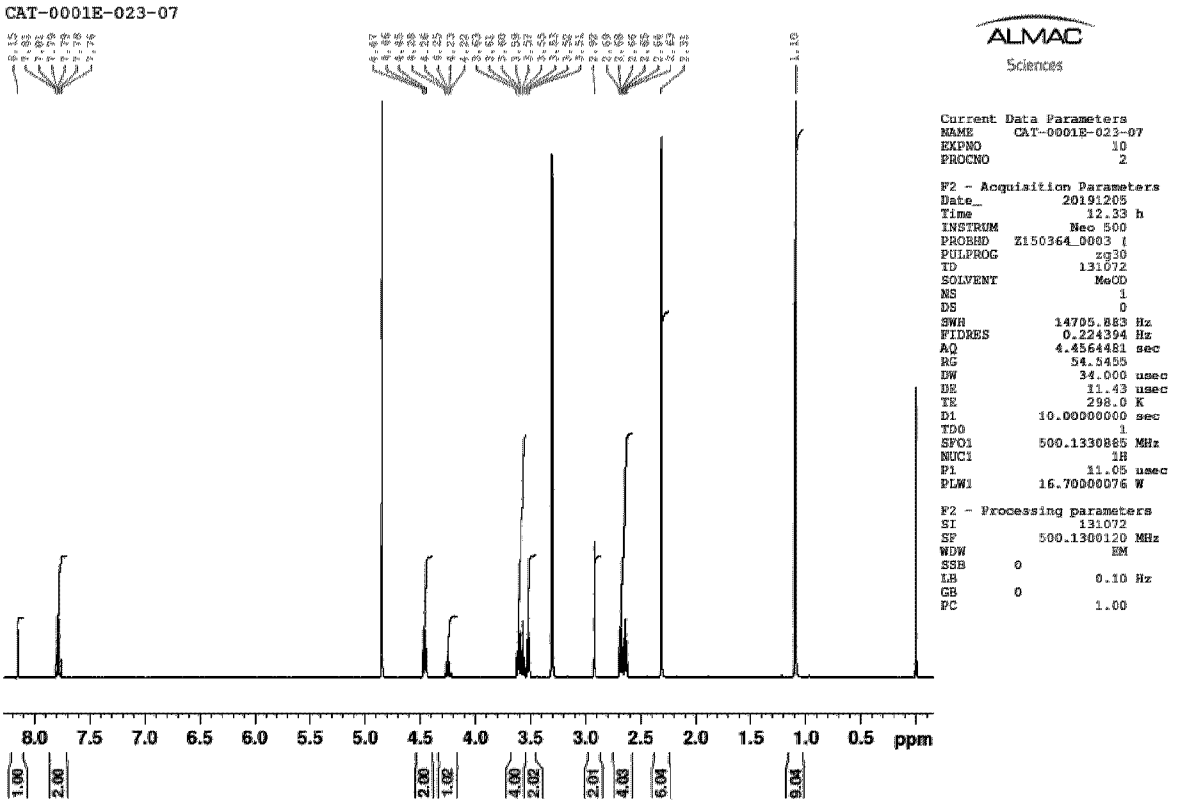
{Fig. 2-7}



{Fig. 2-8}



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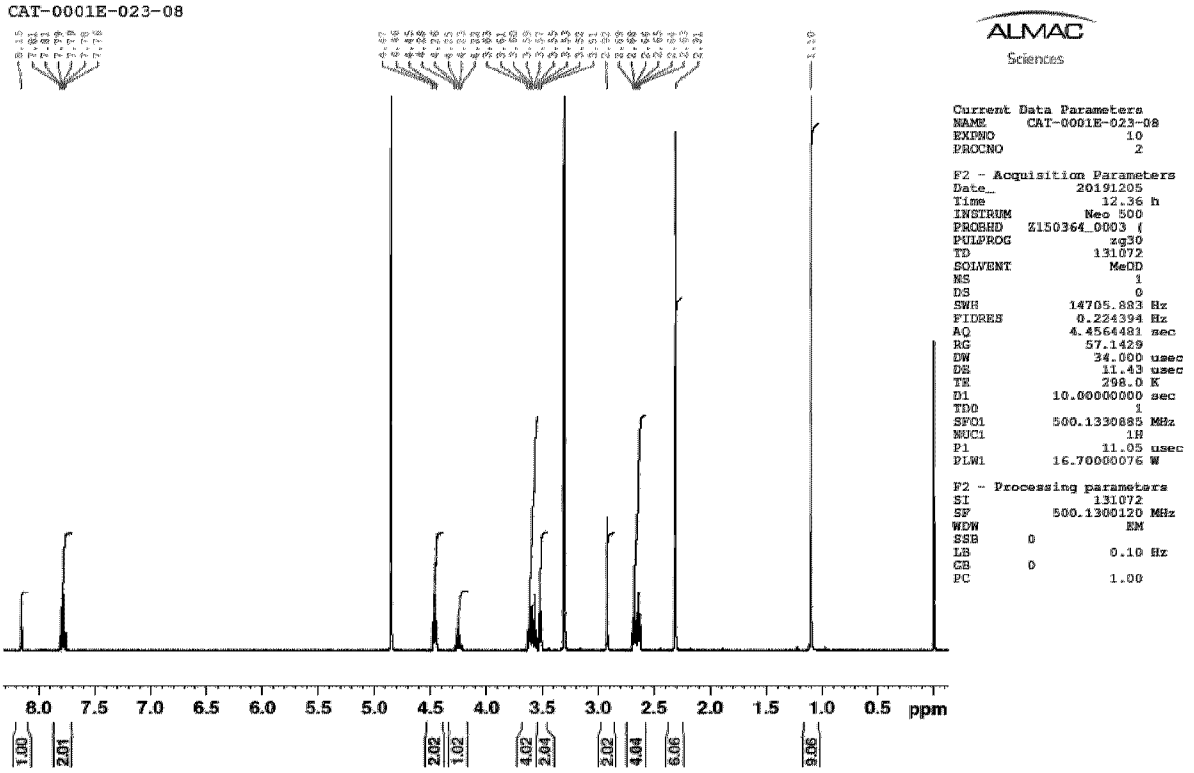
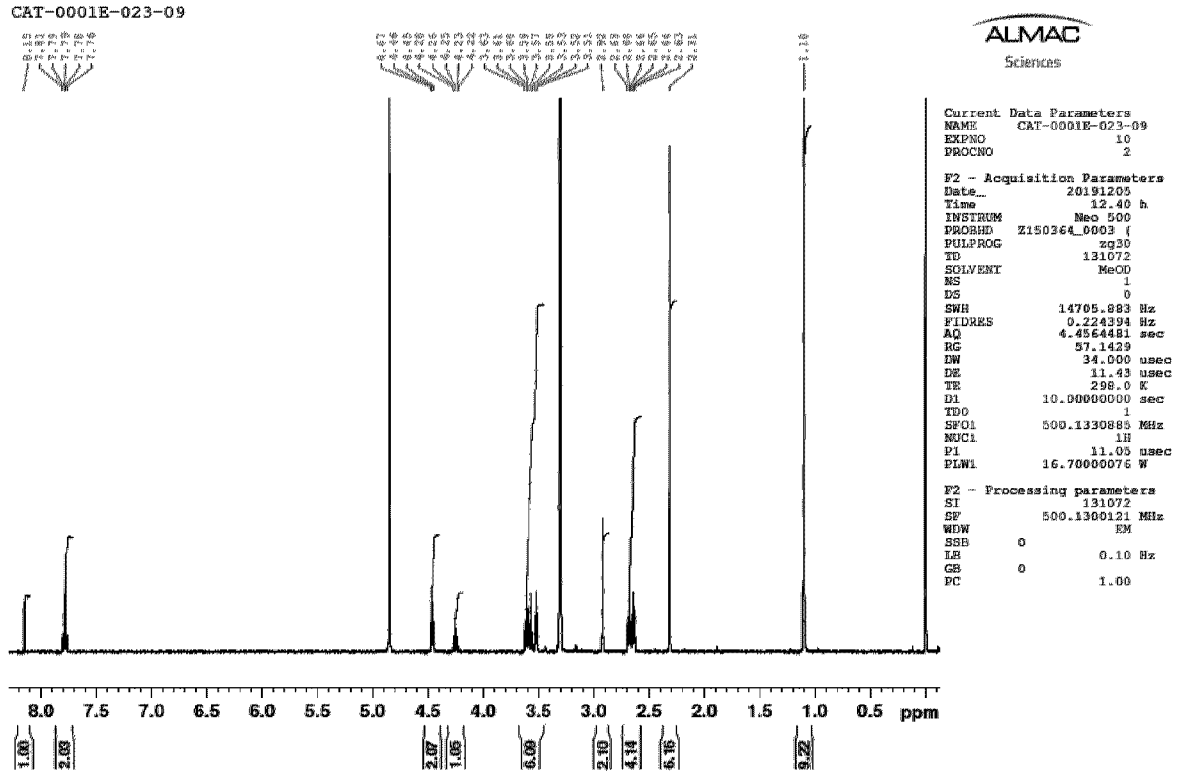
{Fig. 2-9}



{Fig. 2-10}



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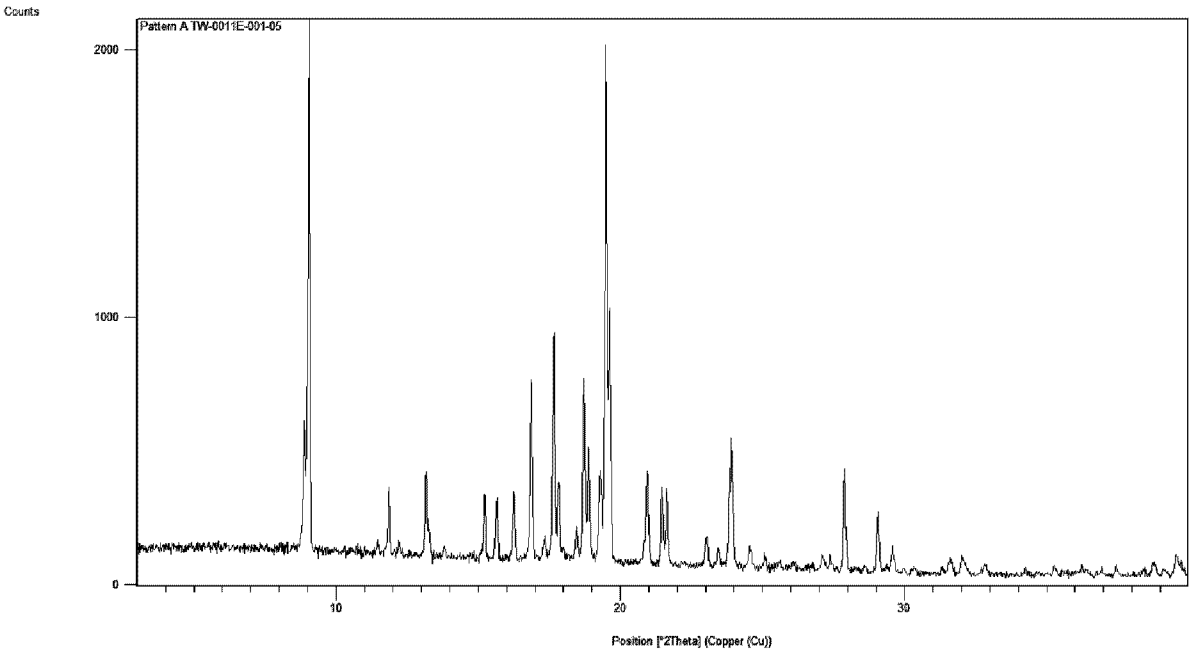
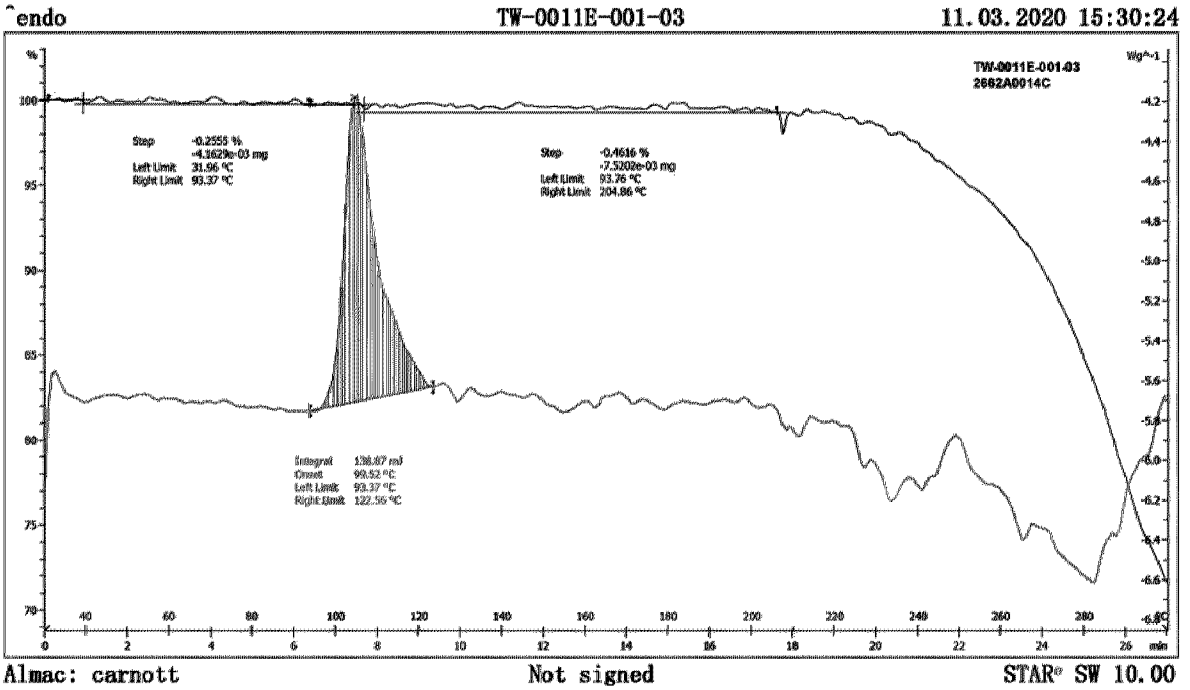
{Fig. 3-1}



{Fig. 3-2}



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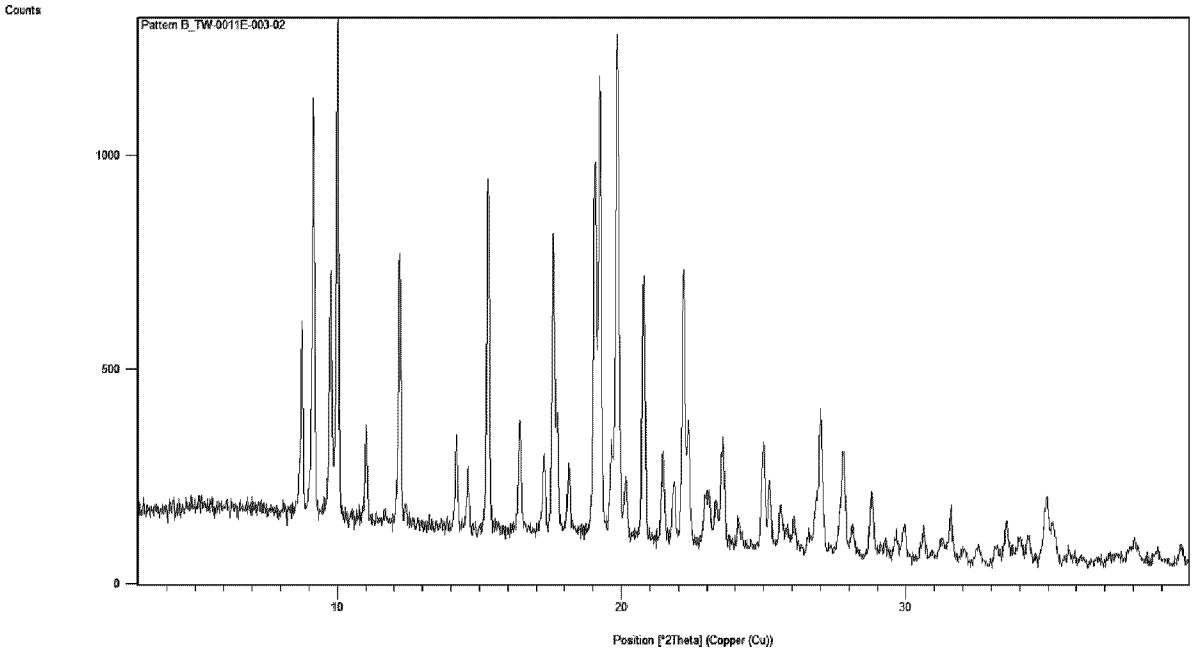
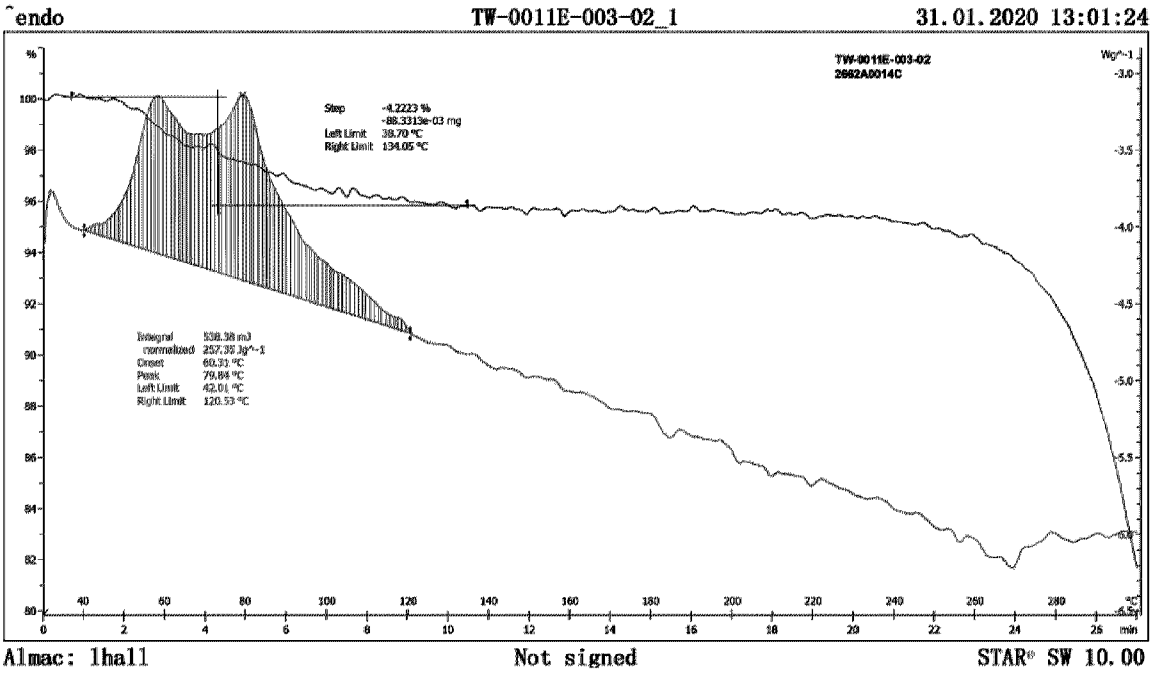
{Fig. 3-3}



{Fig. 3-4}



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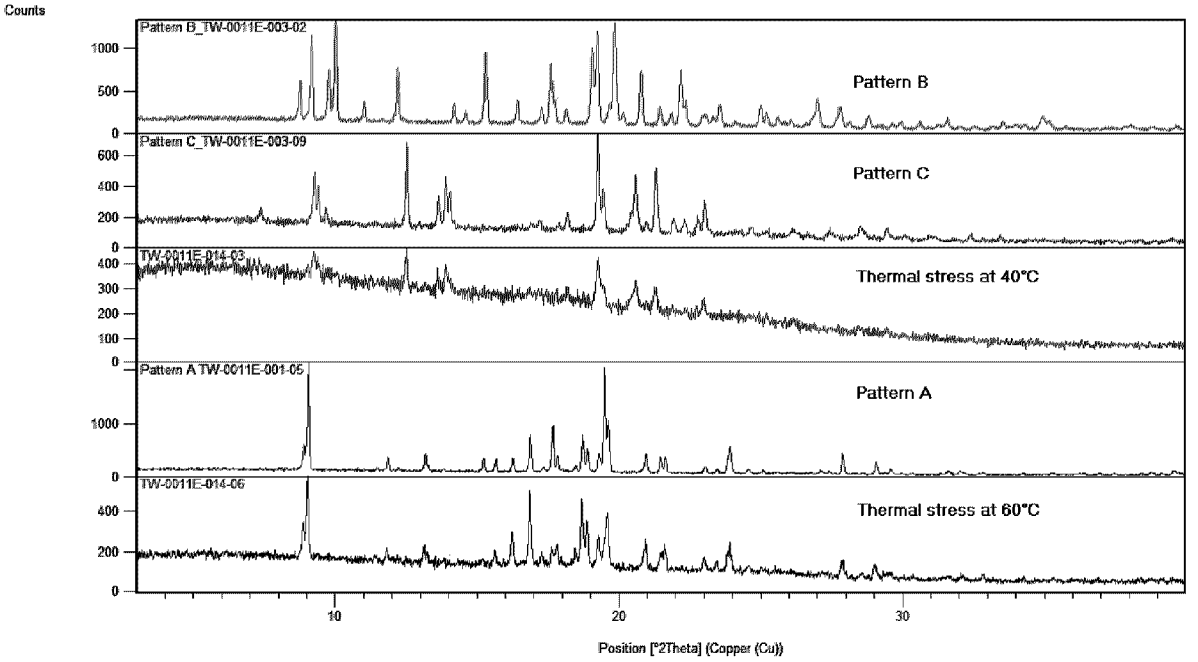
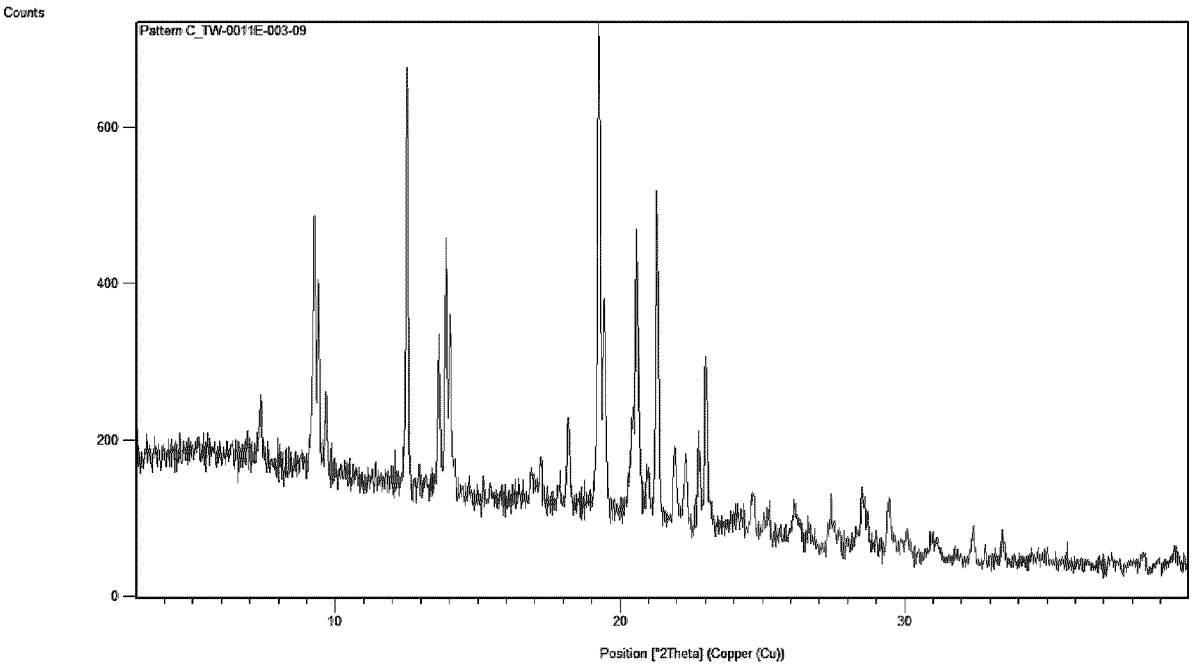
{Fig. 3-5}



{Fig. 3-6}



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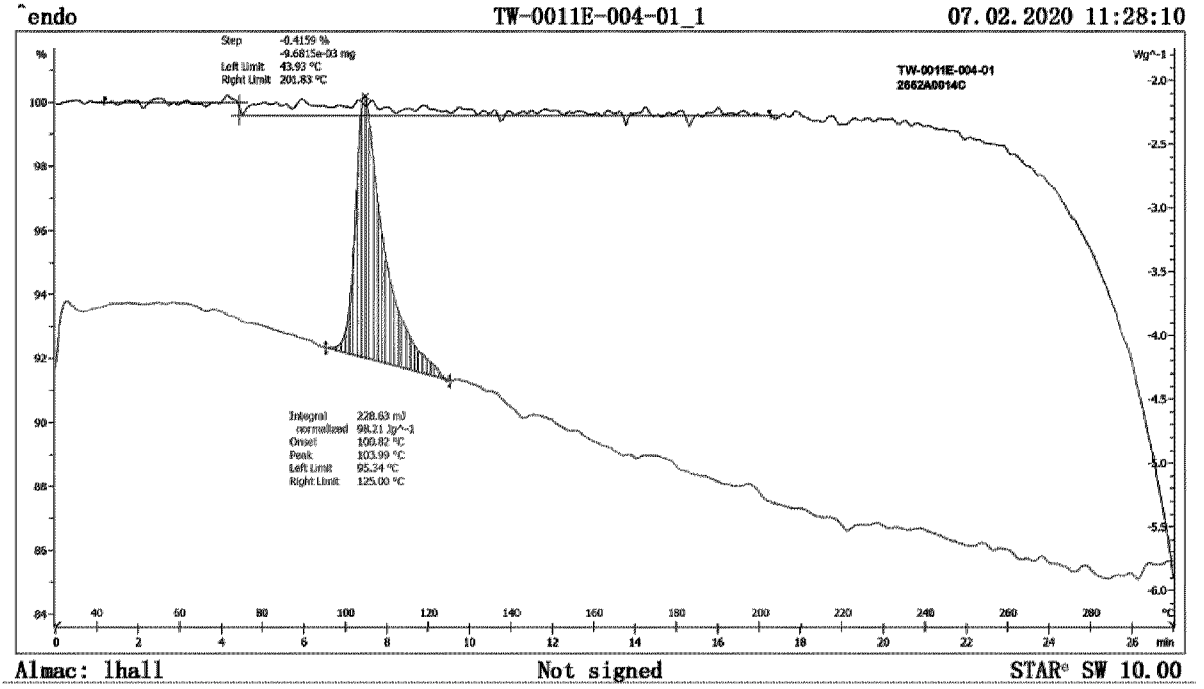
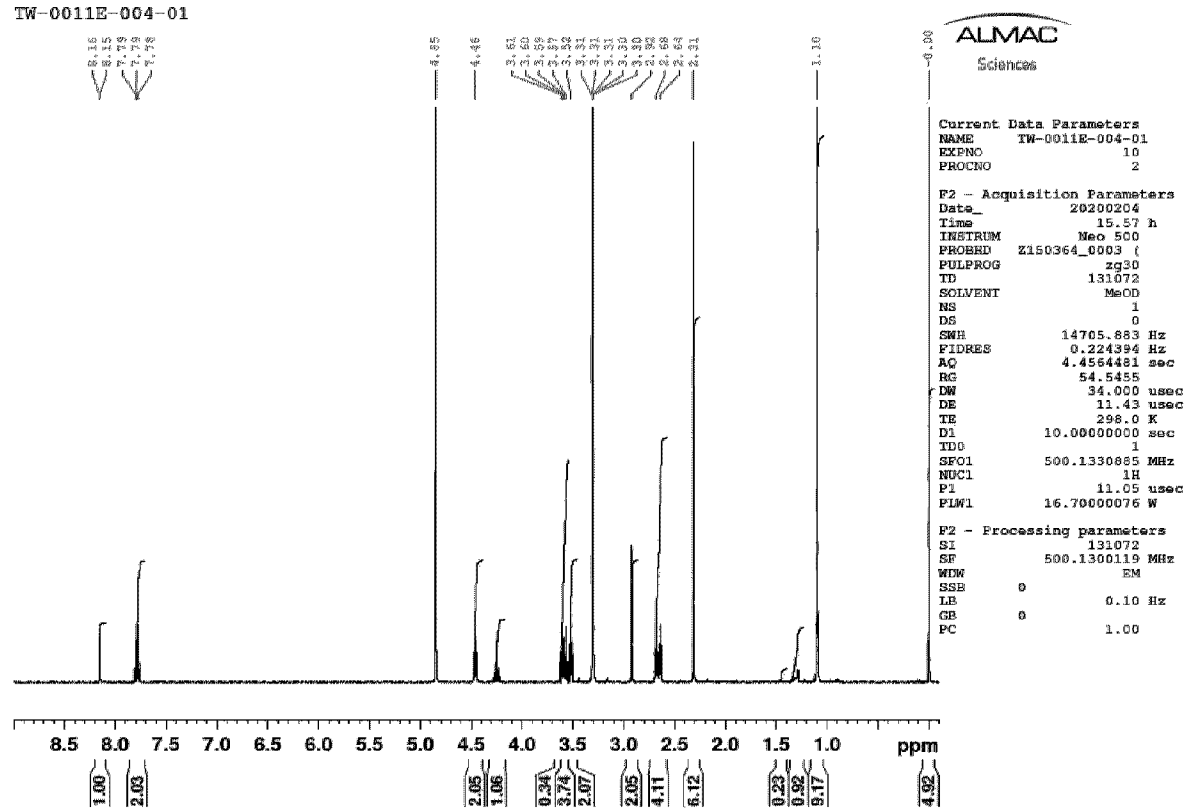
{Fig. 3-7}



{Fig. 3-8}



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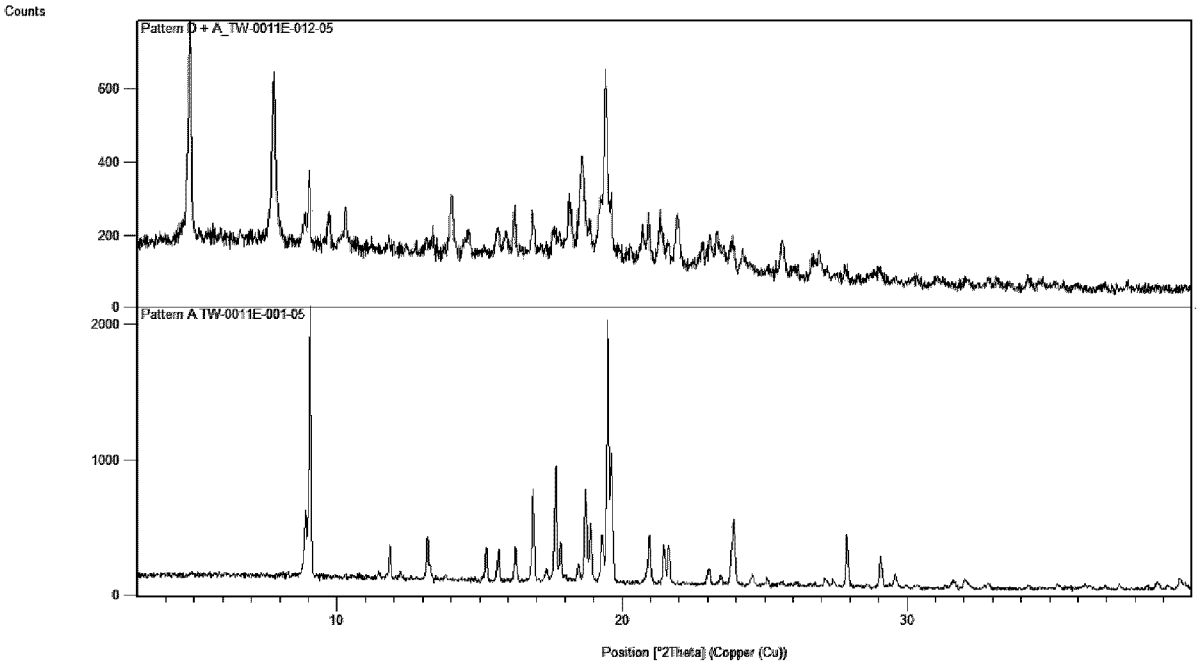
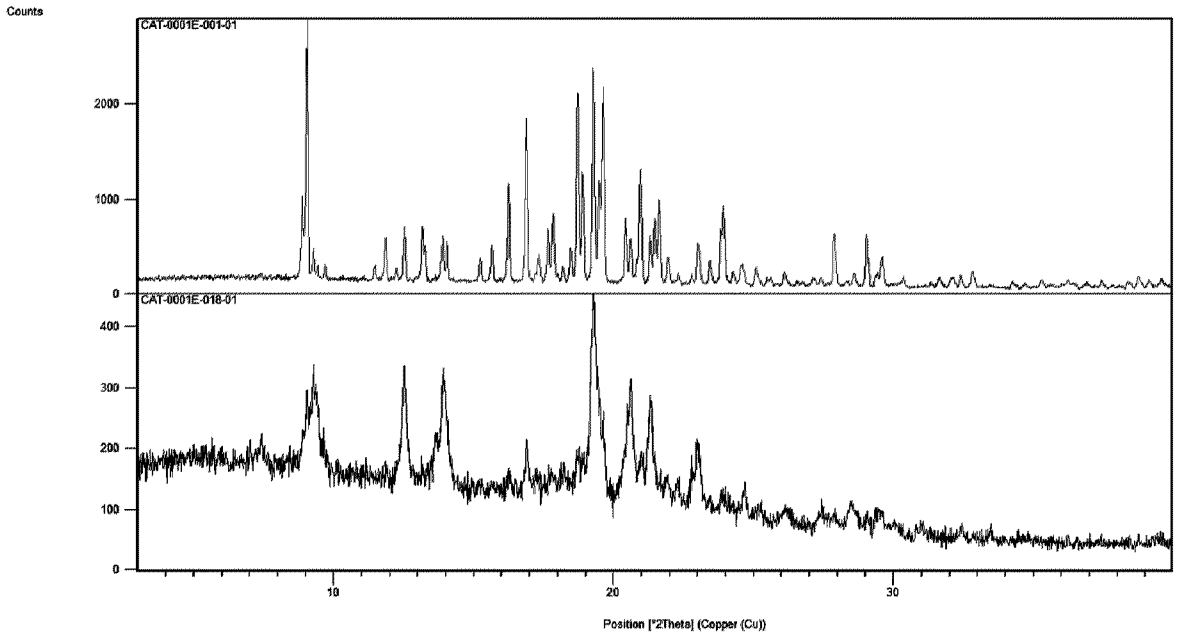
{Fig. 3-9}



{Fig. 4-1}



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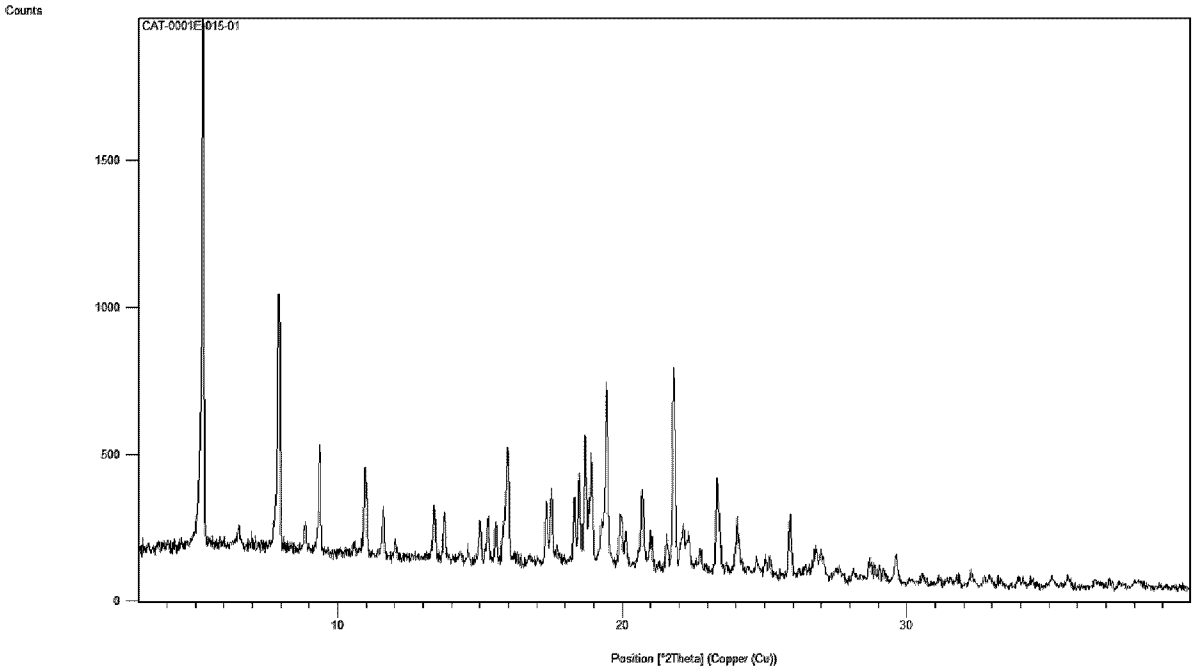
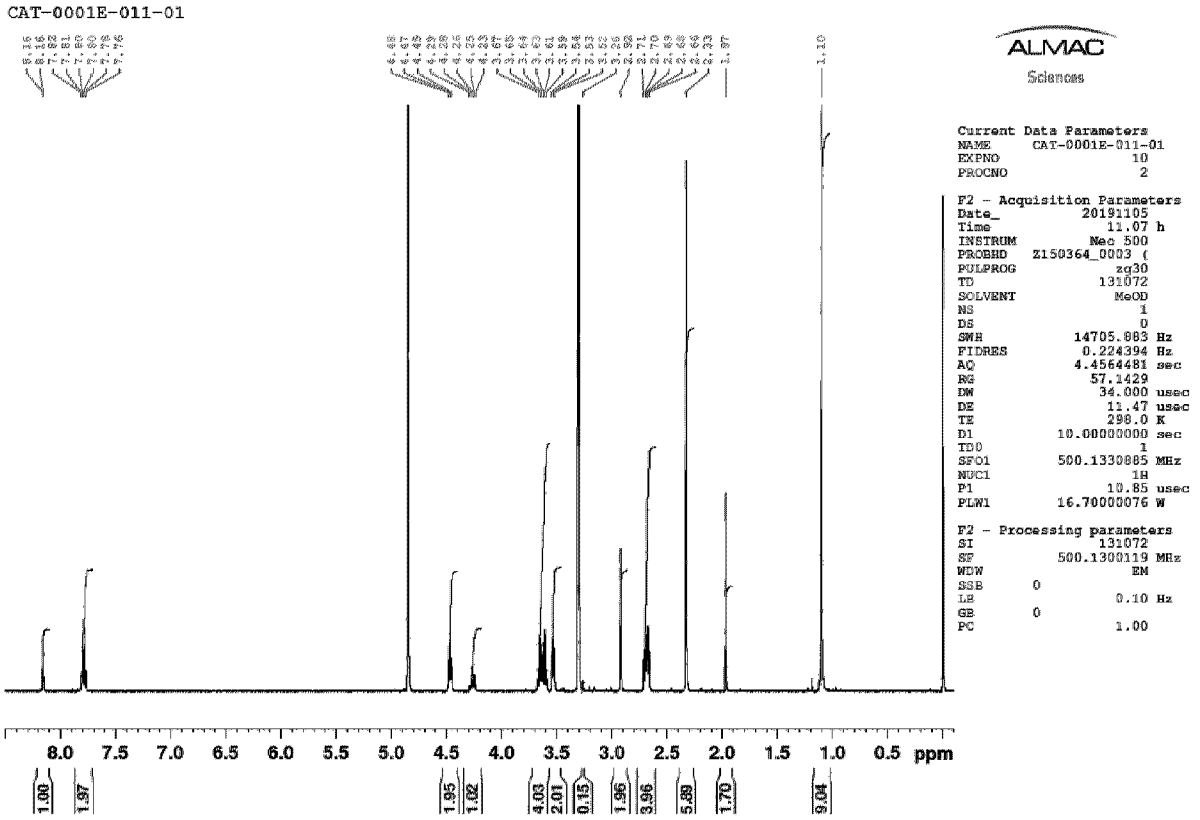
{Fig. 4-2}



{Fig. 4-3}



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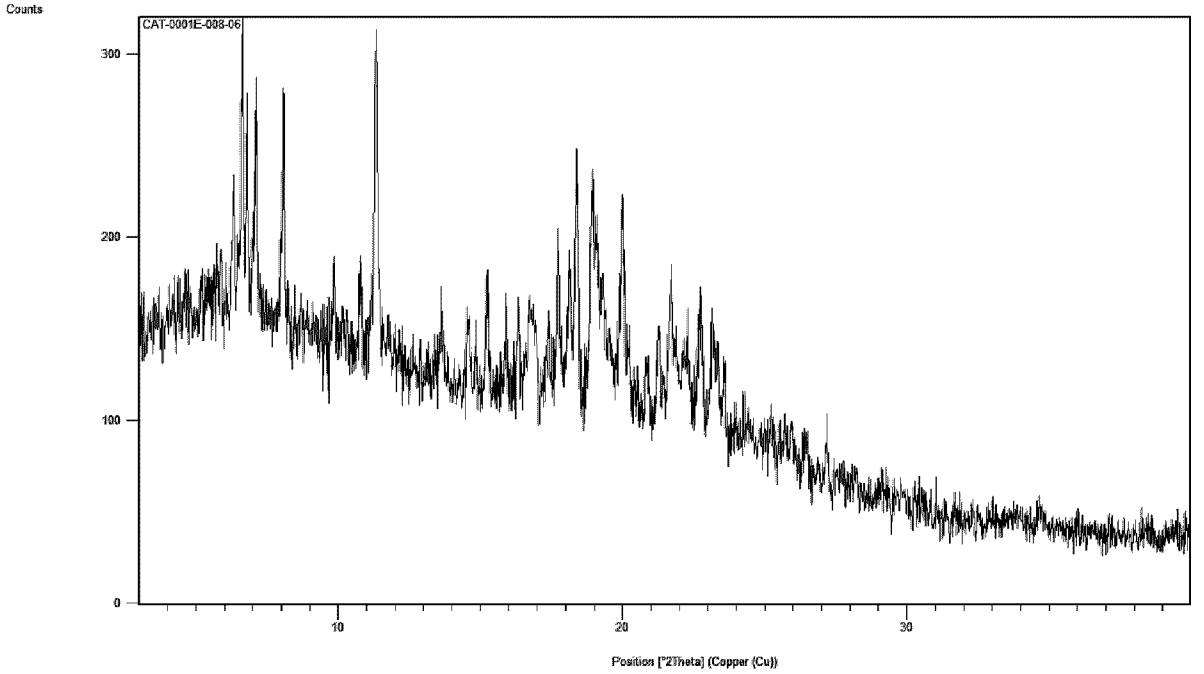
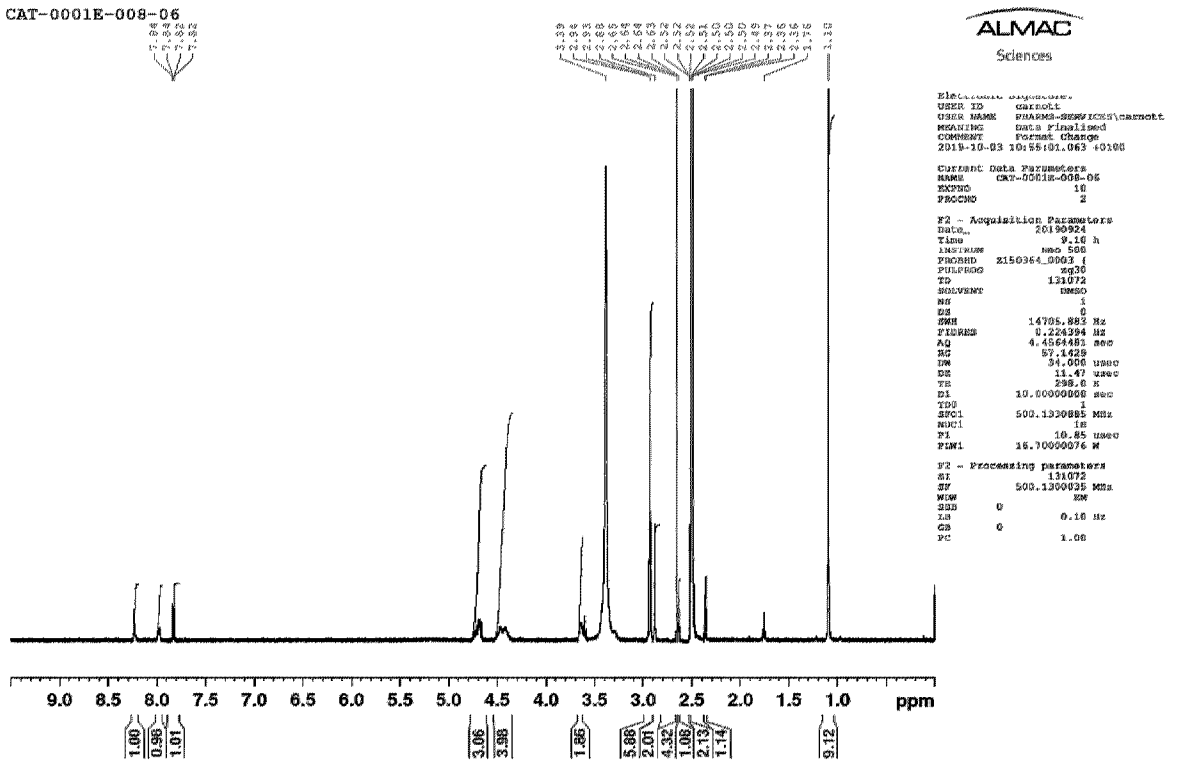
{Fig. 4-4}



{Fig. 4-5}



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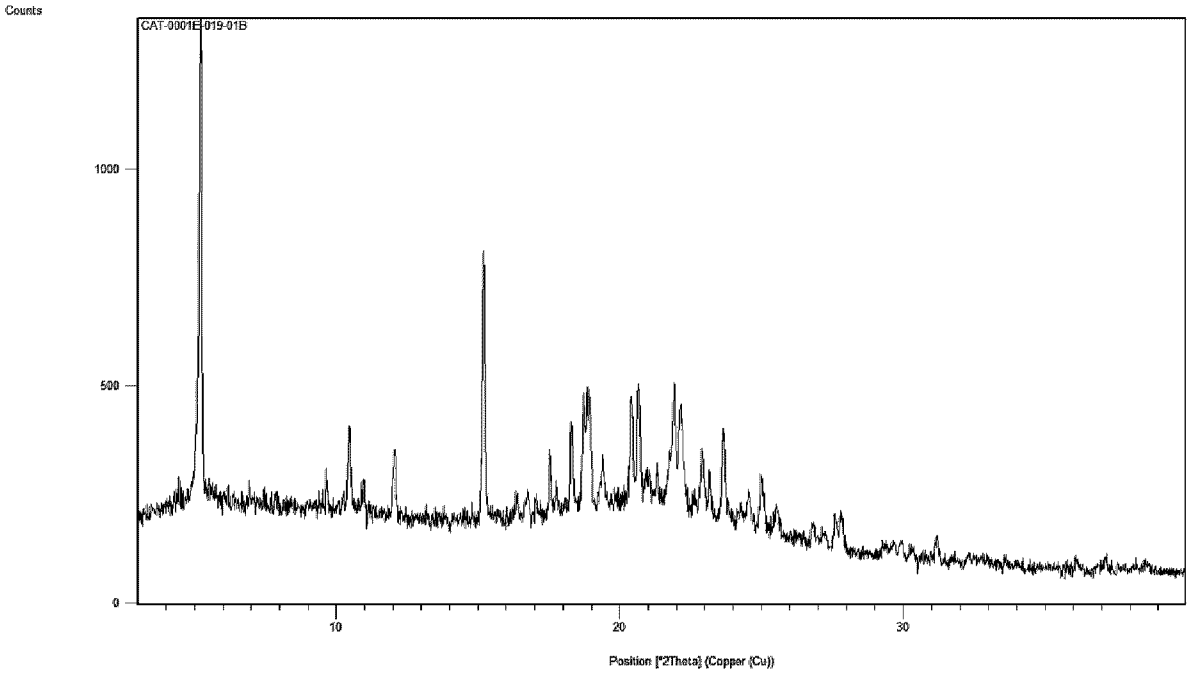
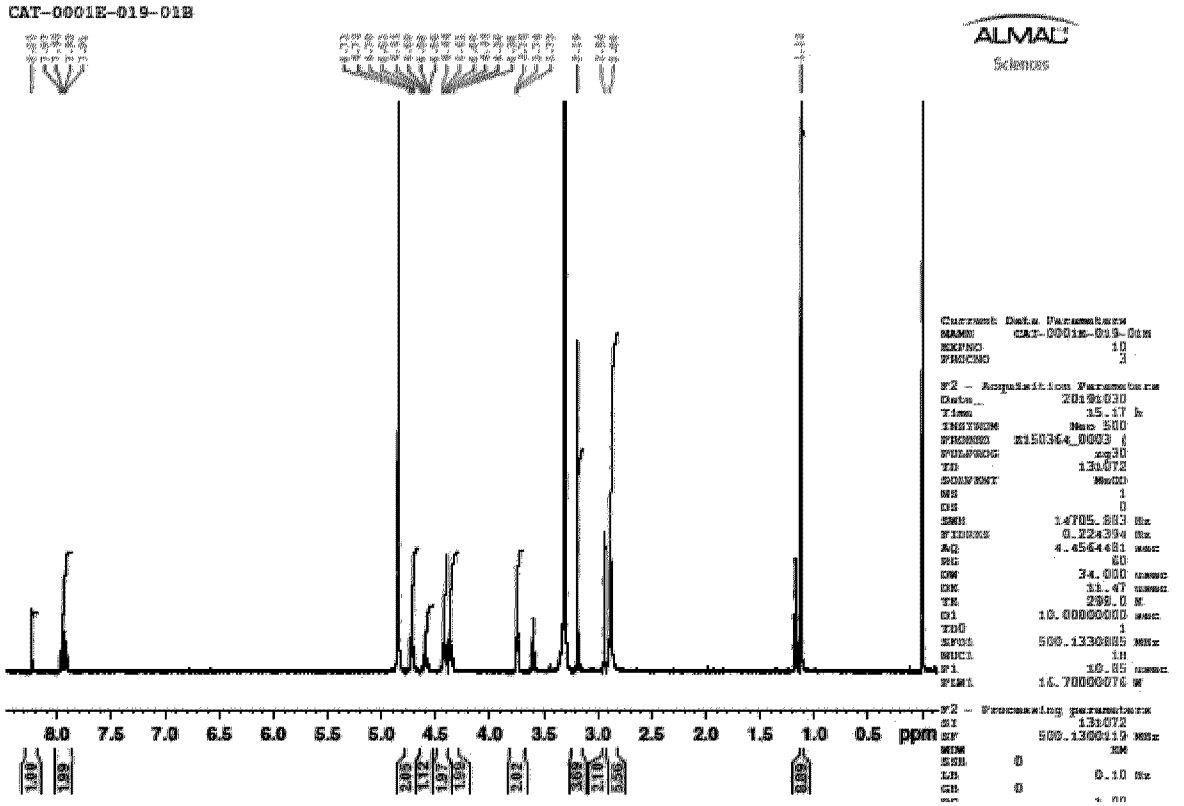
{Fig. 4-6}



{Fig. 4-7}



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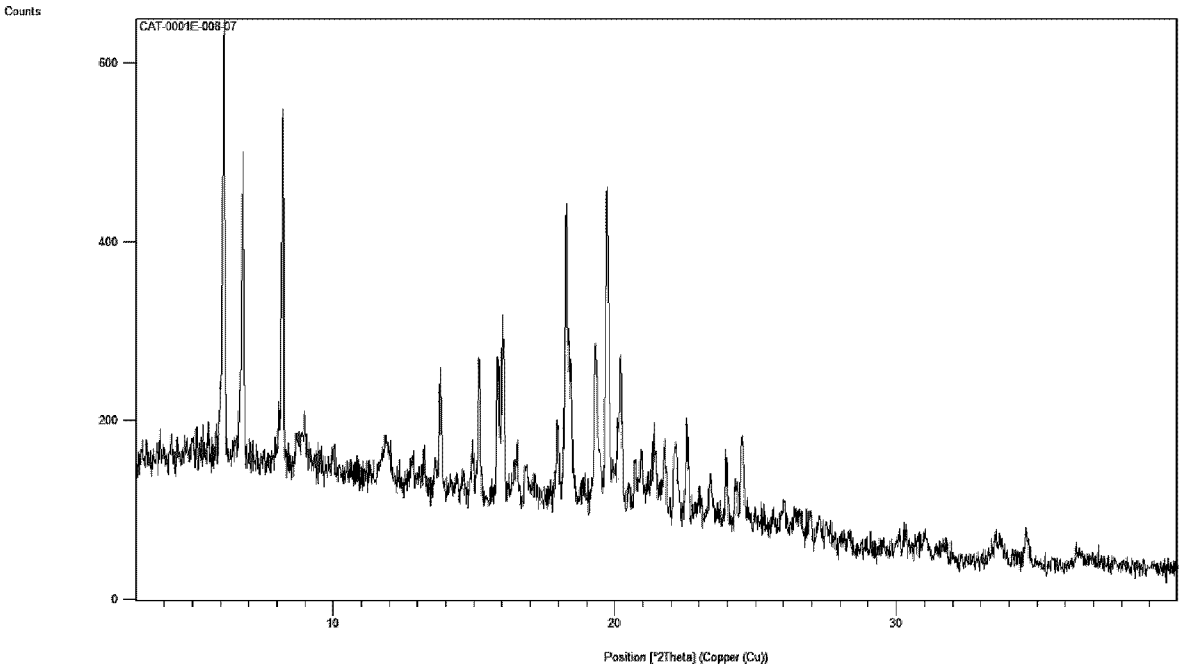
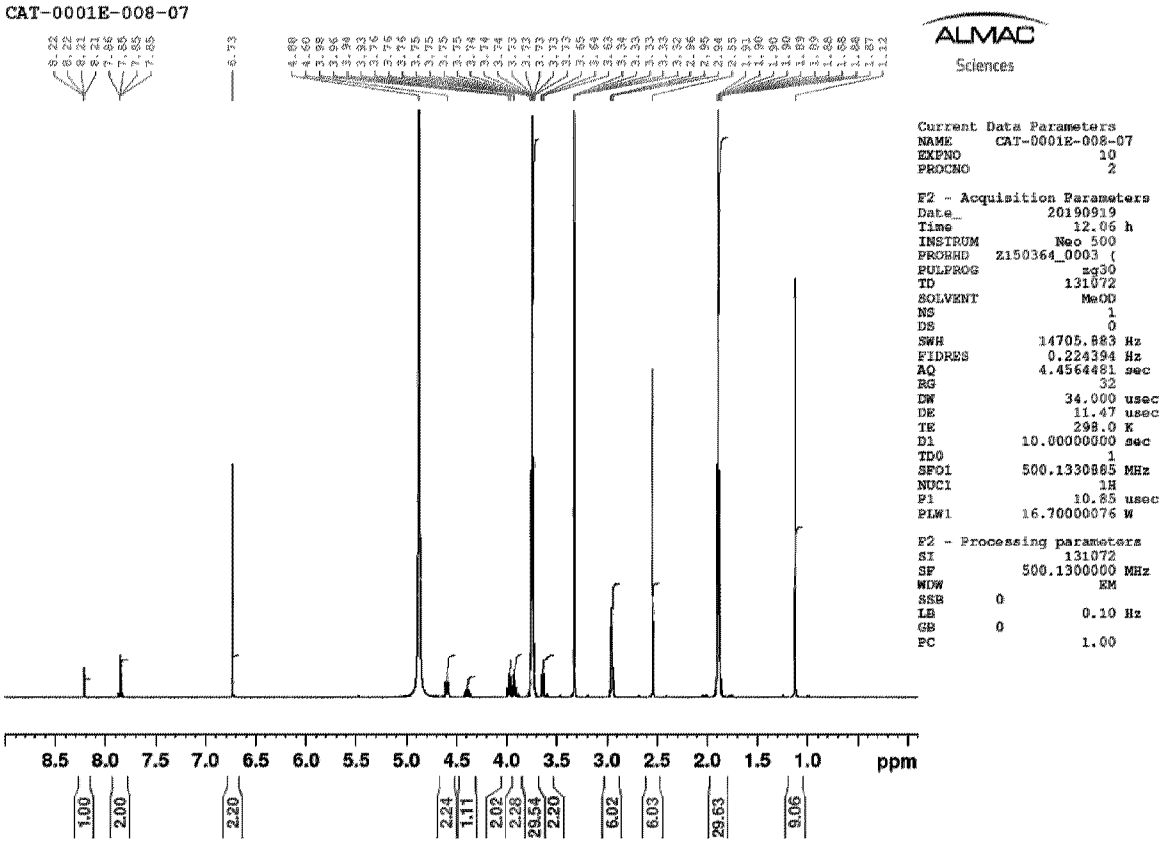
{Fig. 4-8}



{Fig. 4-9}



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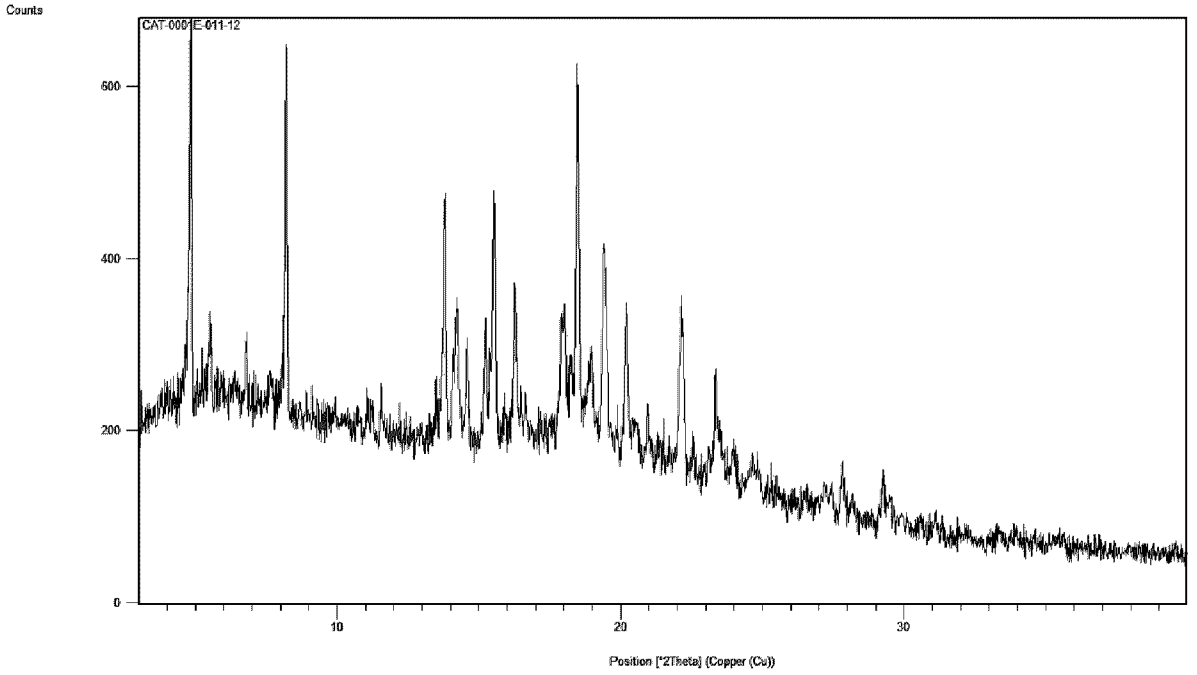
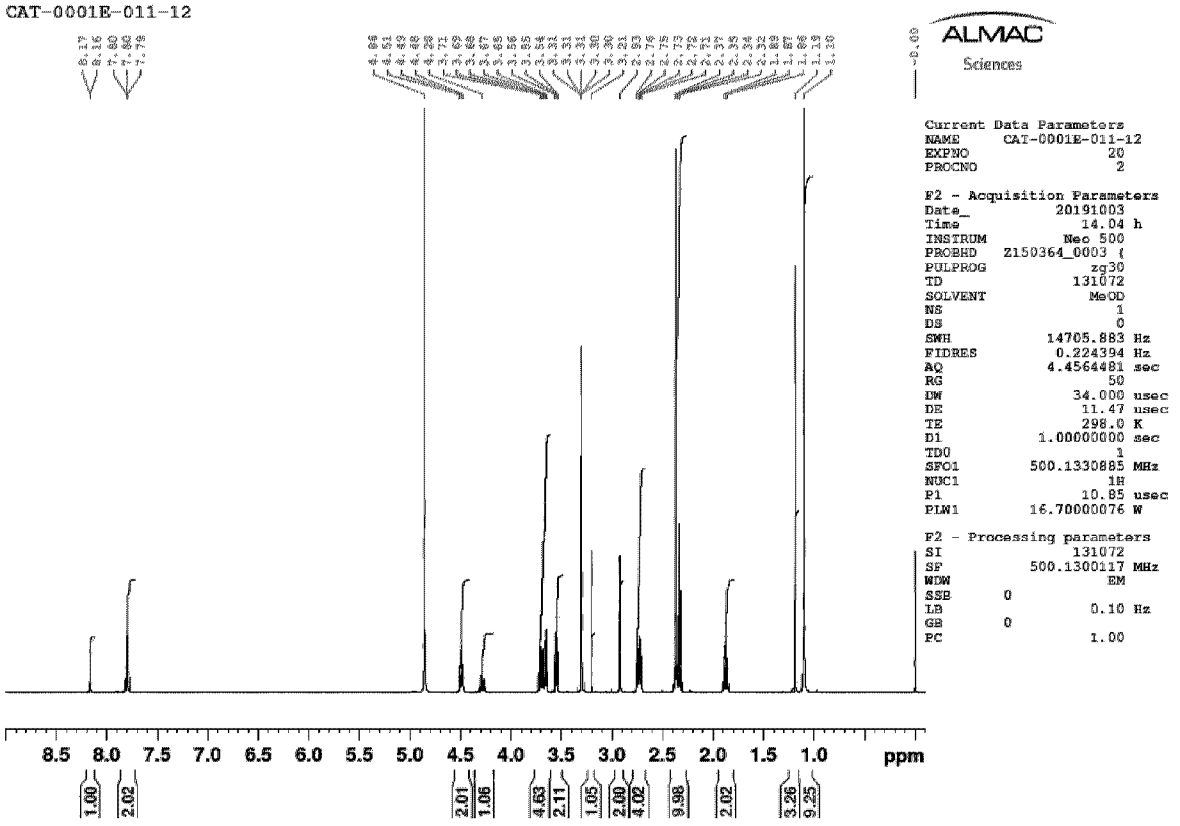
{Fig. 4-10}



{Fig. 4-11}



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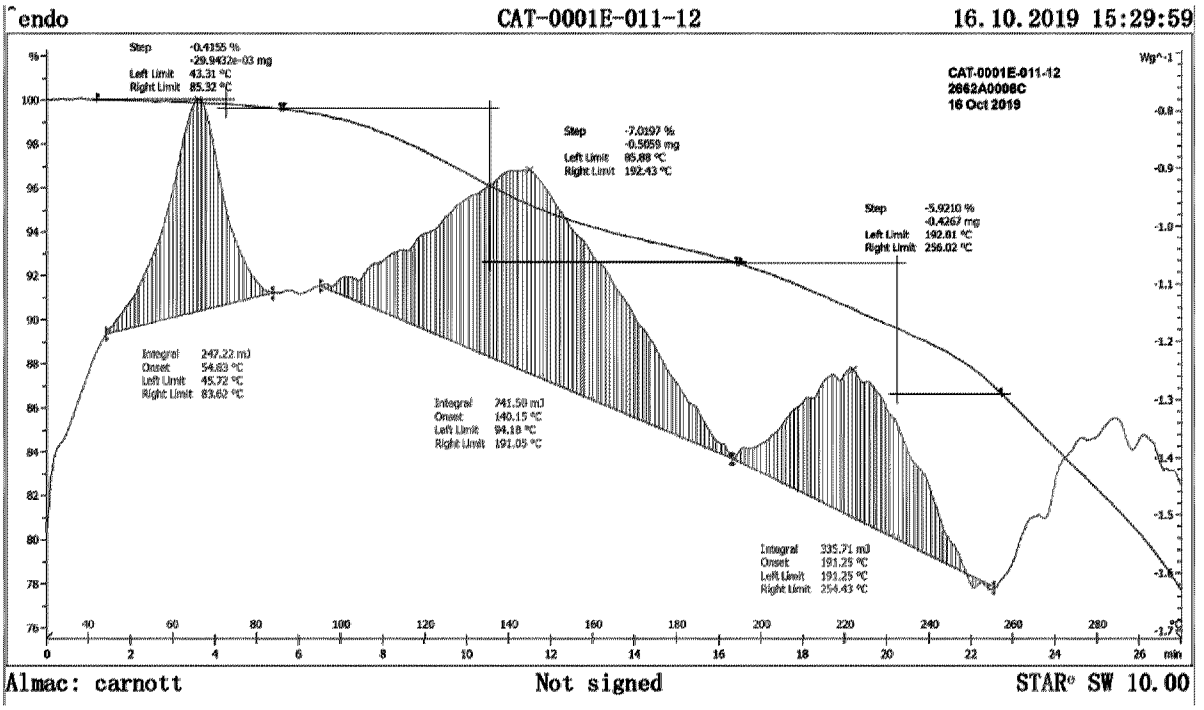
{Fig. 4-12}



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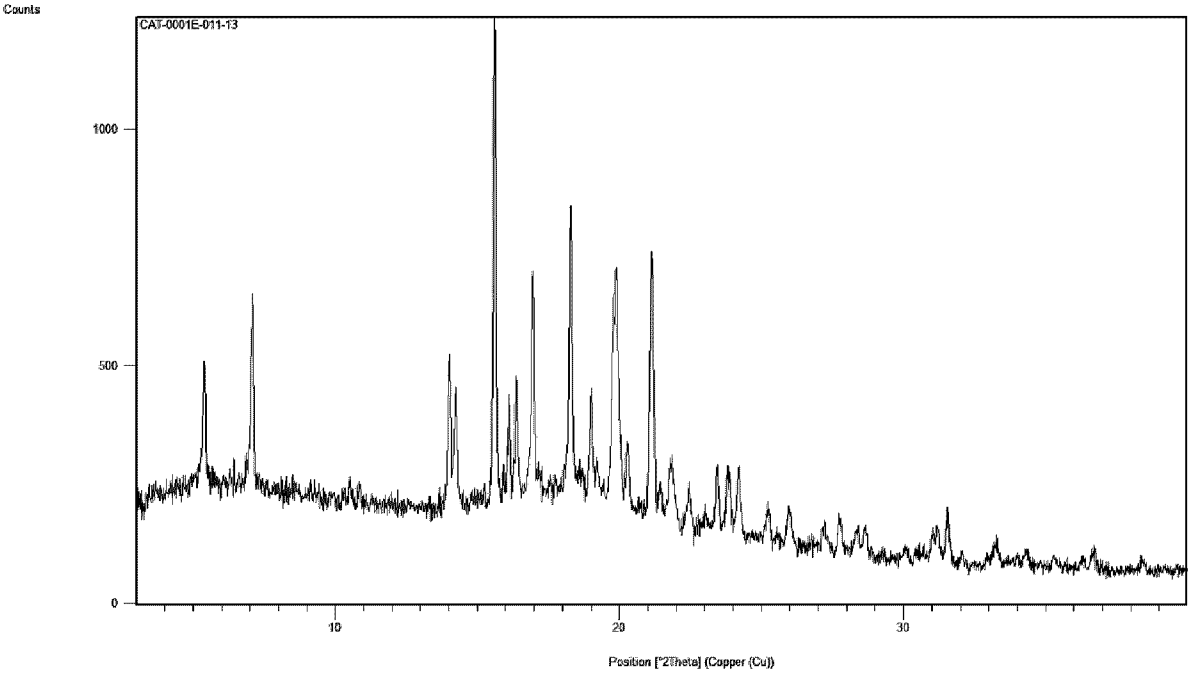

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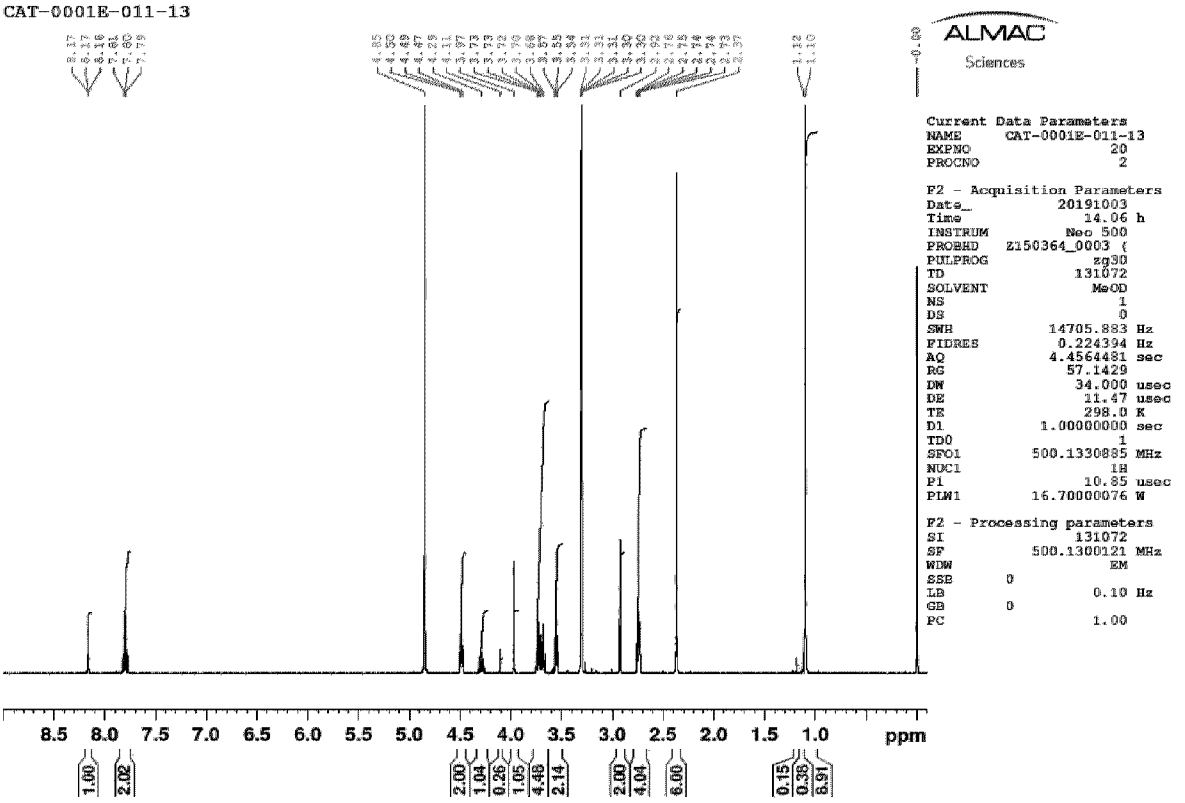
{Fig. 4-14}



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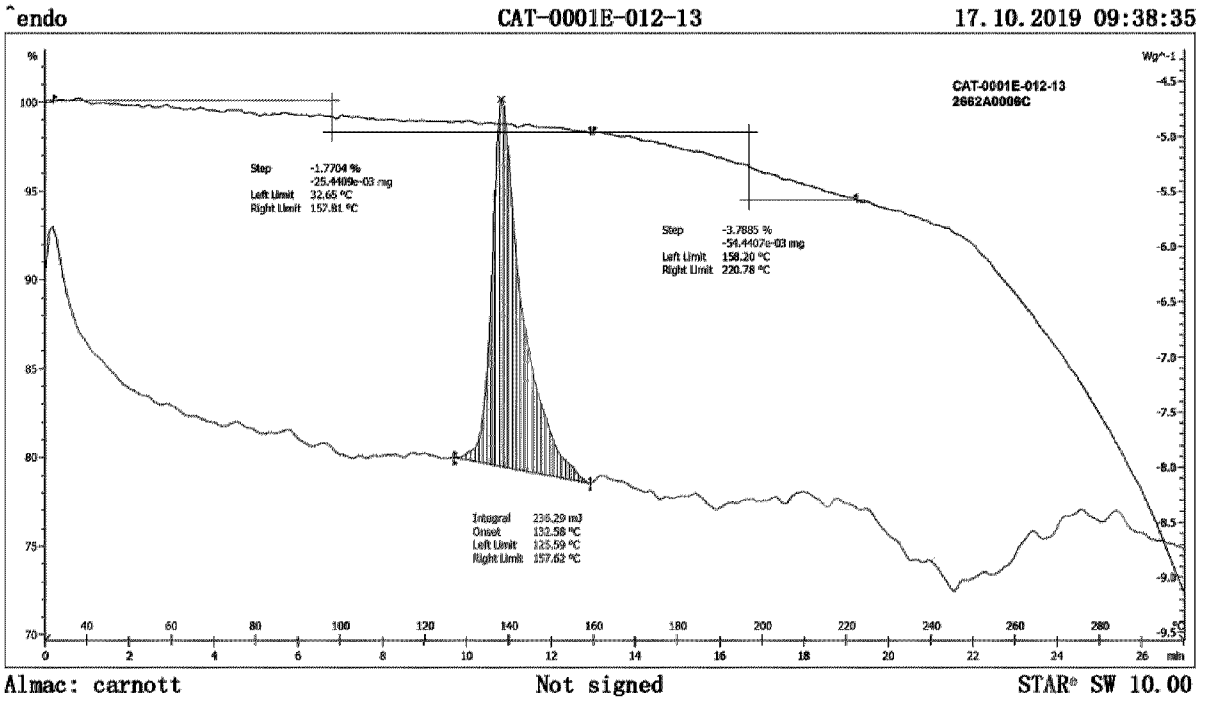

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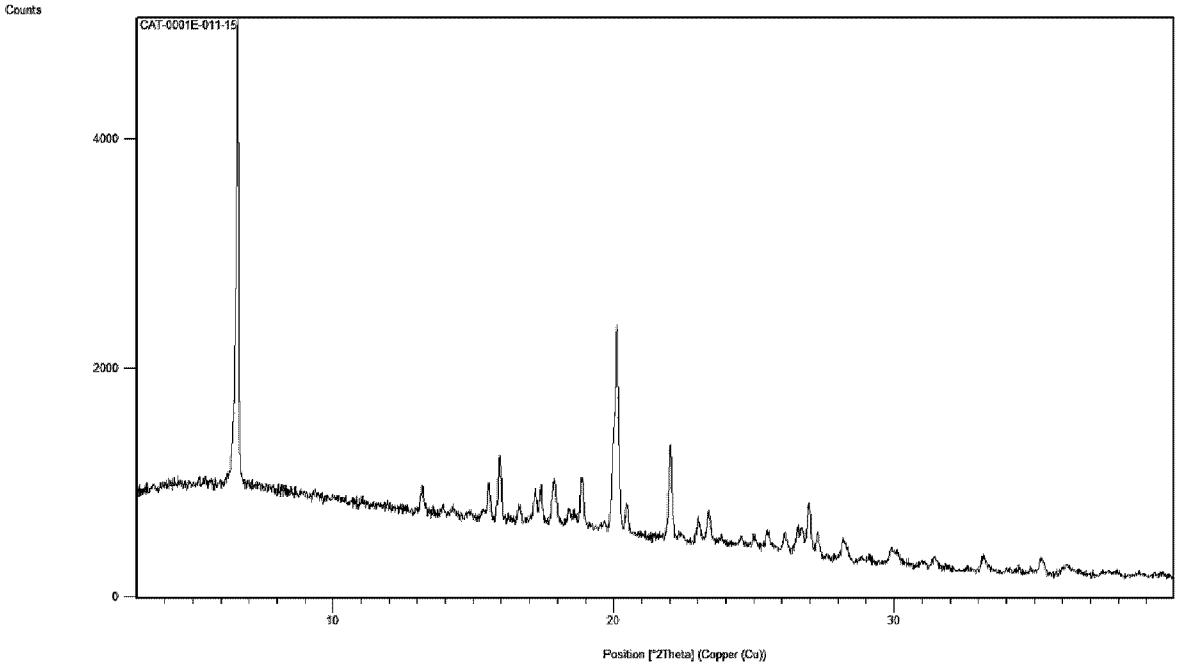

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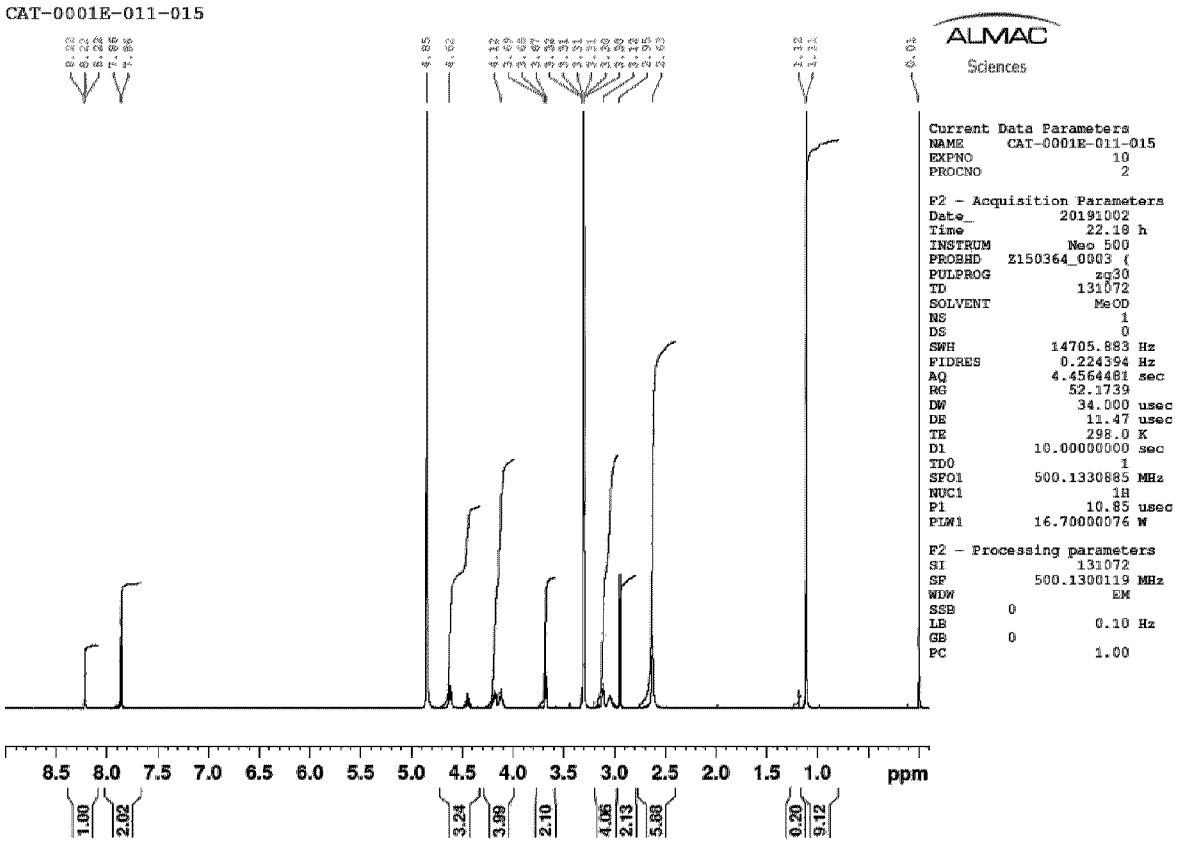

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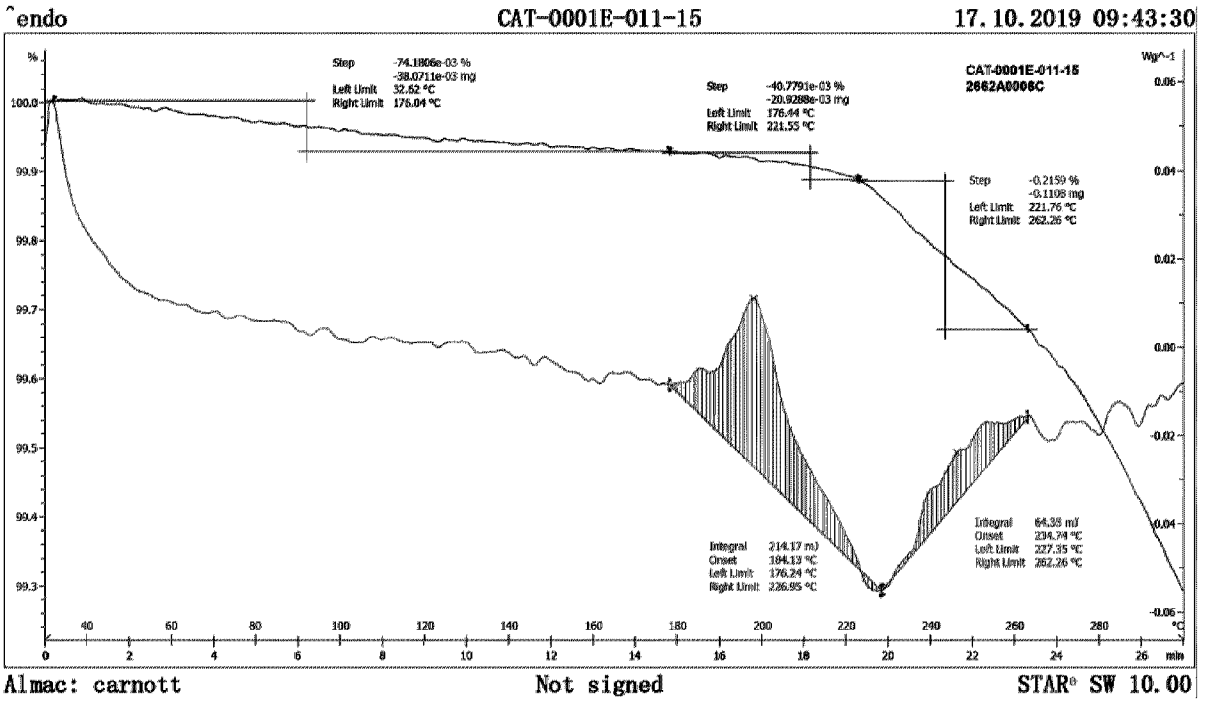

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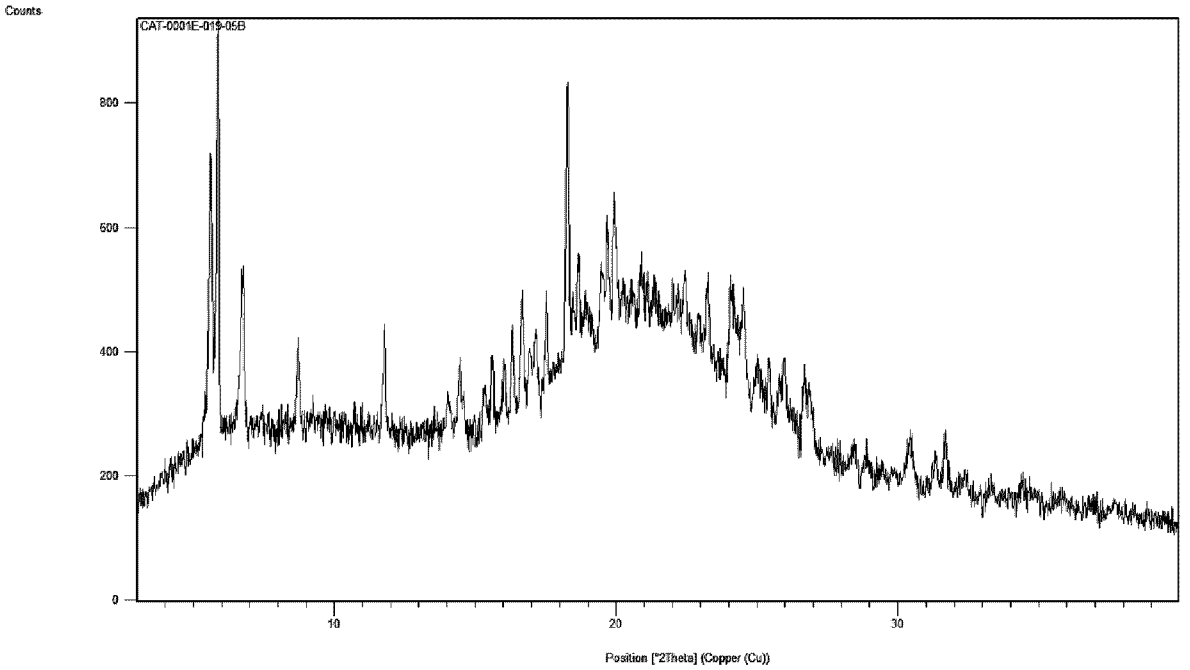

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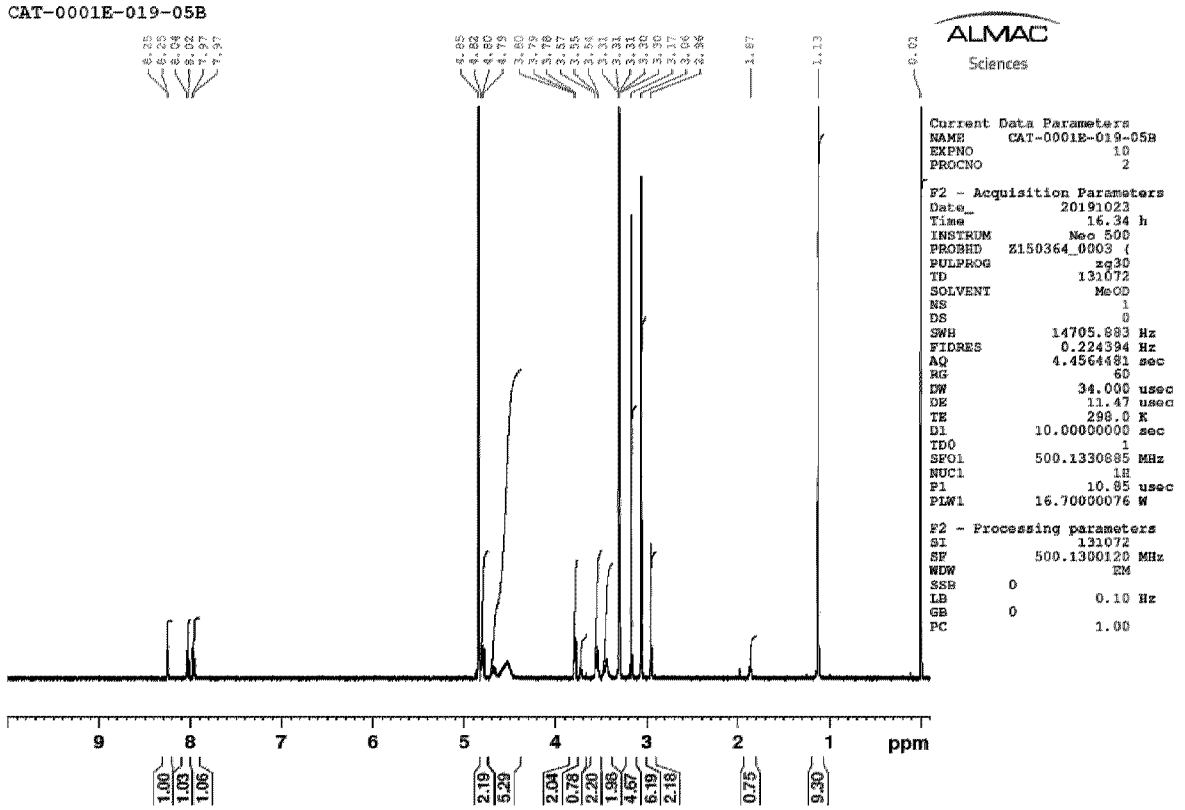

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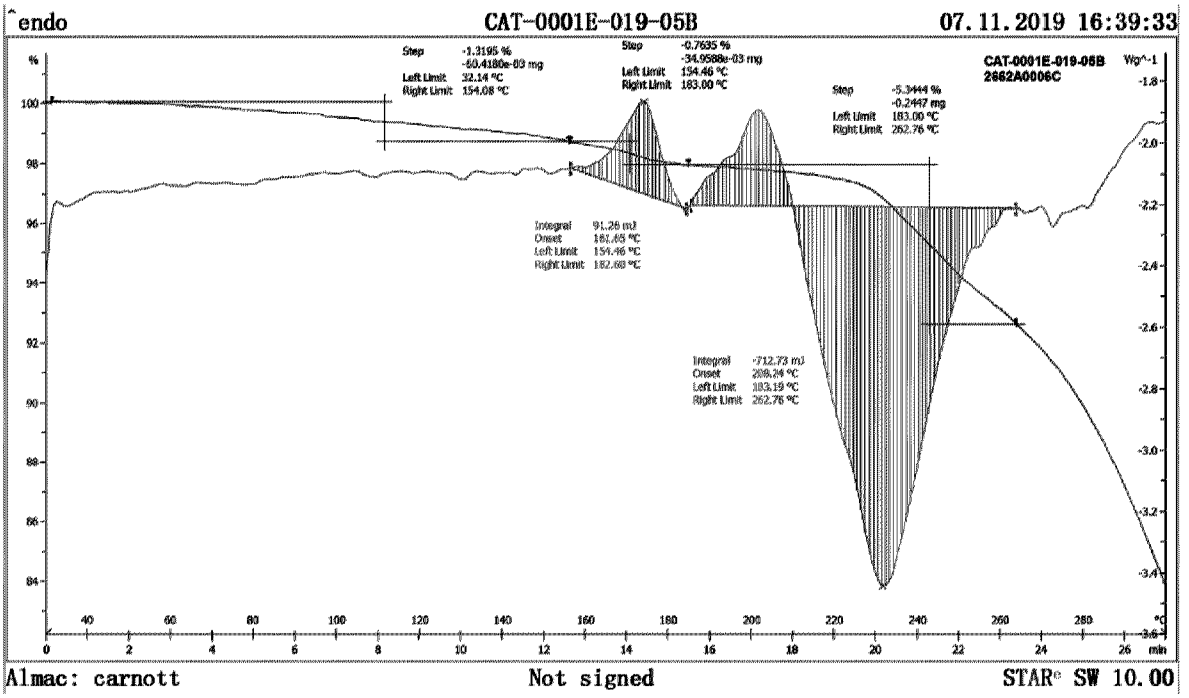

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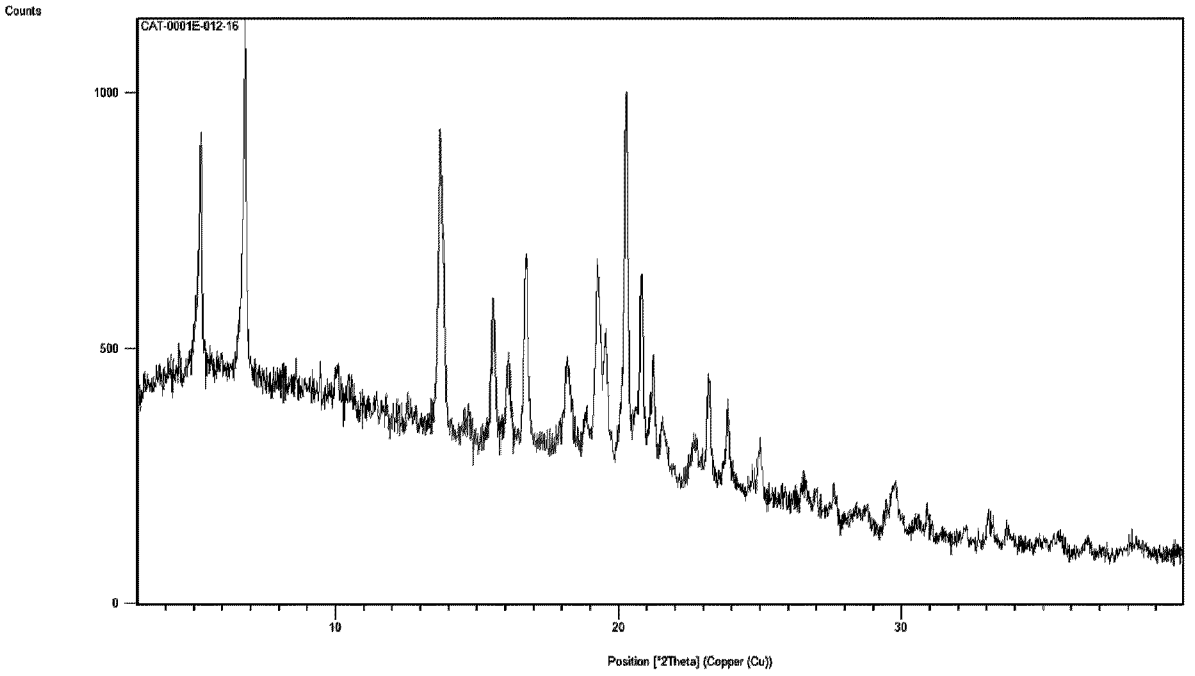

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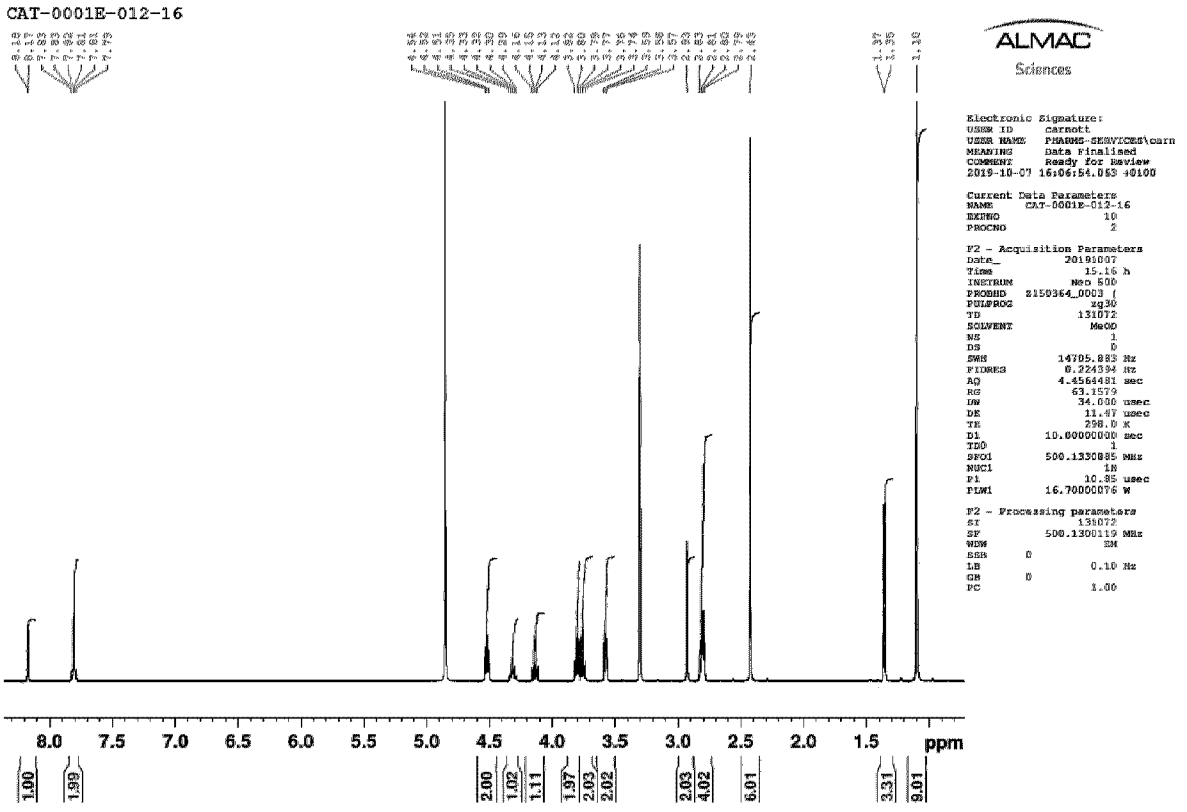

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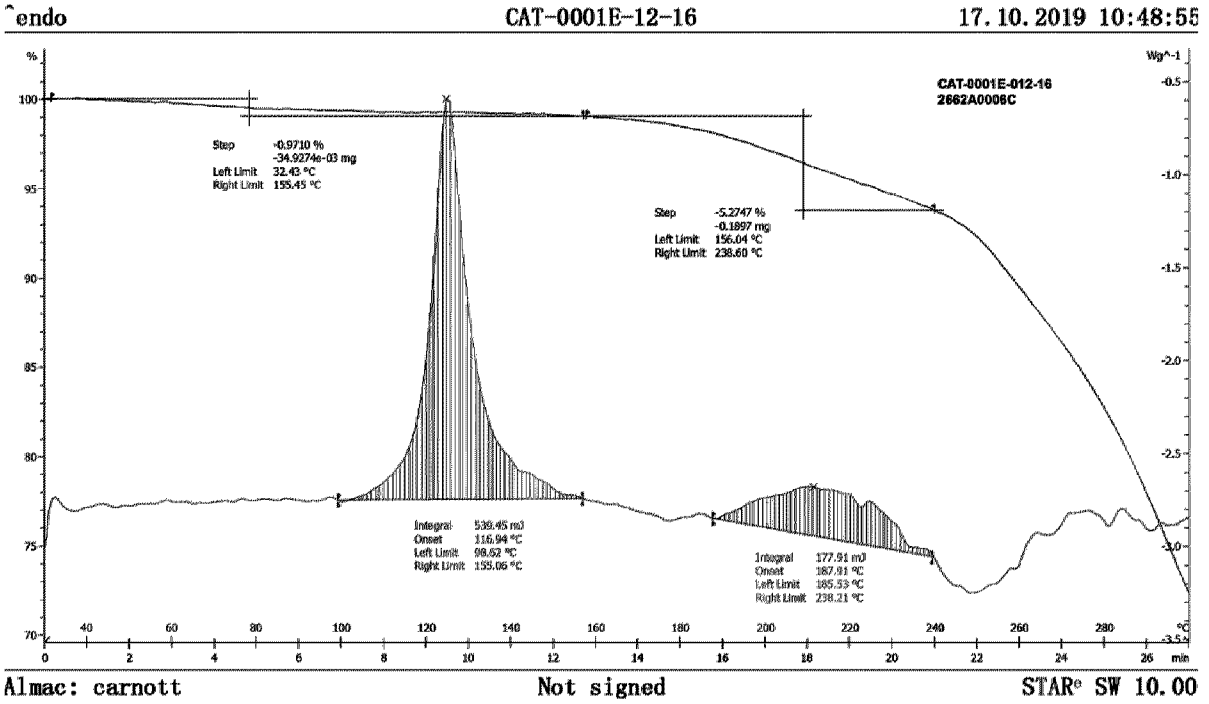

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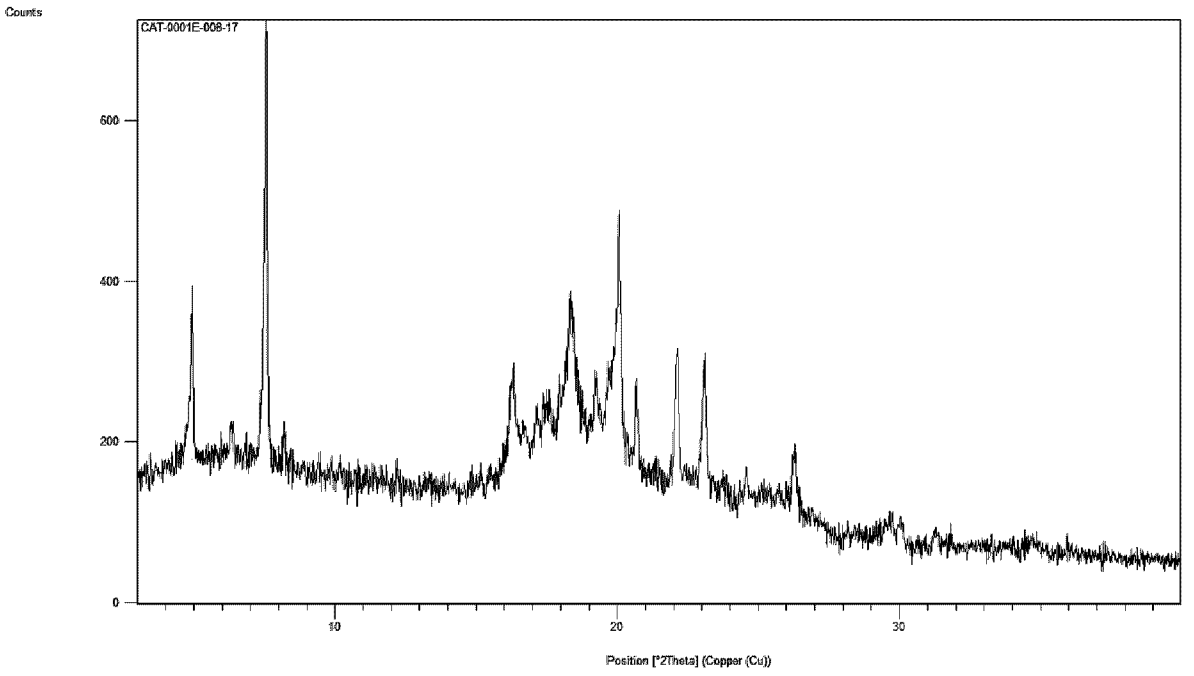

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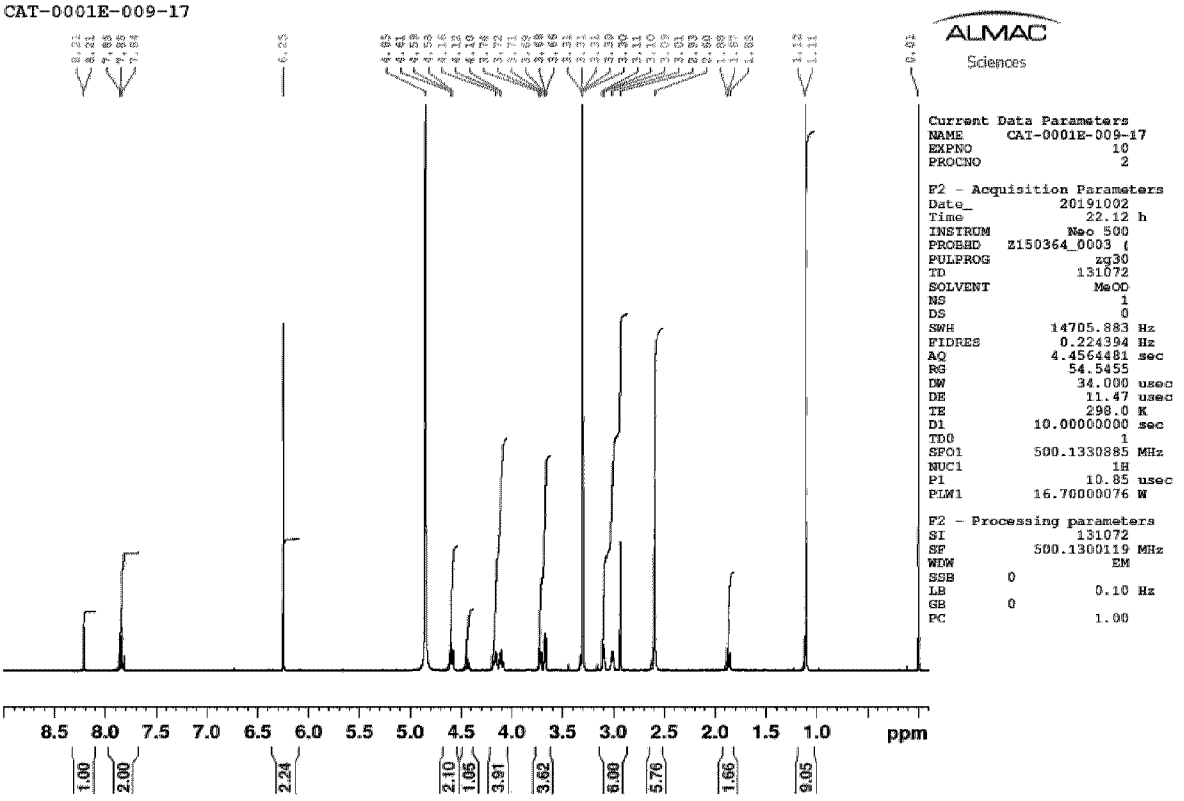

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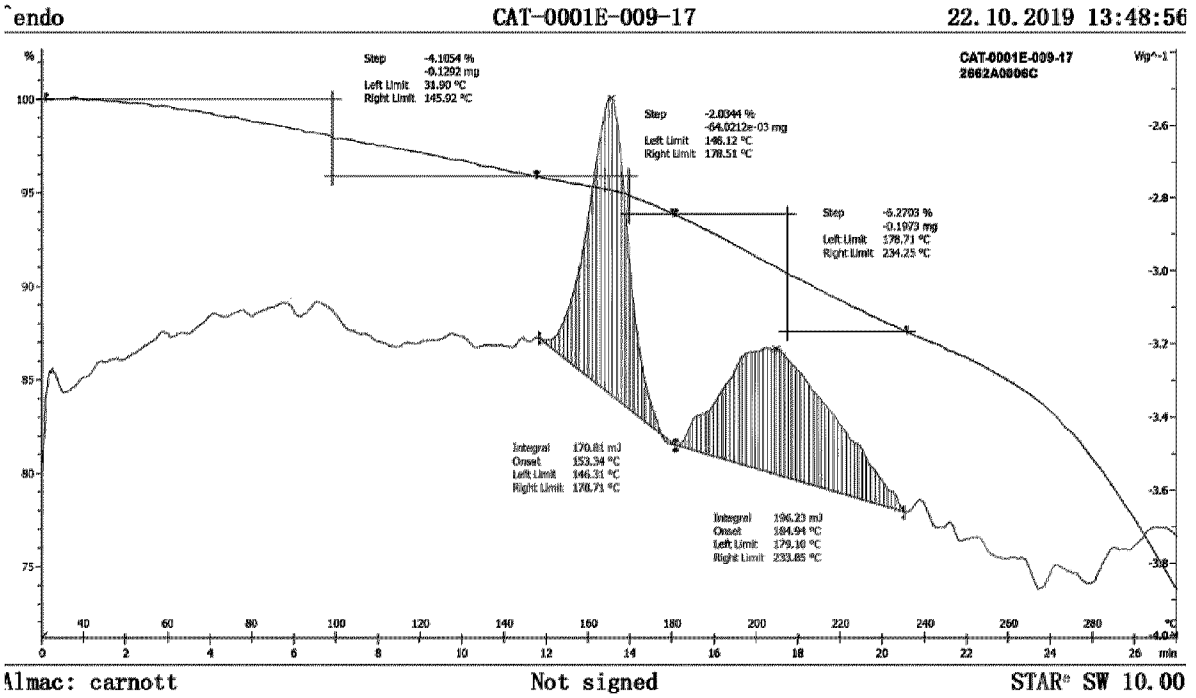

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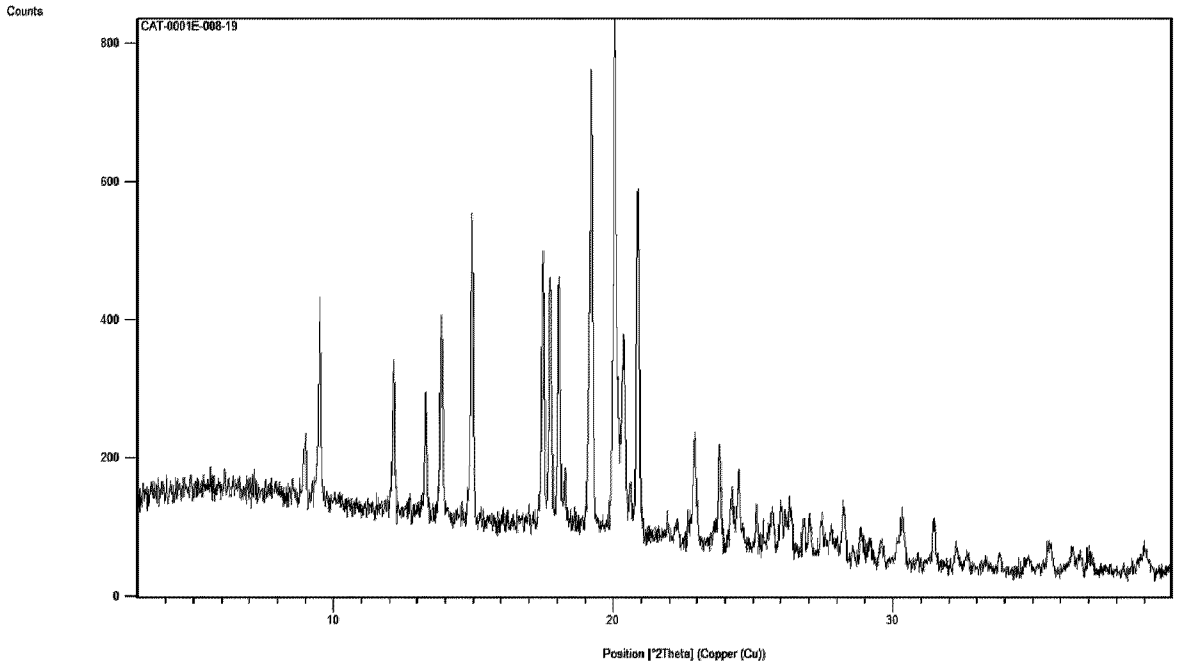

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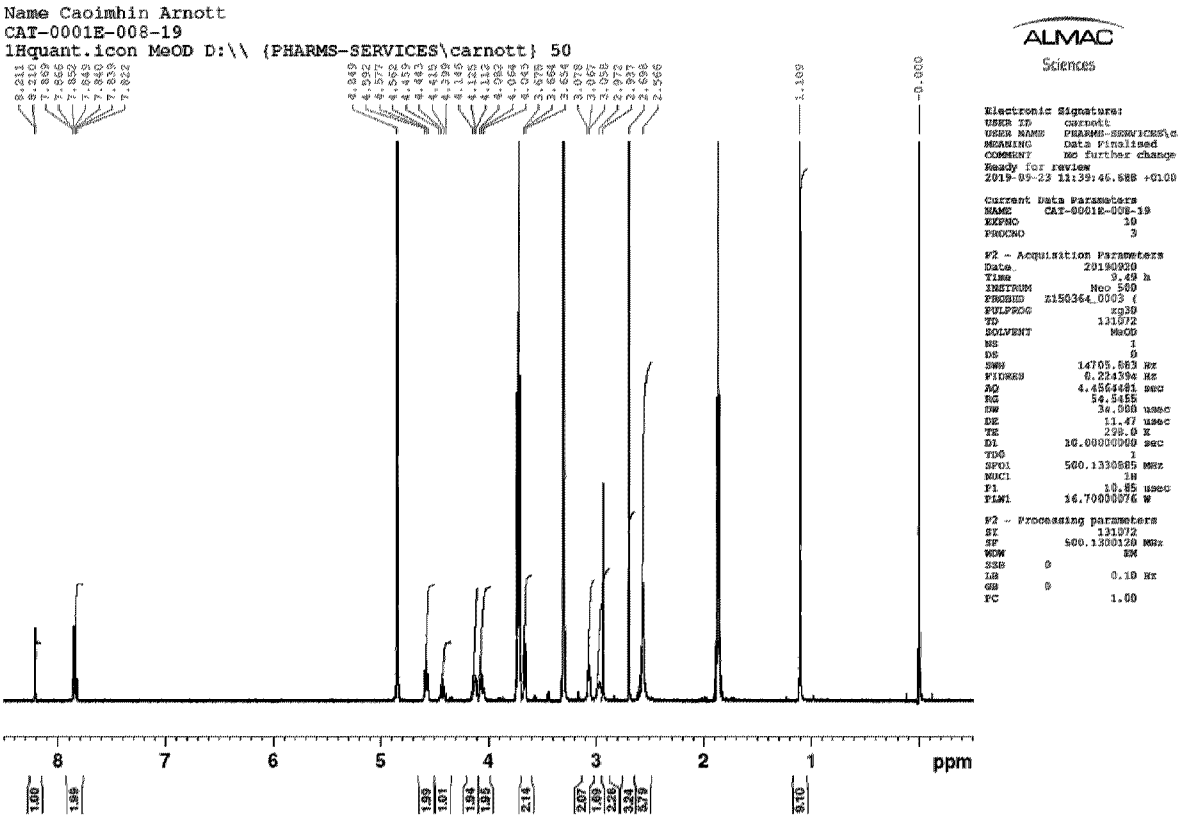

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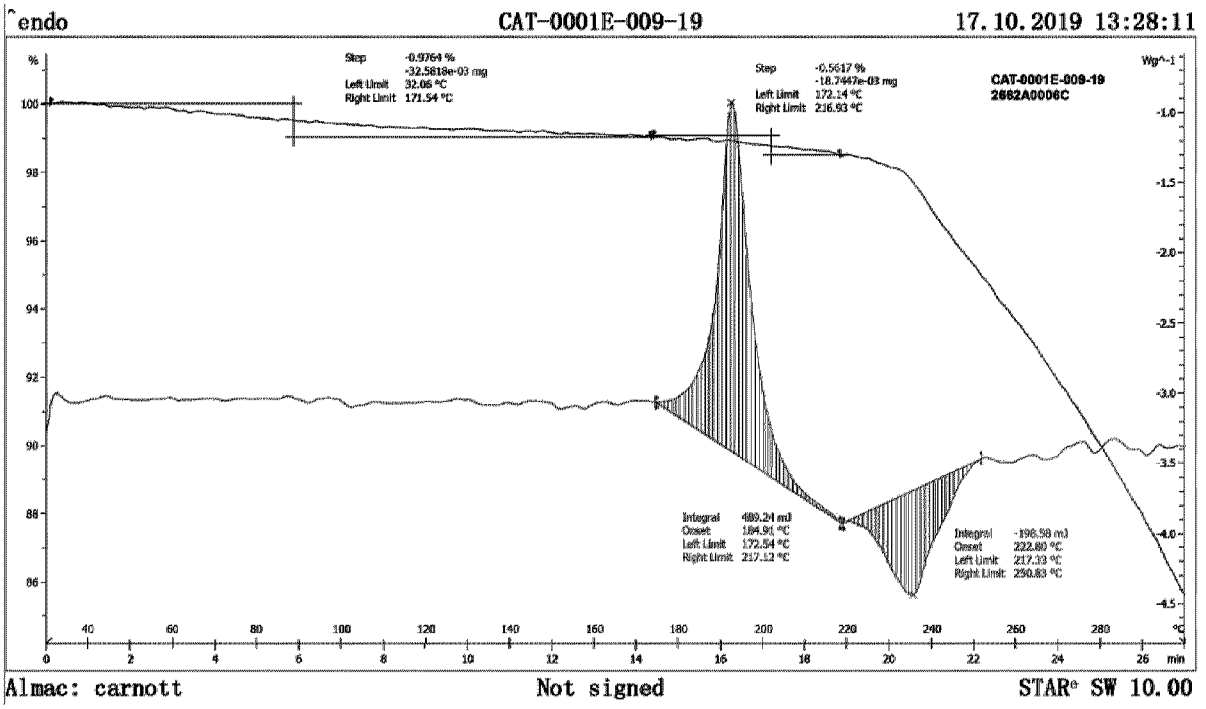

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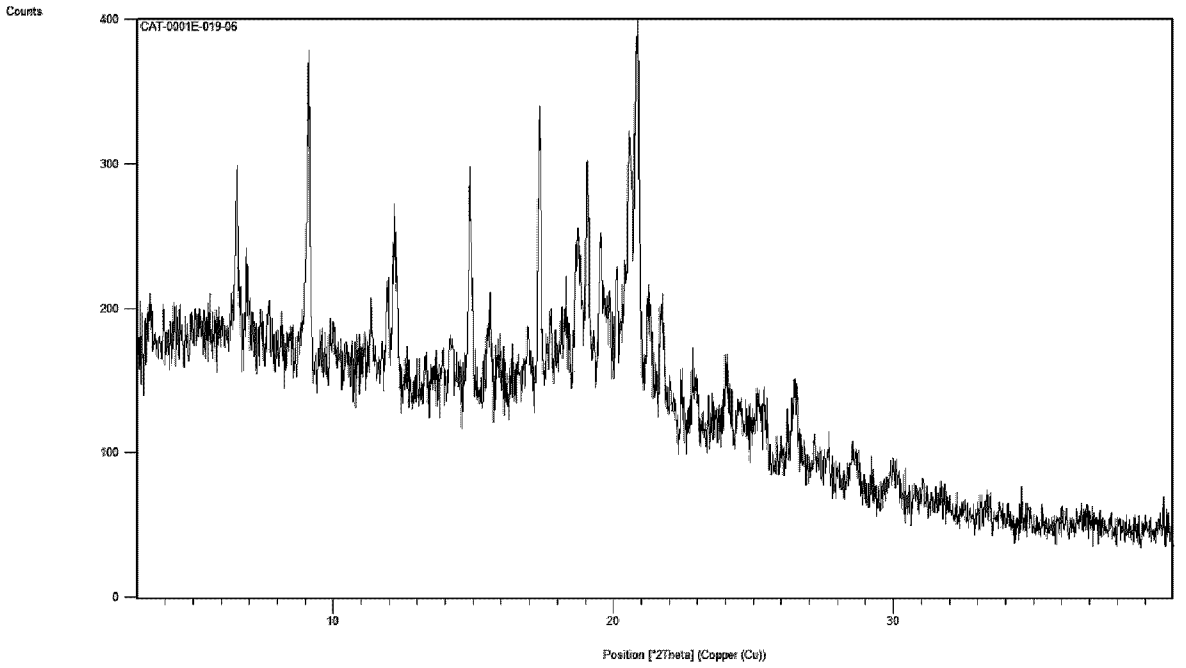

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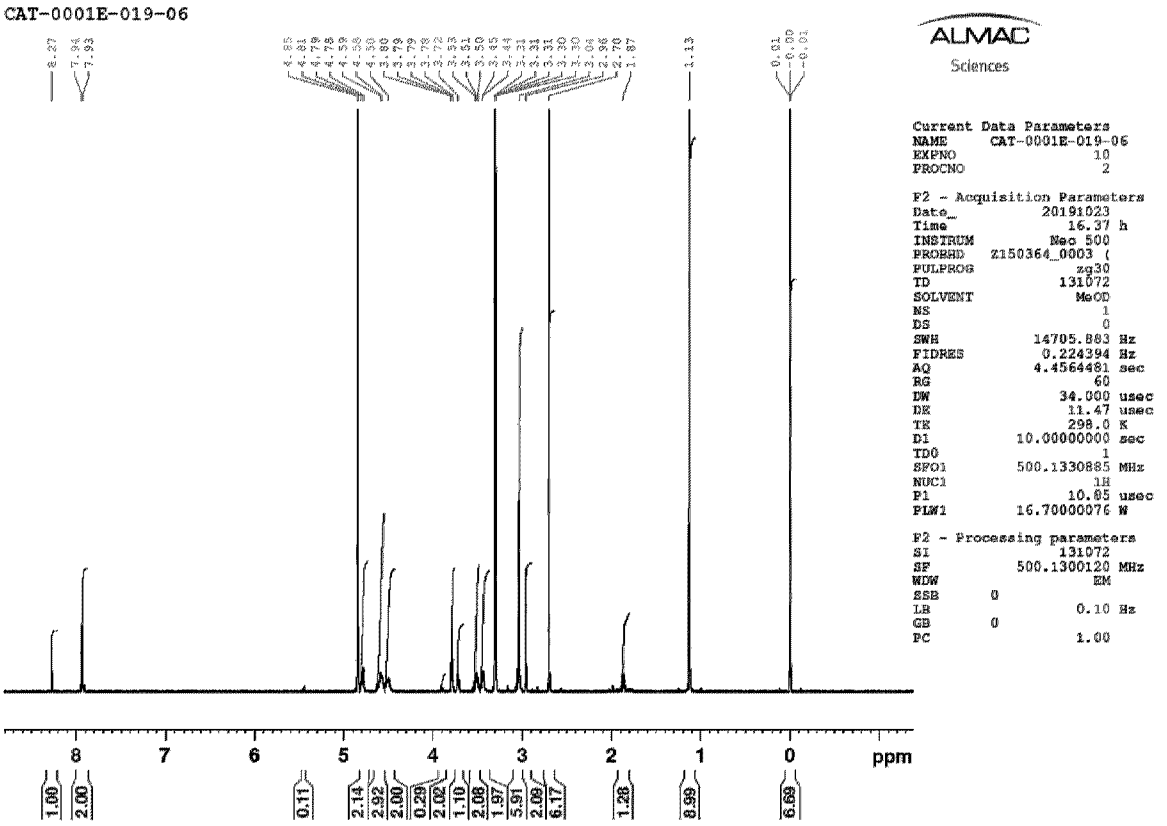

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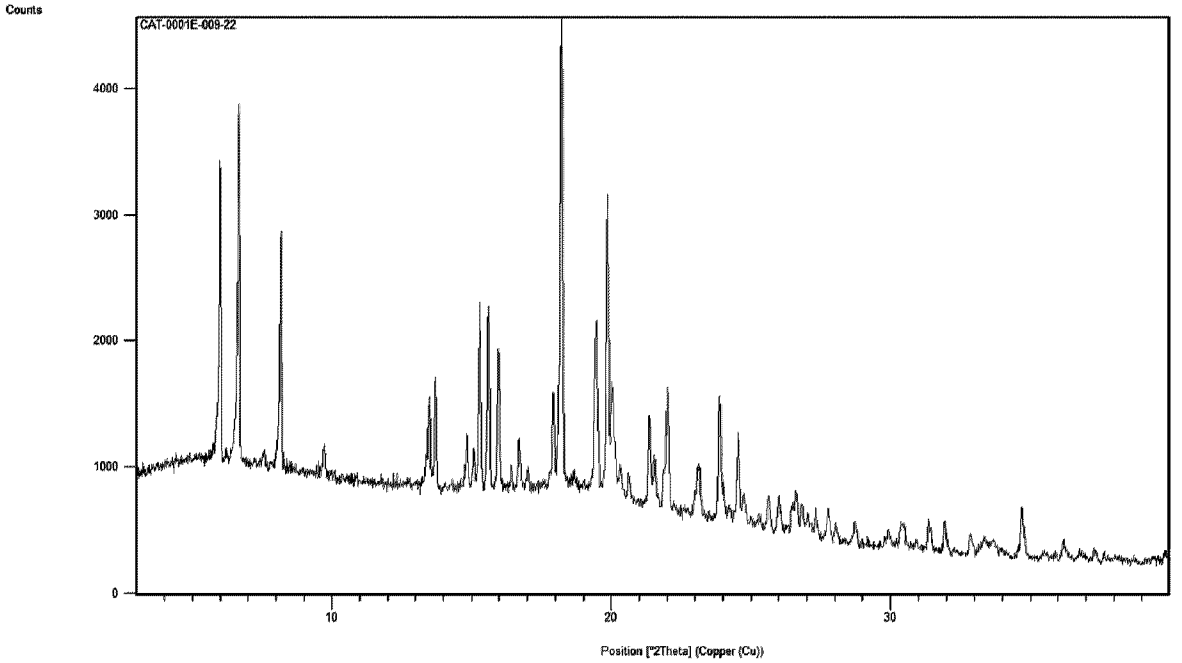

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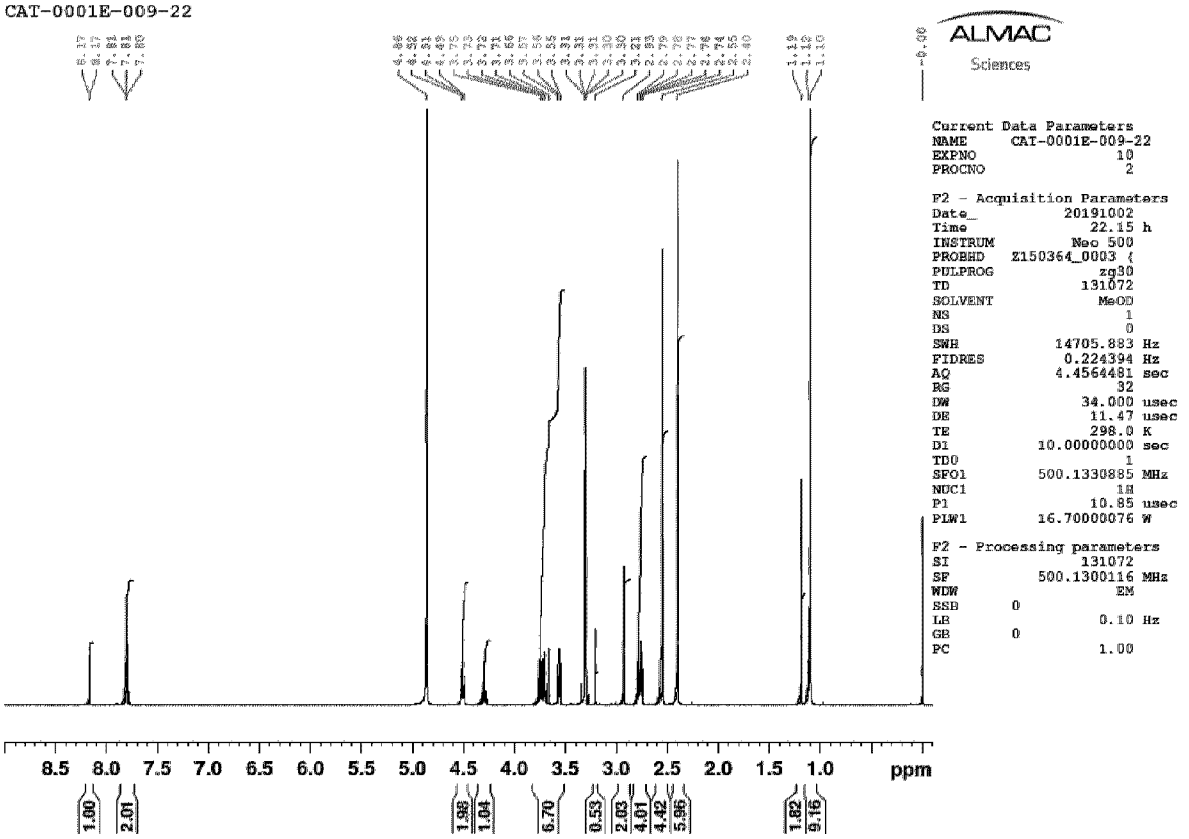

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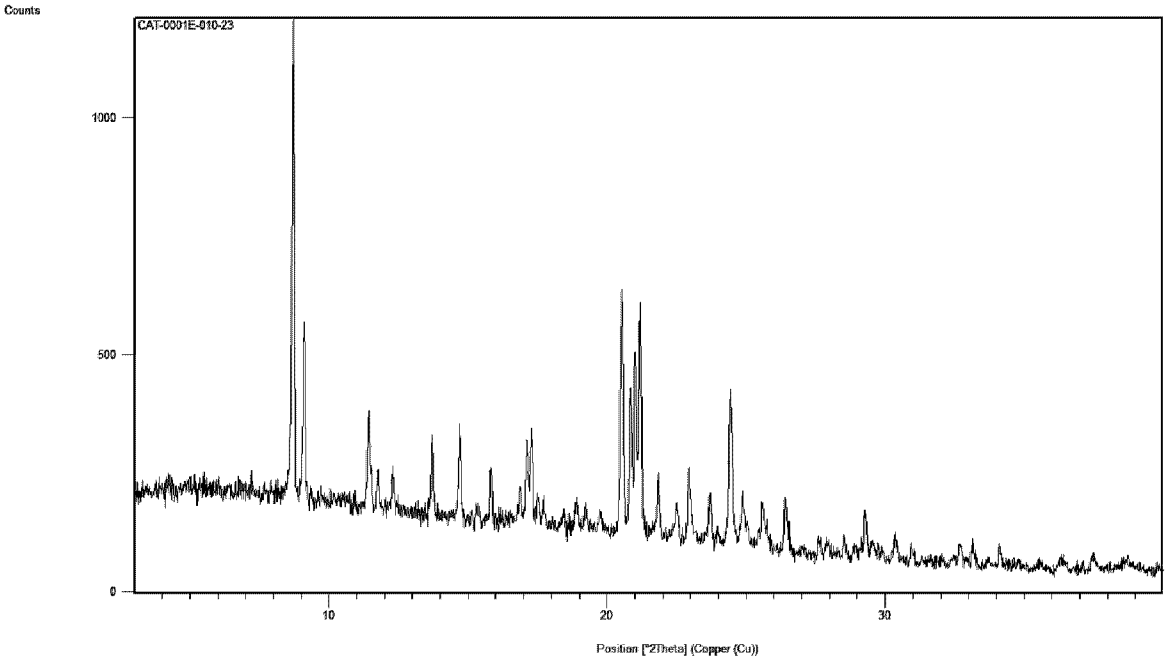

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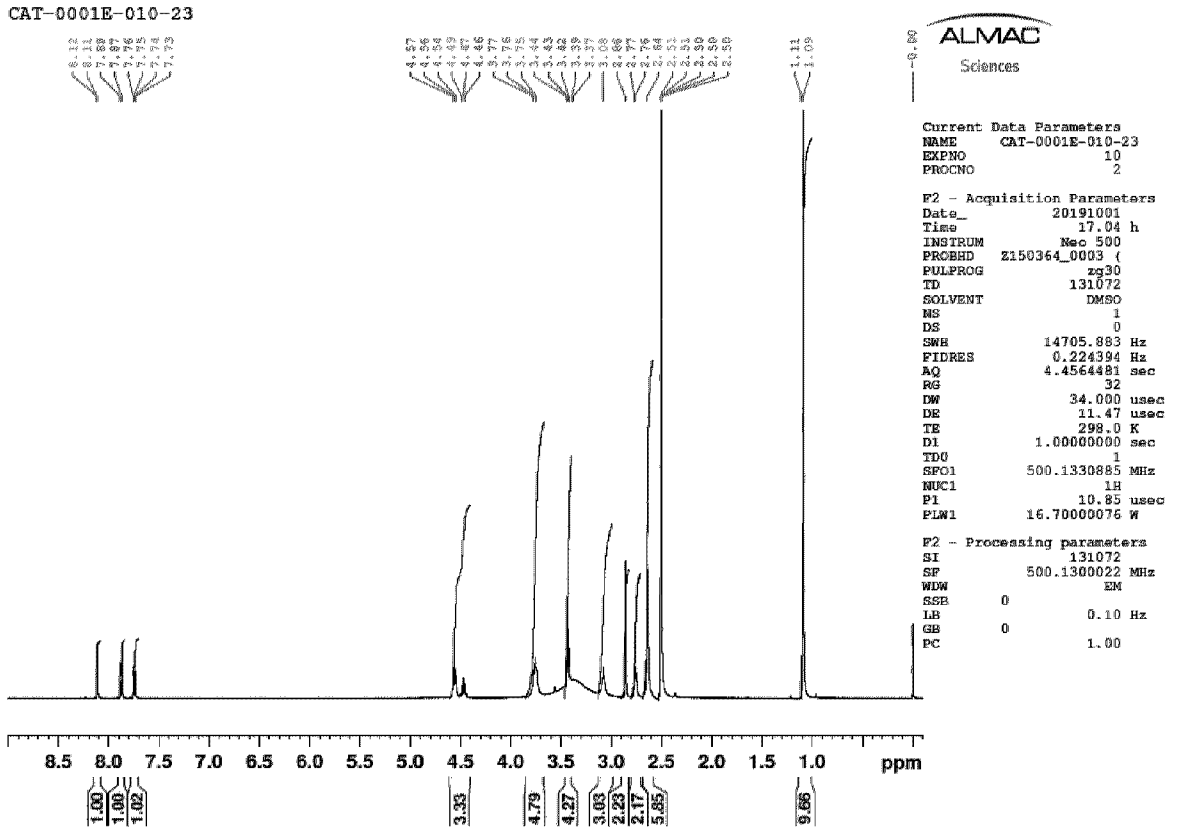

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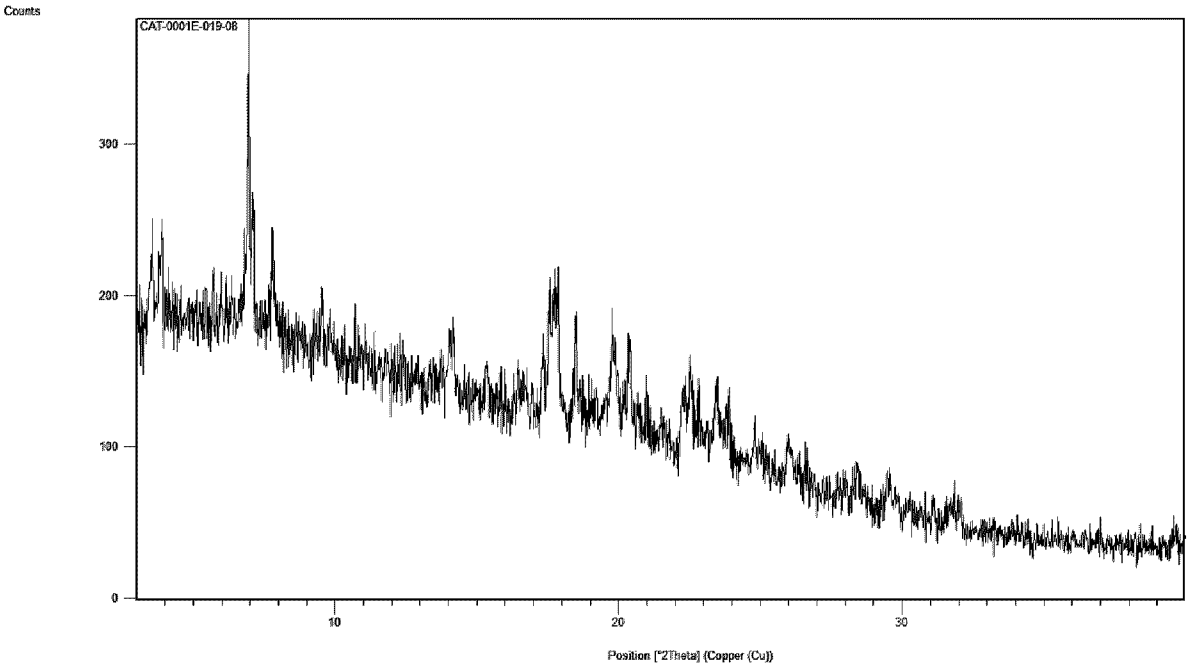

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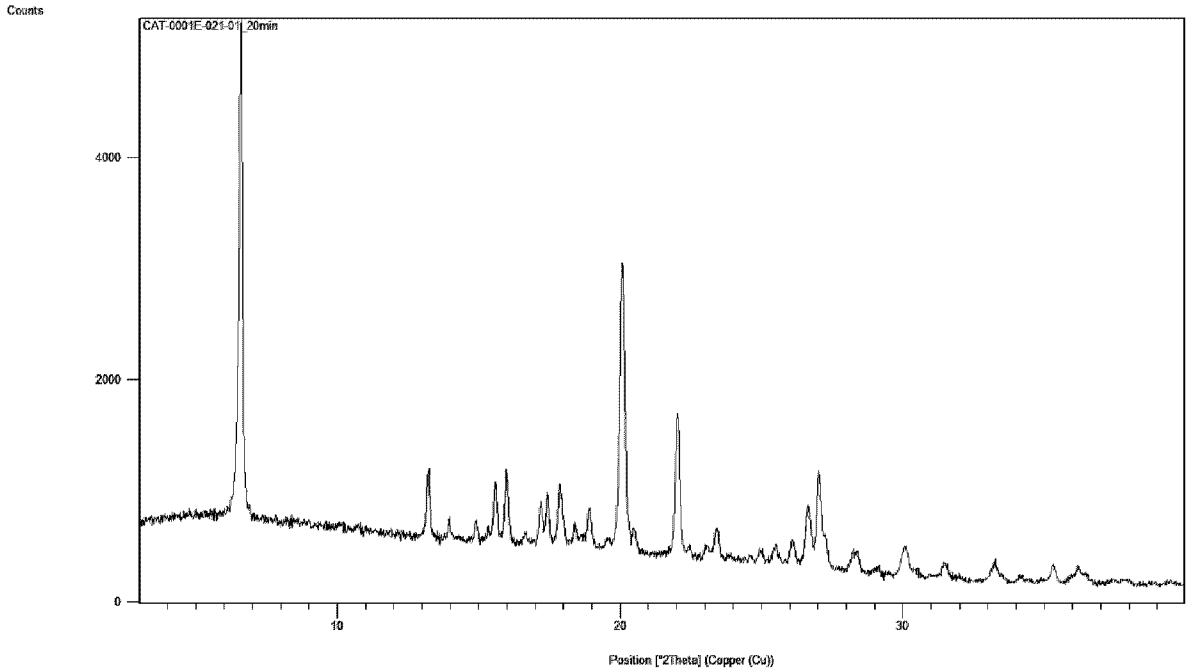
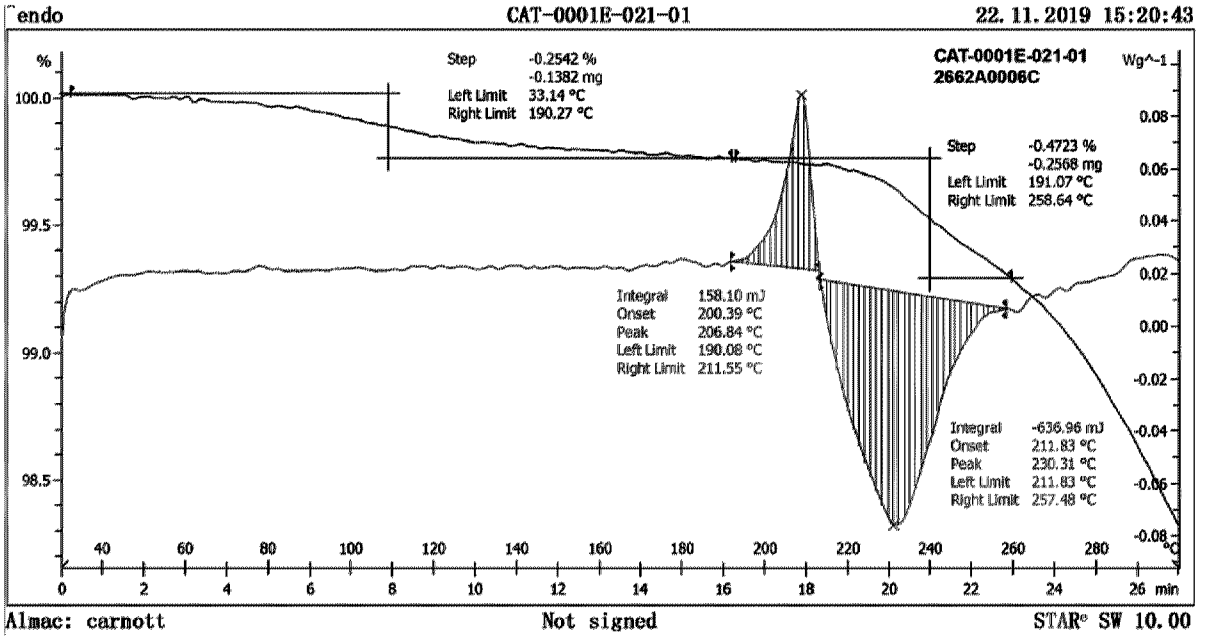


{Fig. 5-2}



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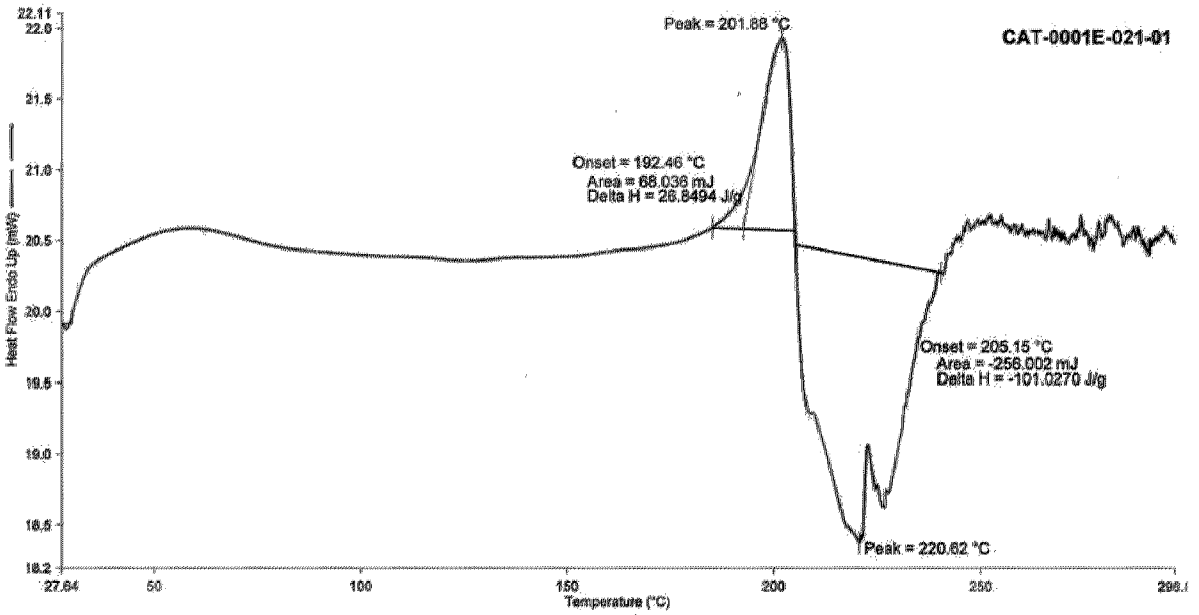

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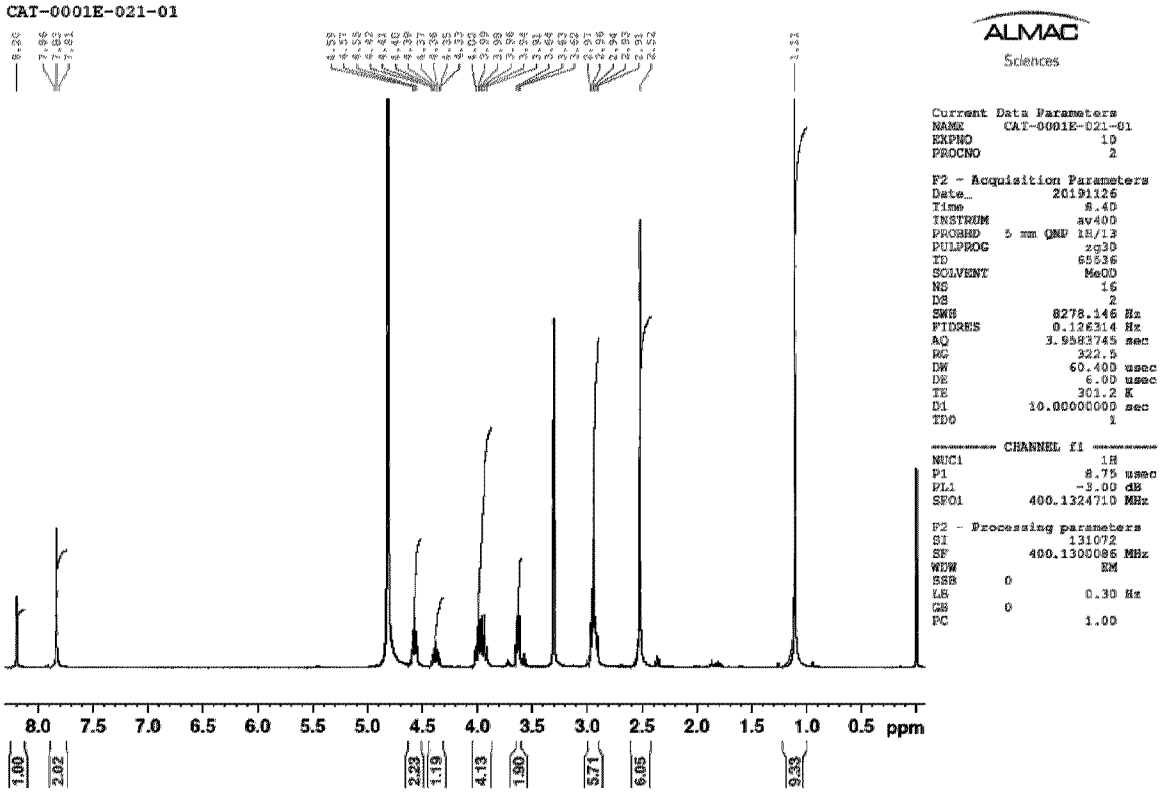

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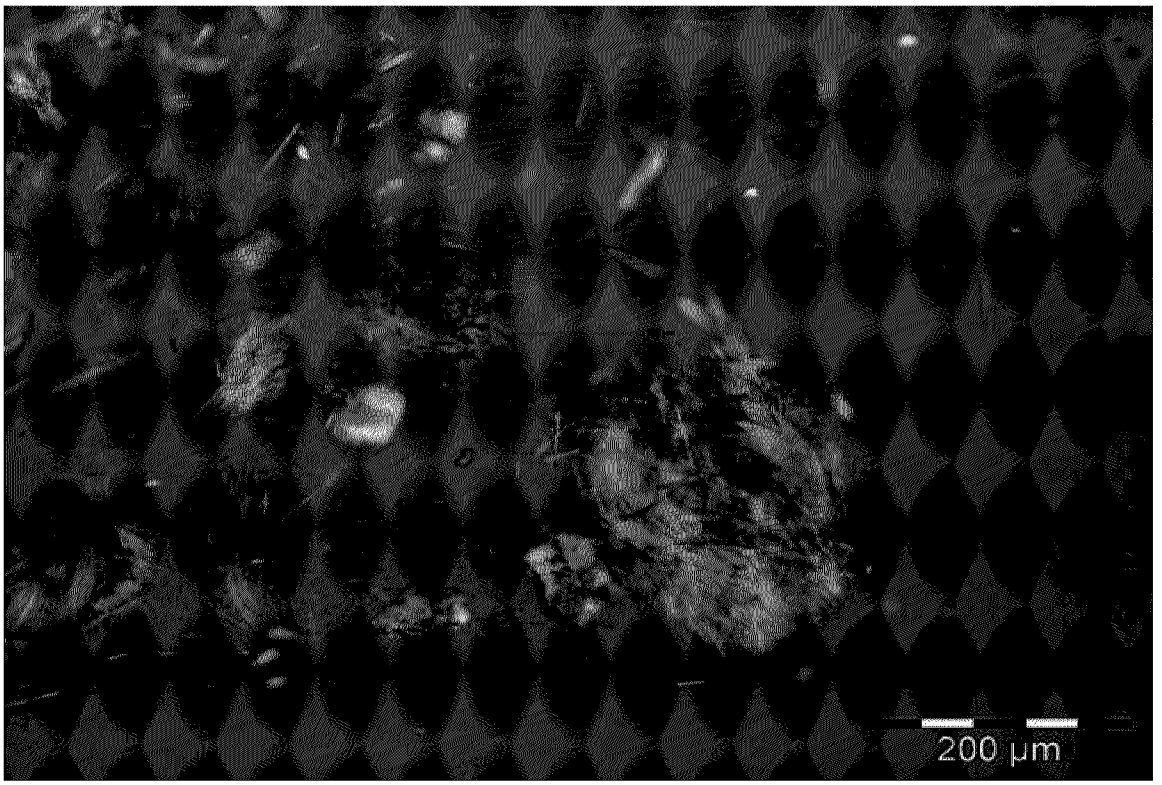

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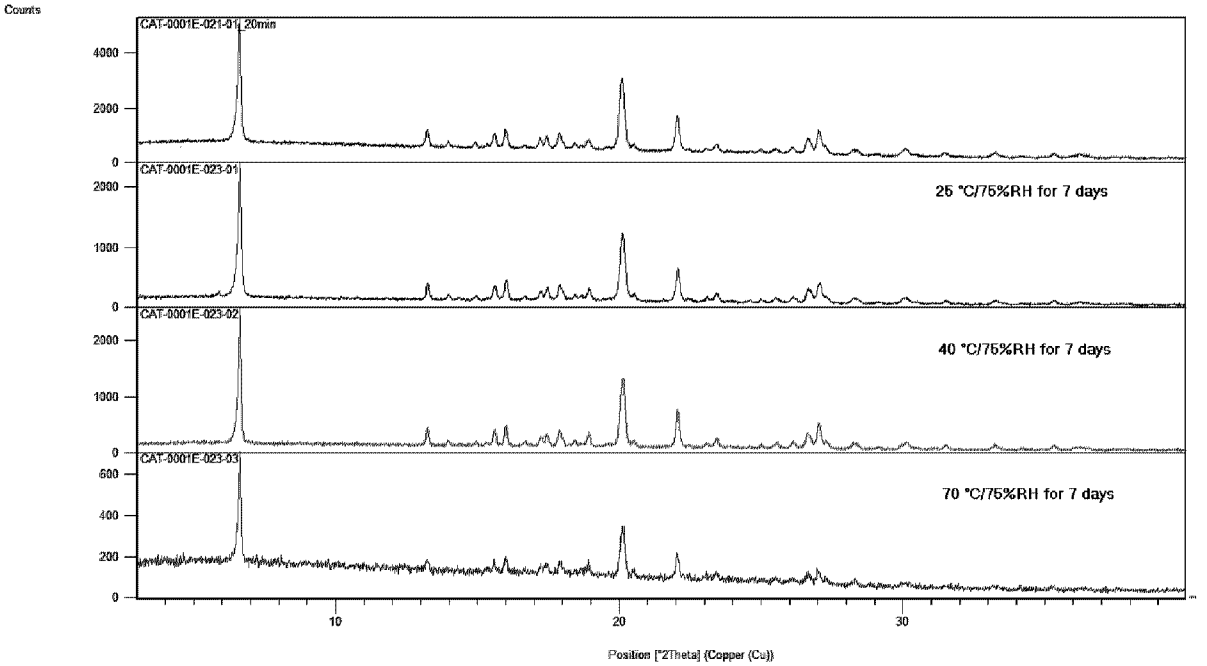

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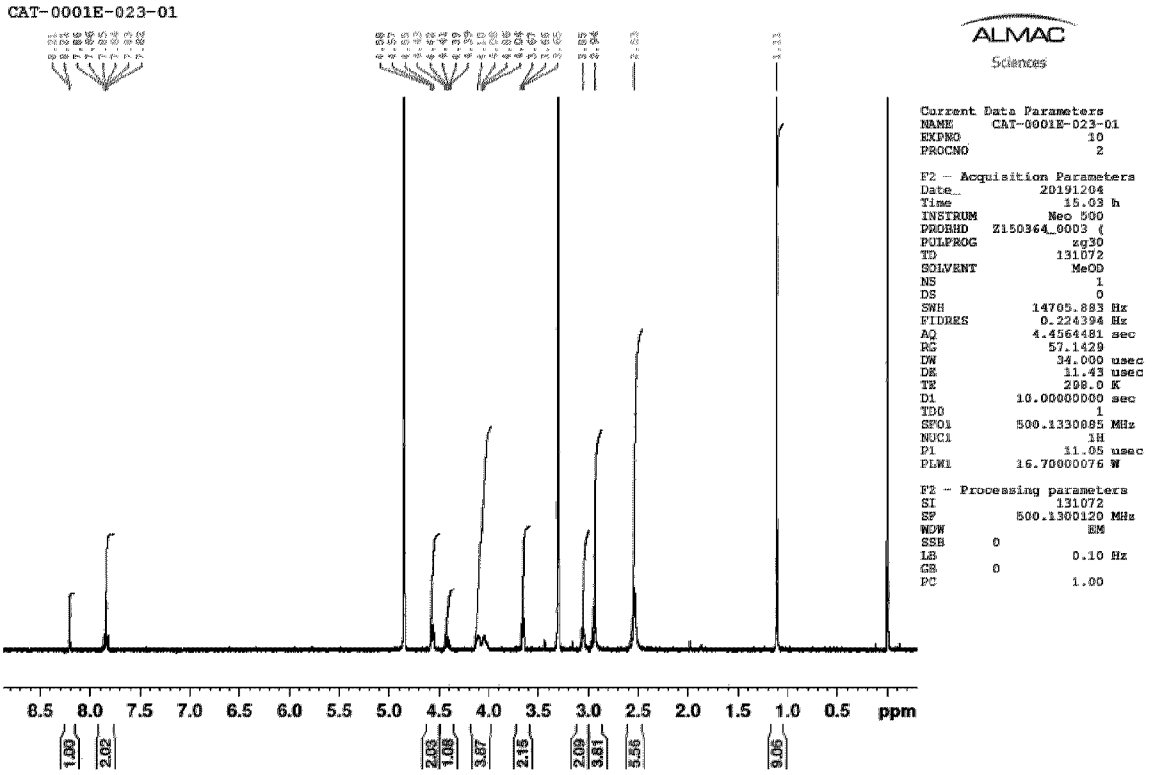

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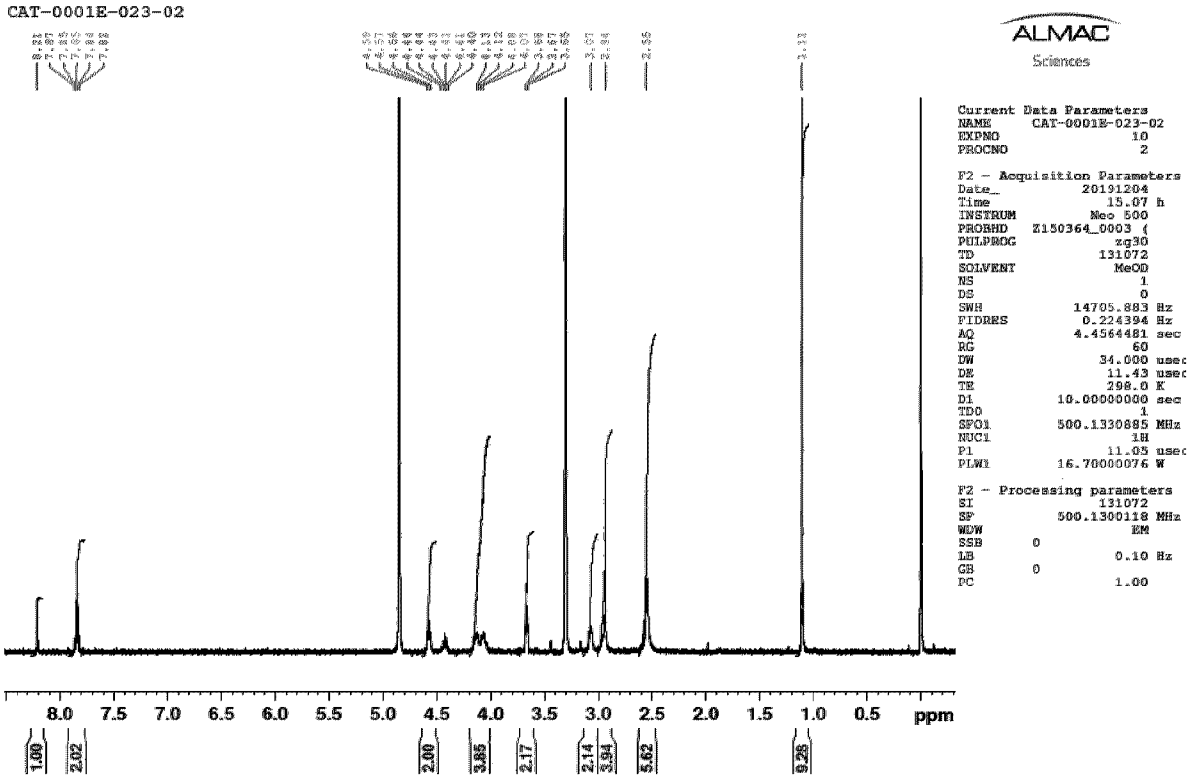

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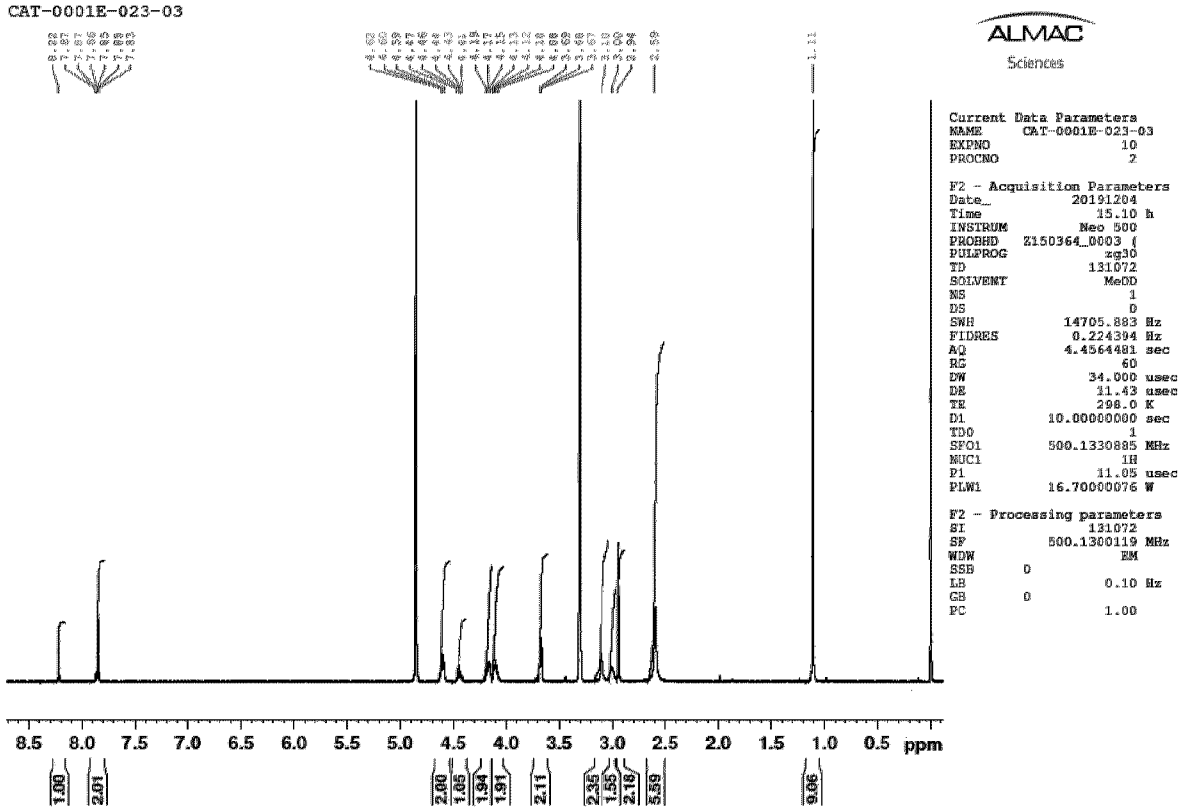

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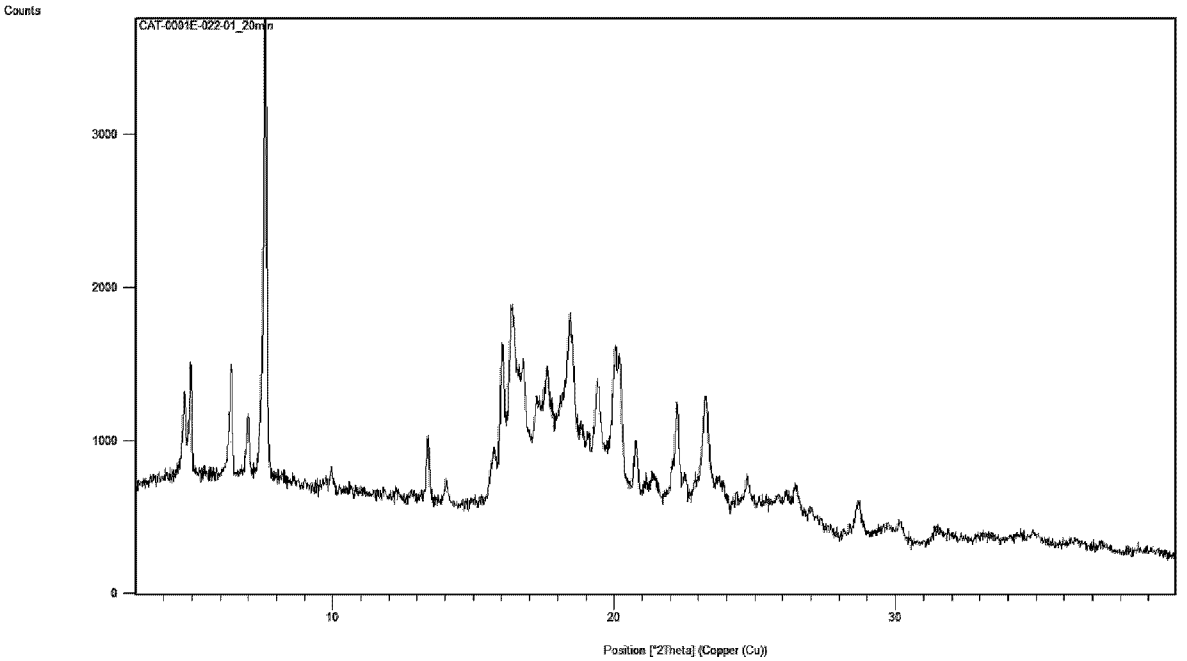

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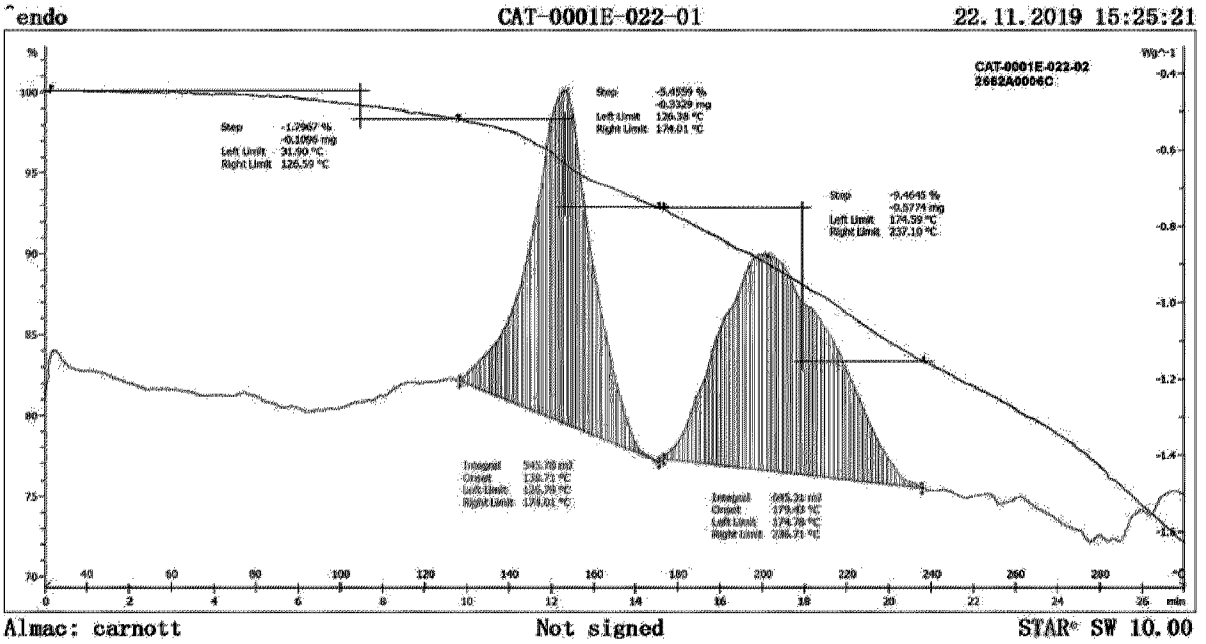

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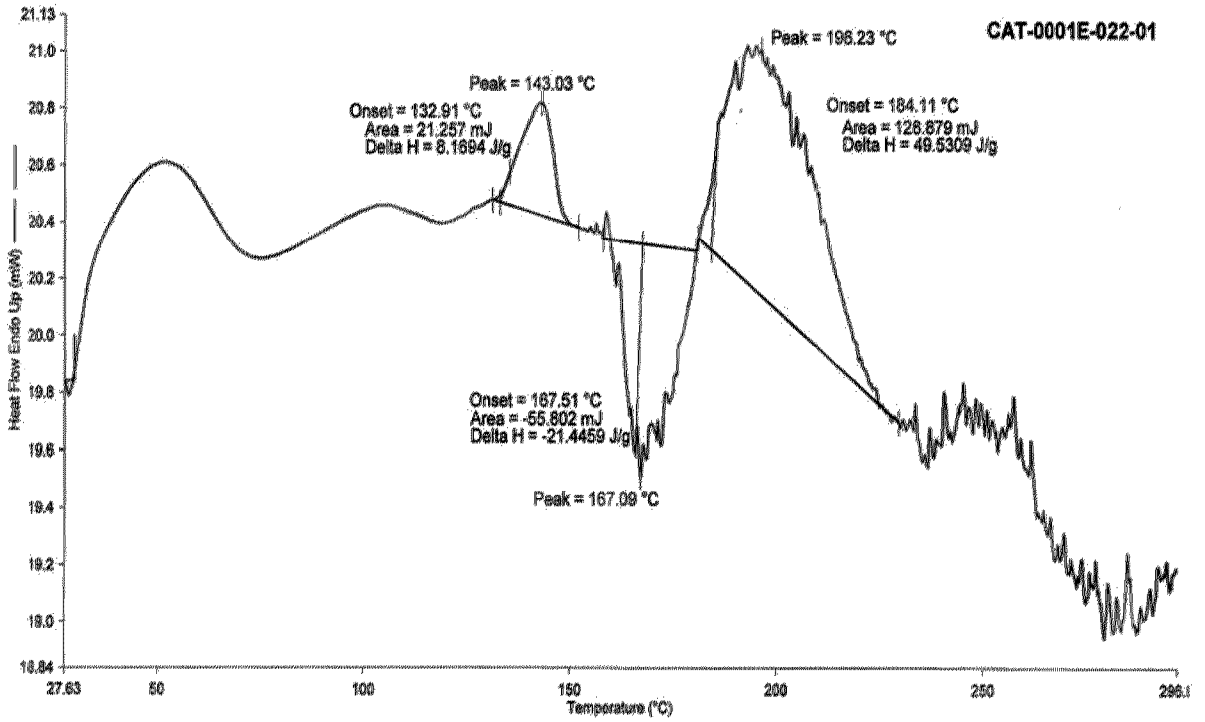

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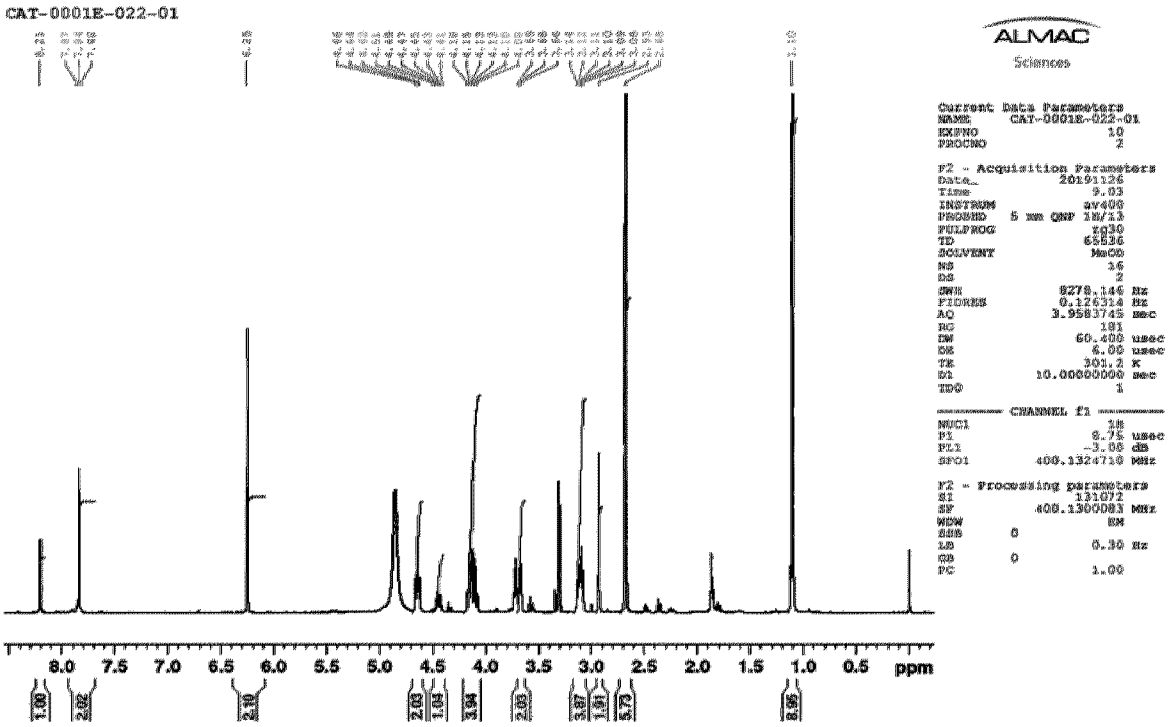

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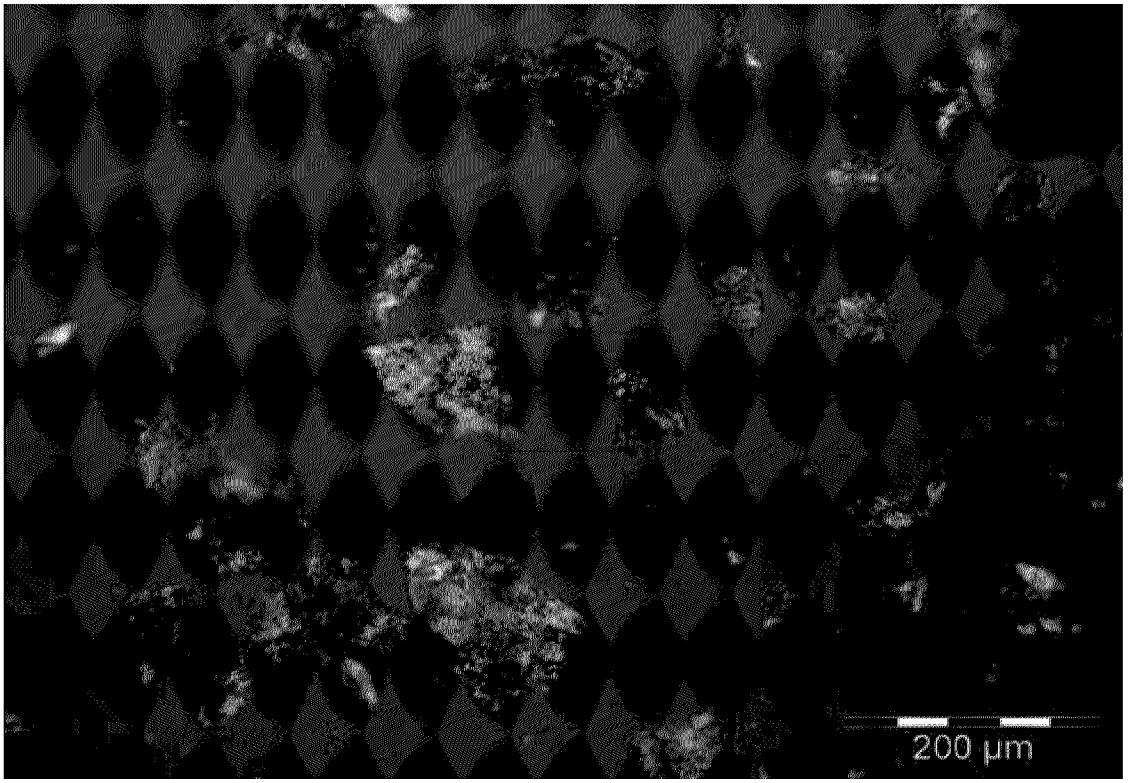

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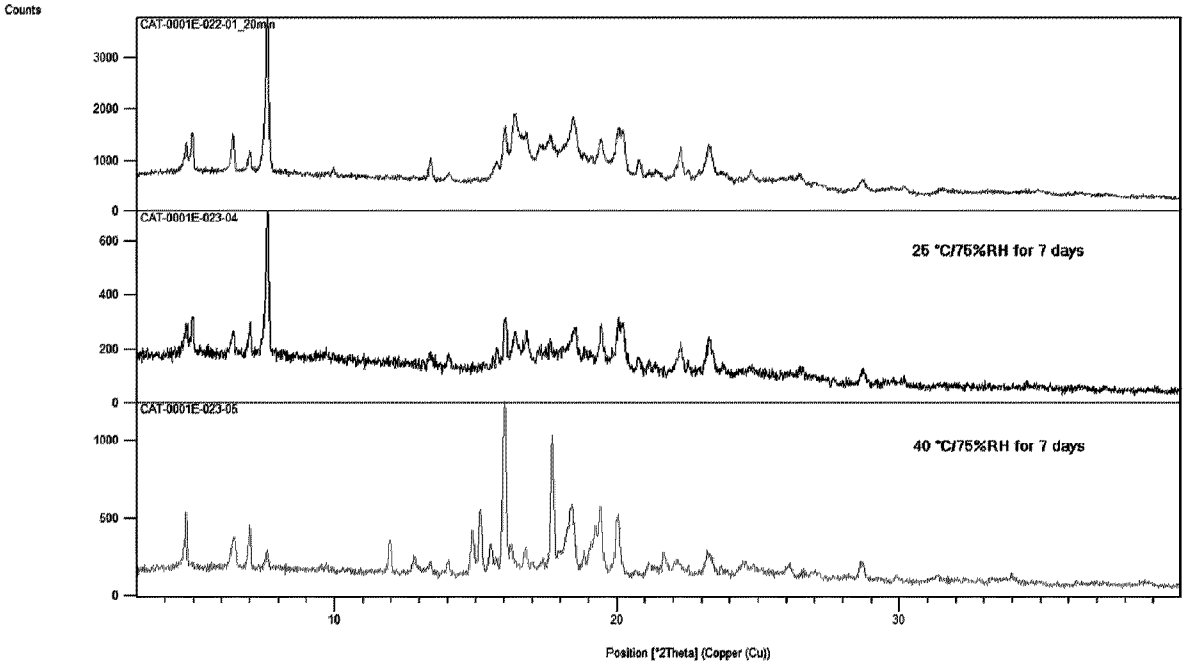

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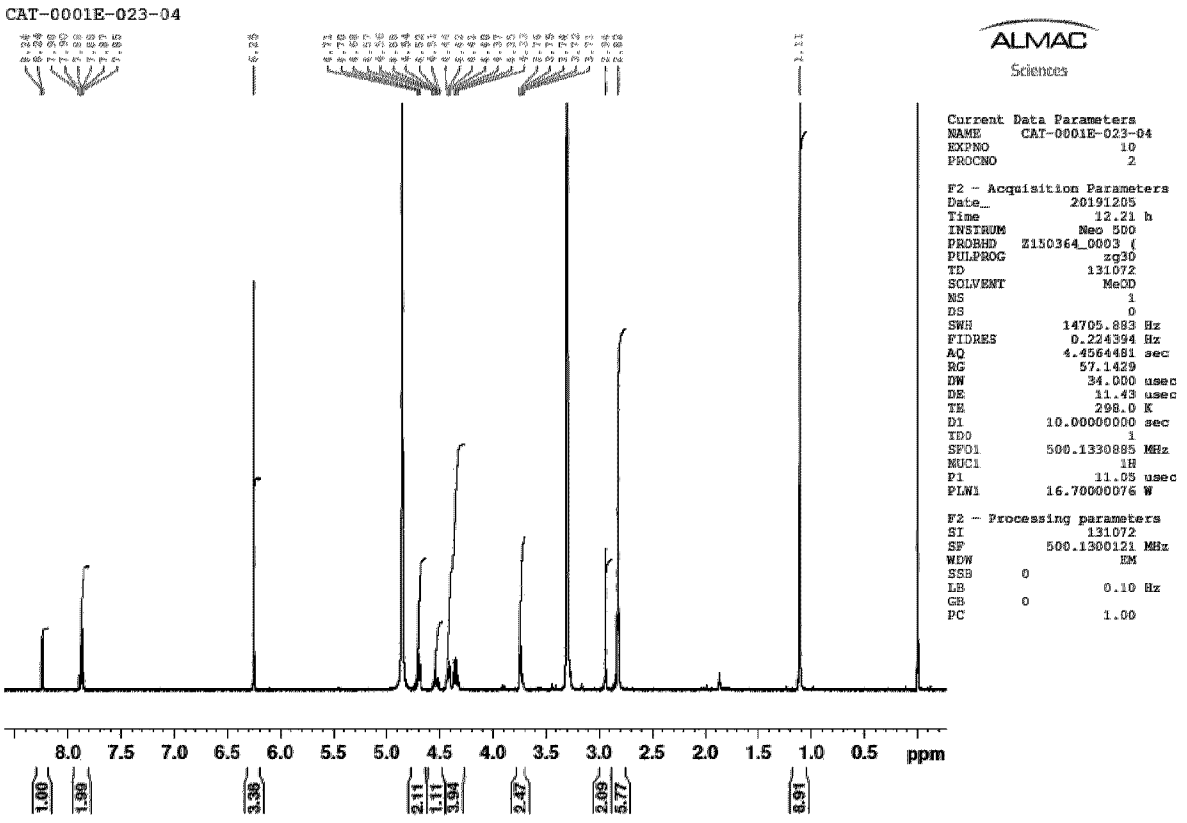

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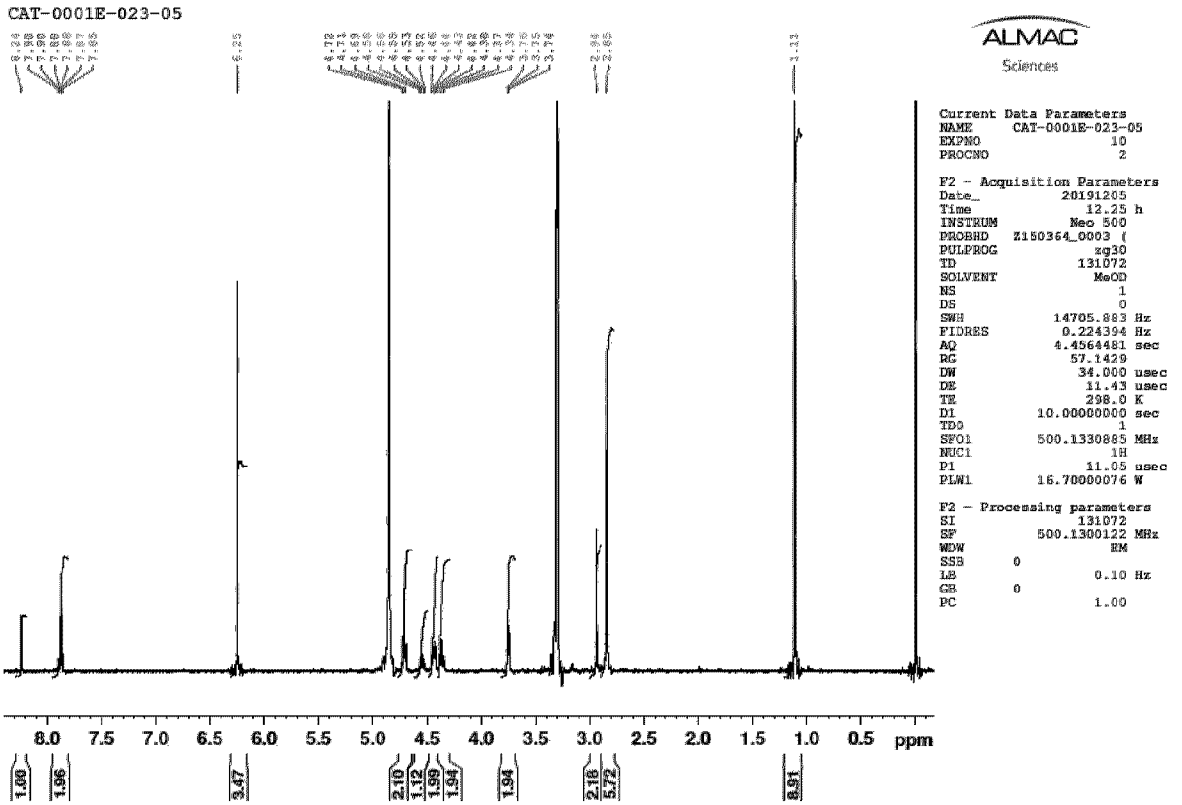
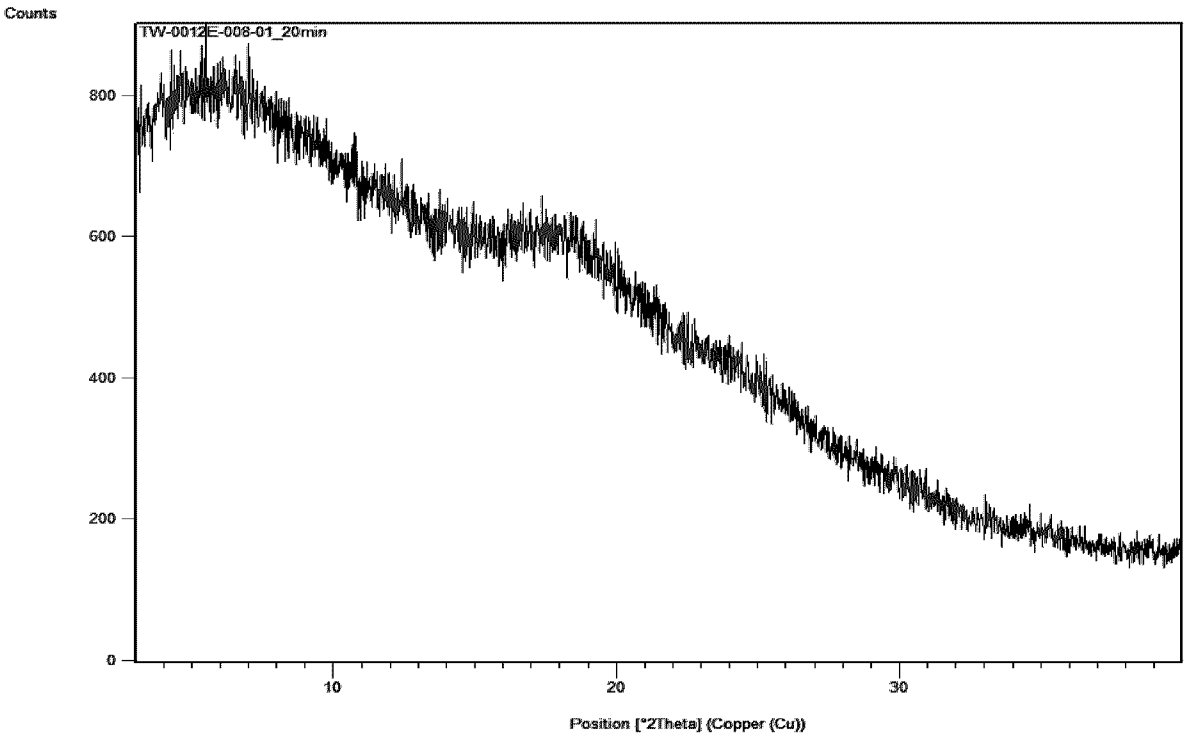


{Fig. 6-1}



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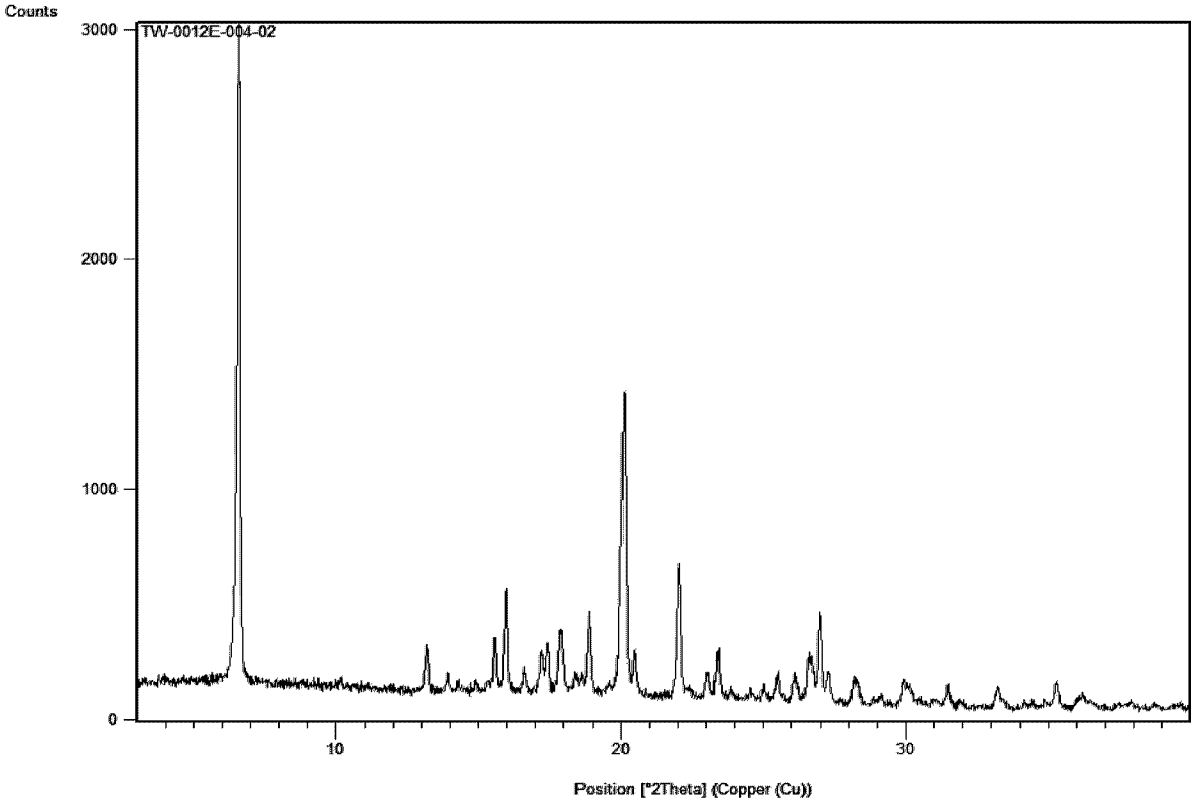
{Fig. 6-2}



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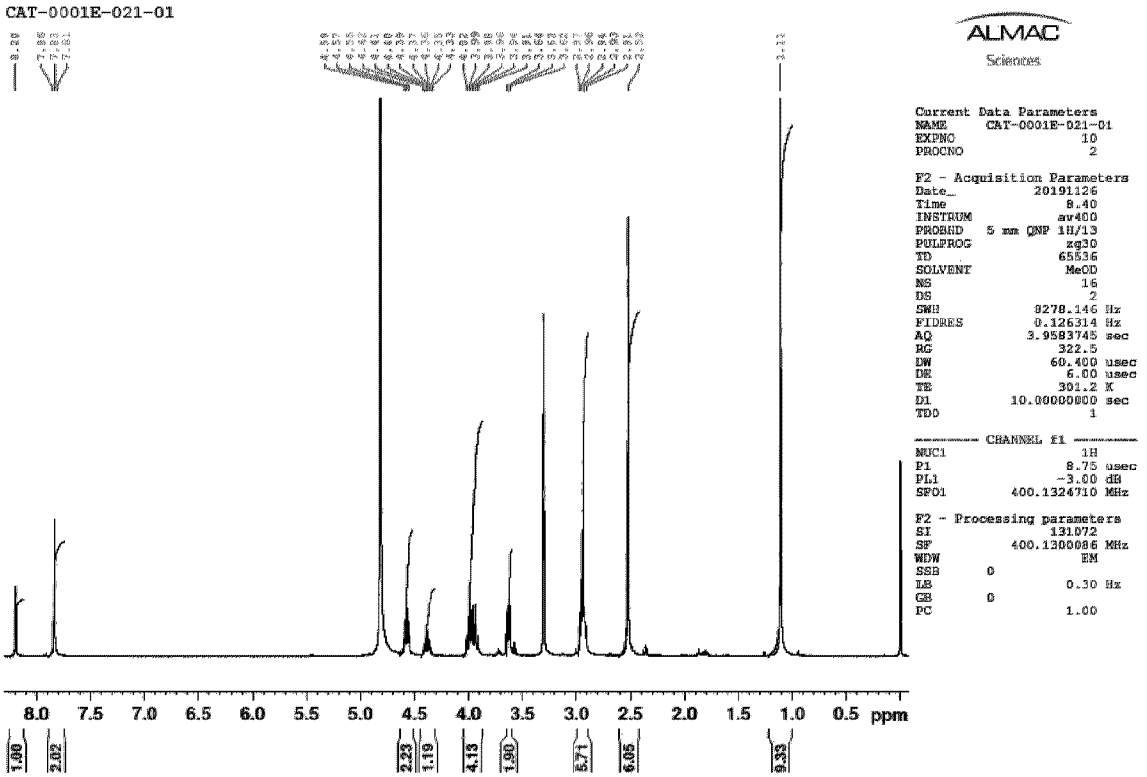

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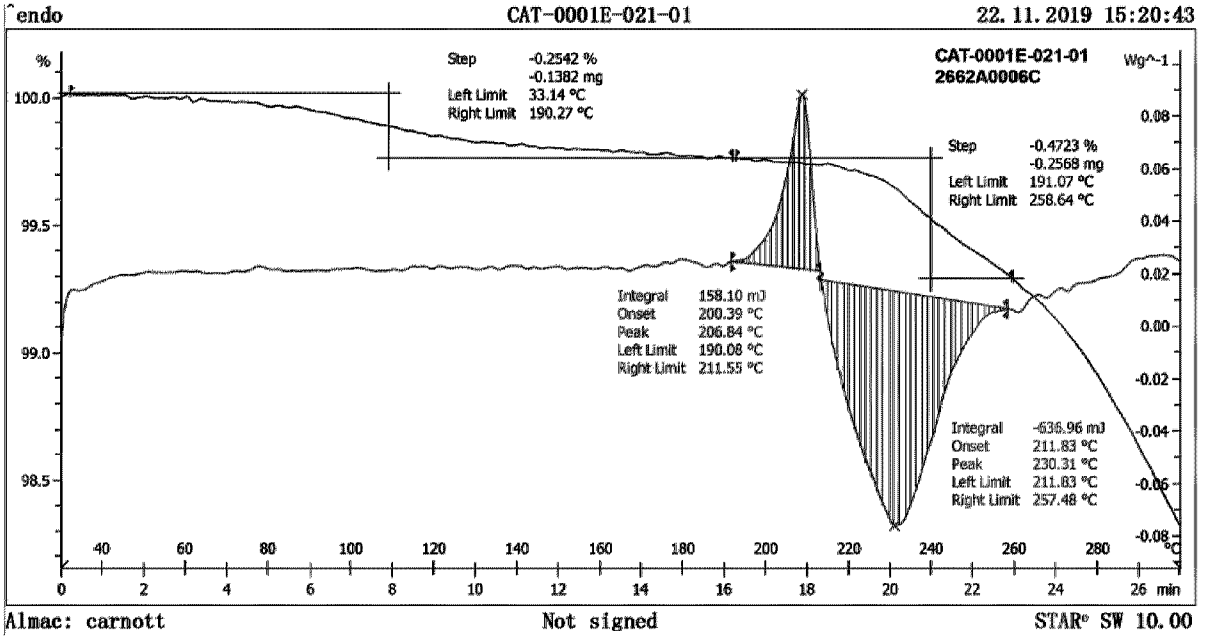

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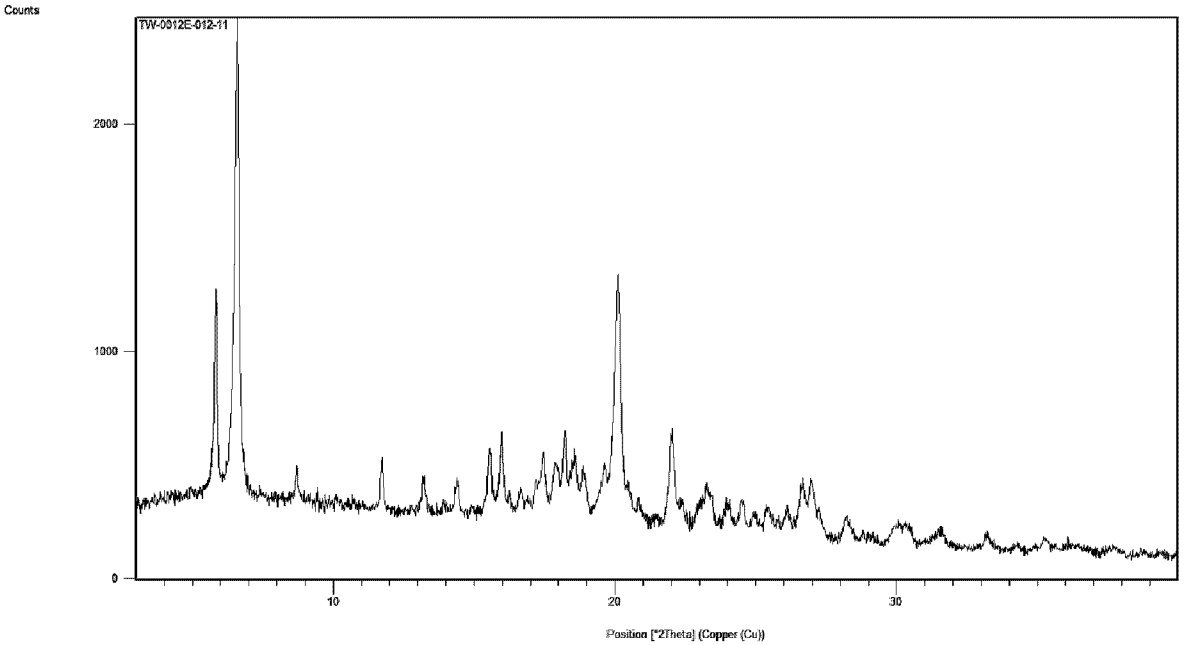

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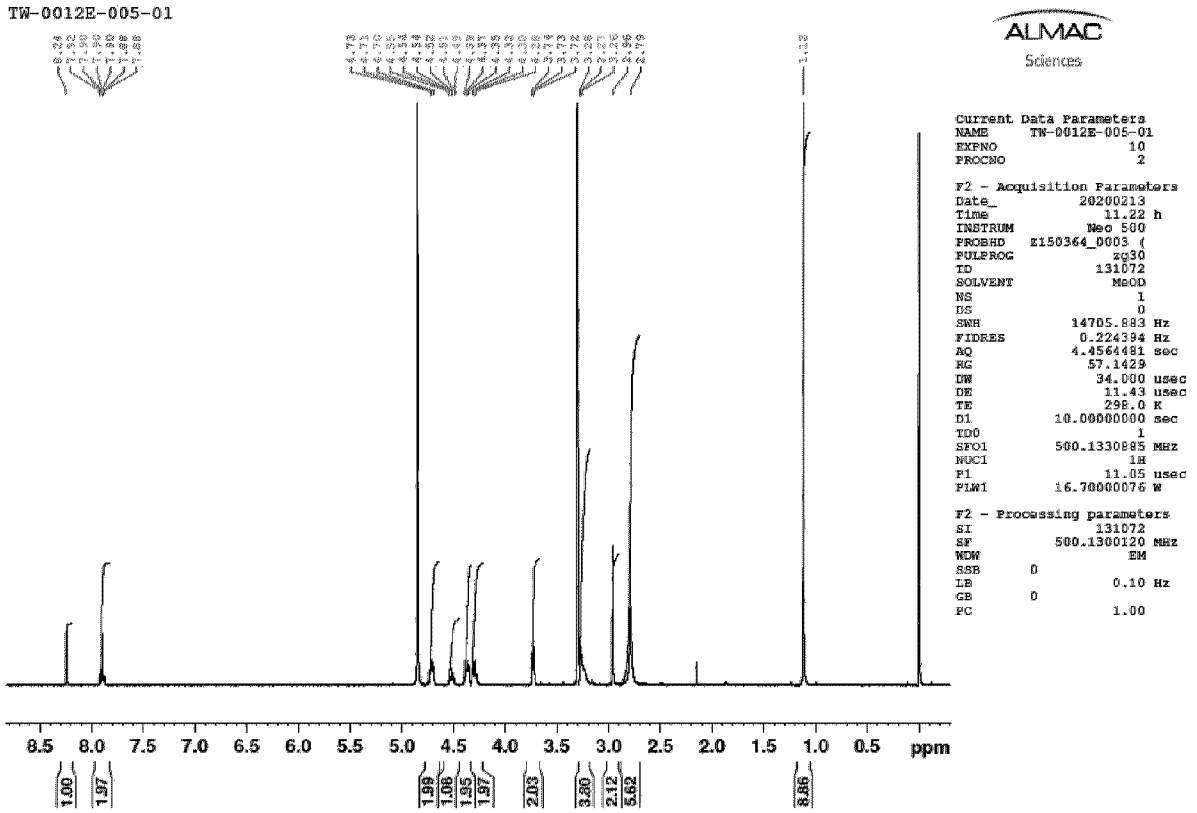

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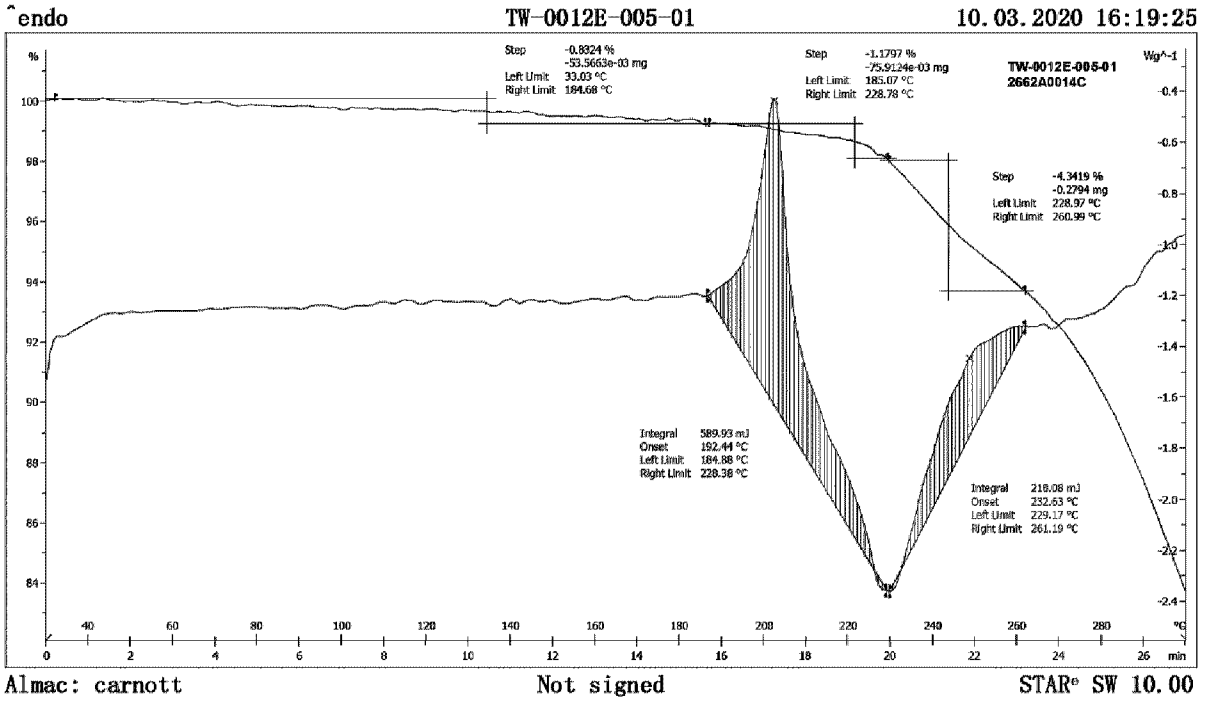

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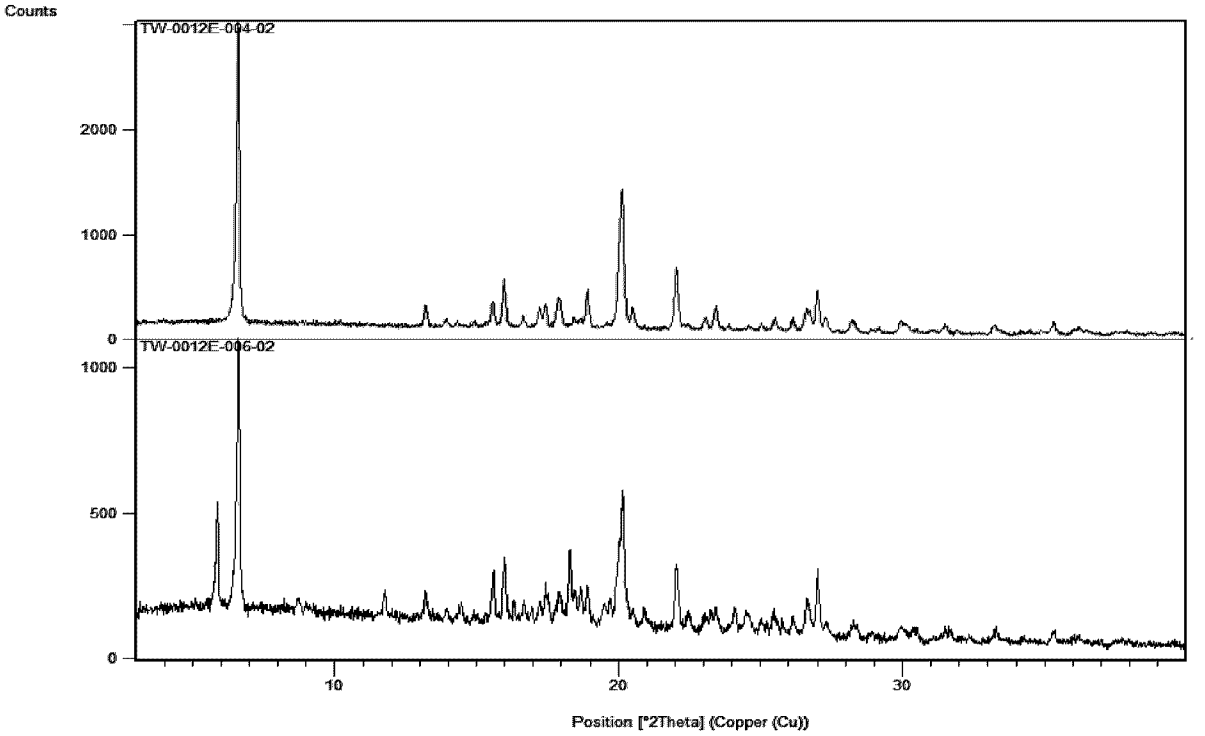

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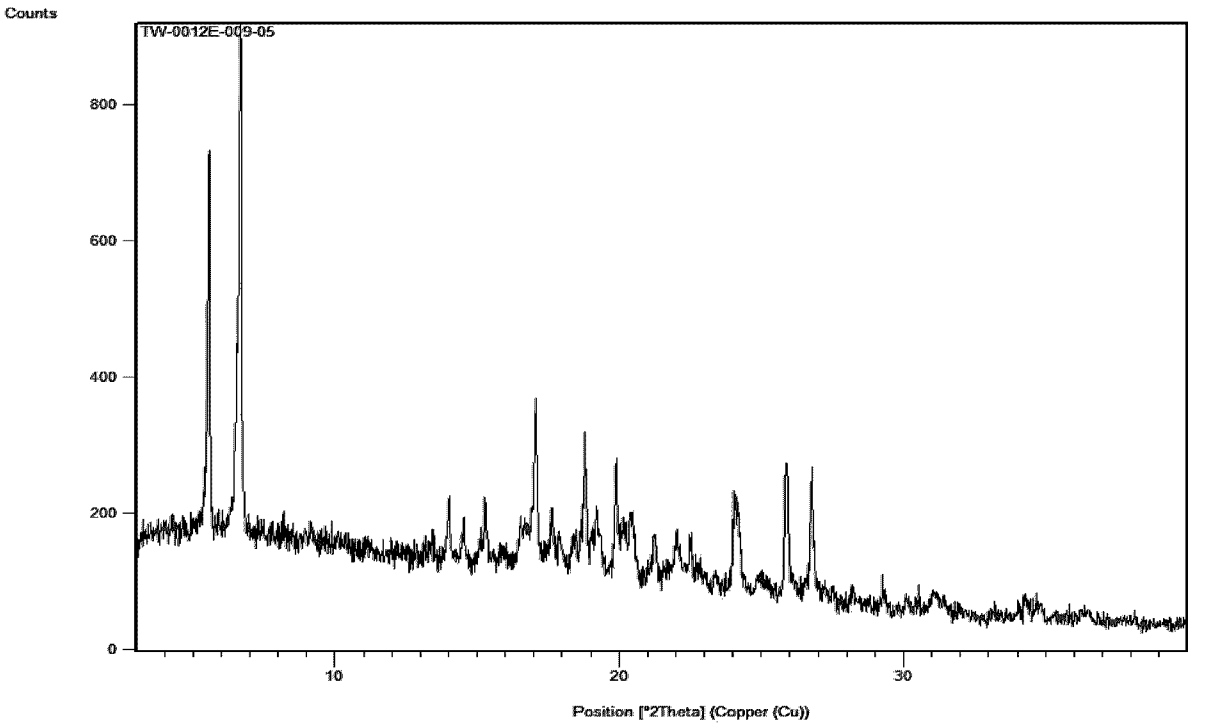

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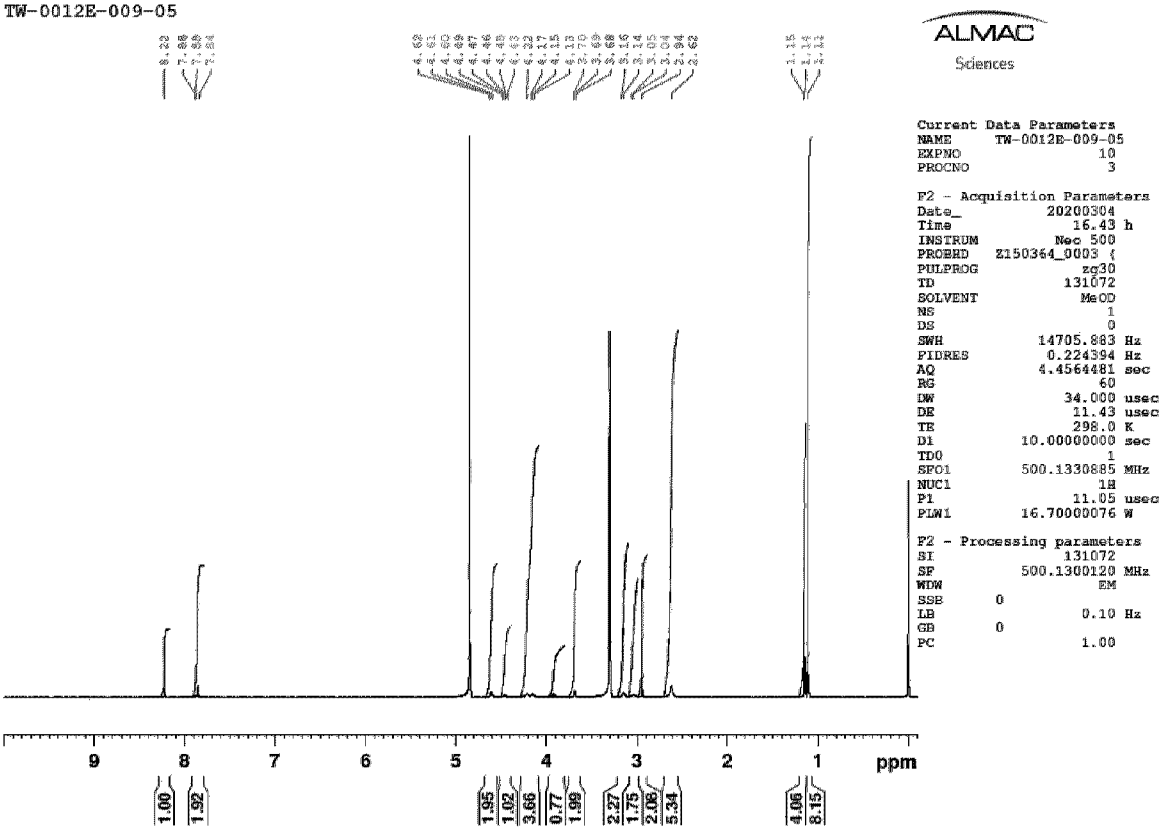

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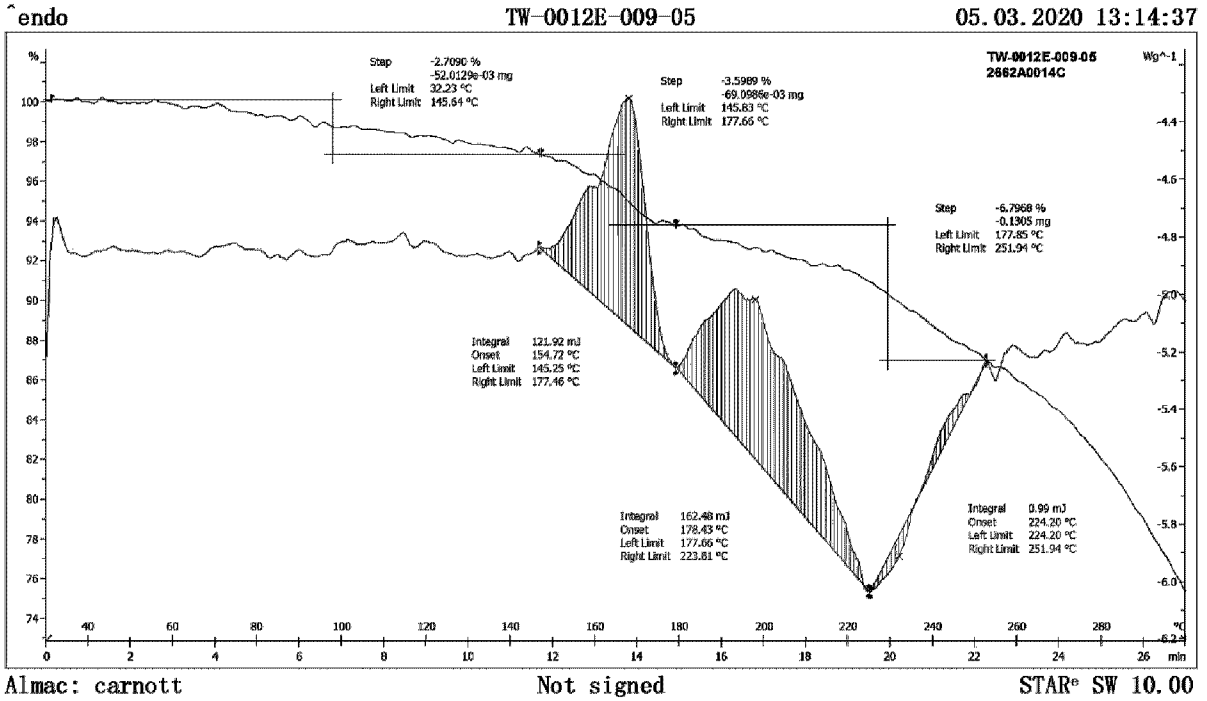

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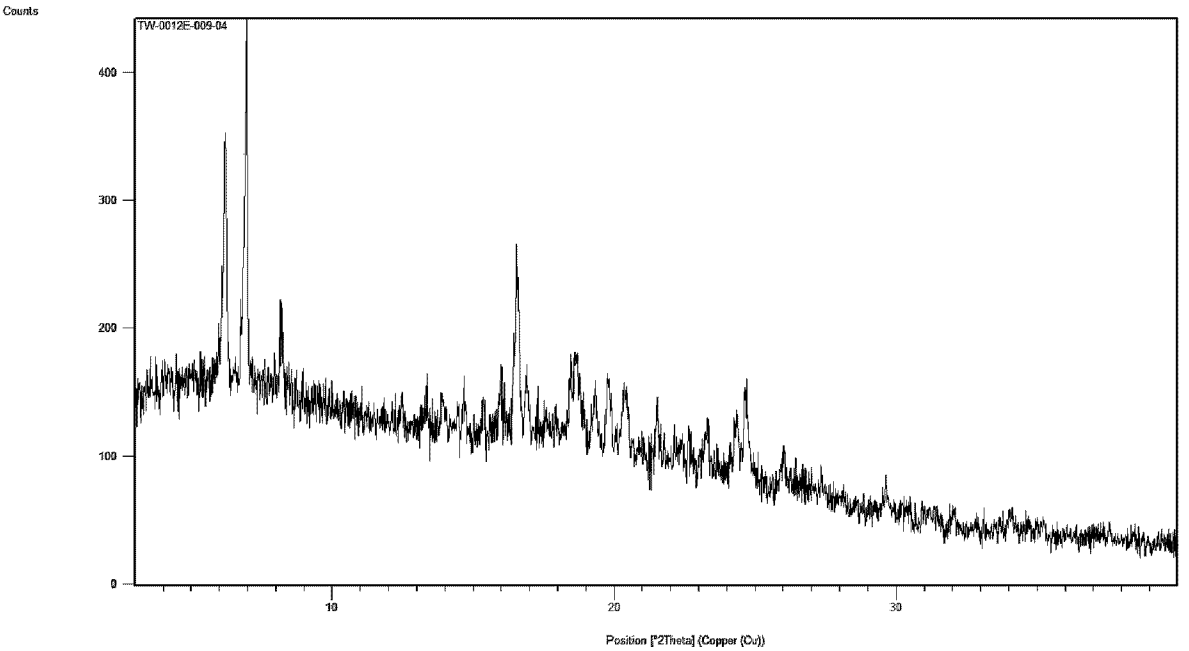

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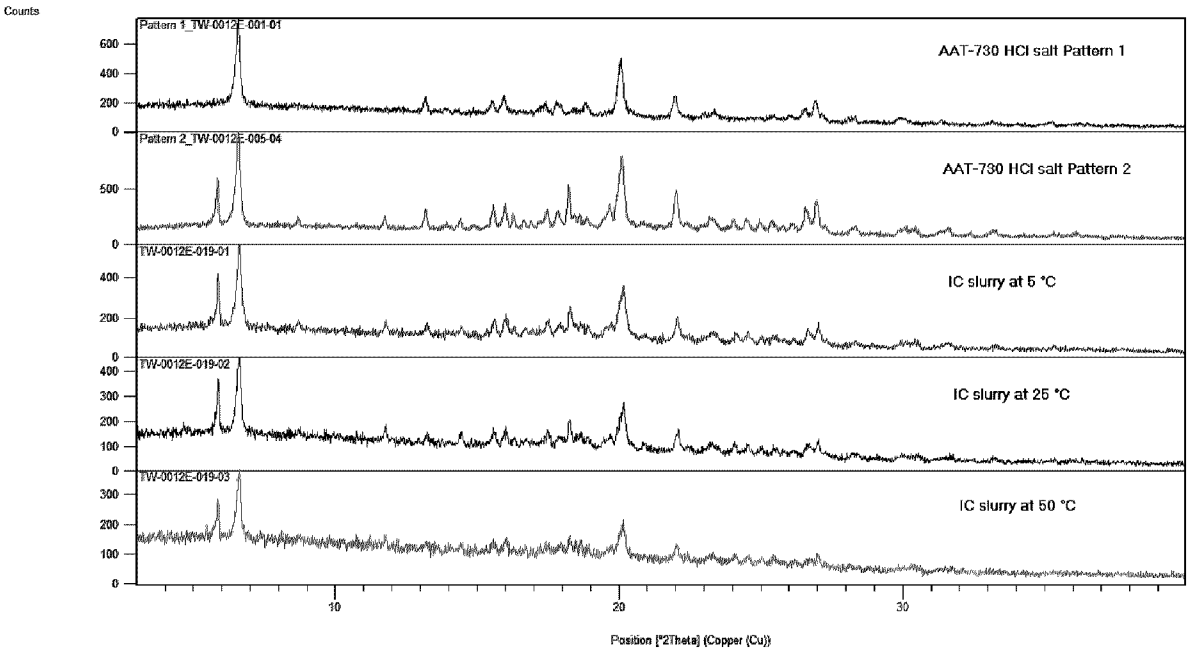

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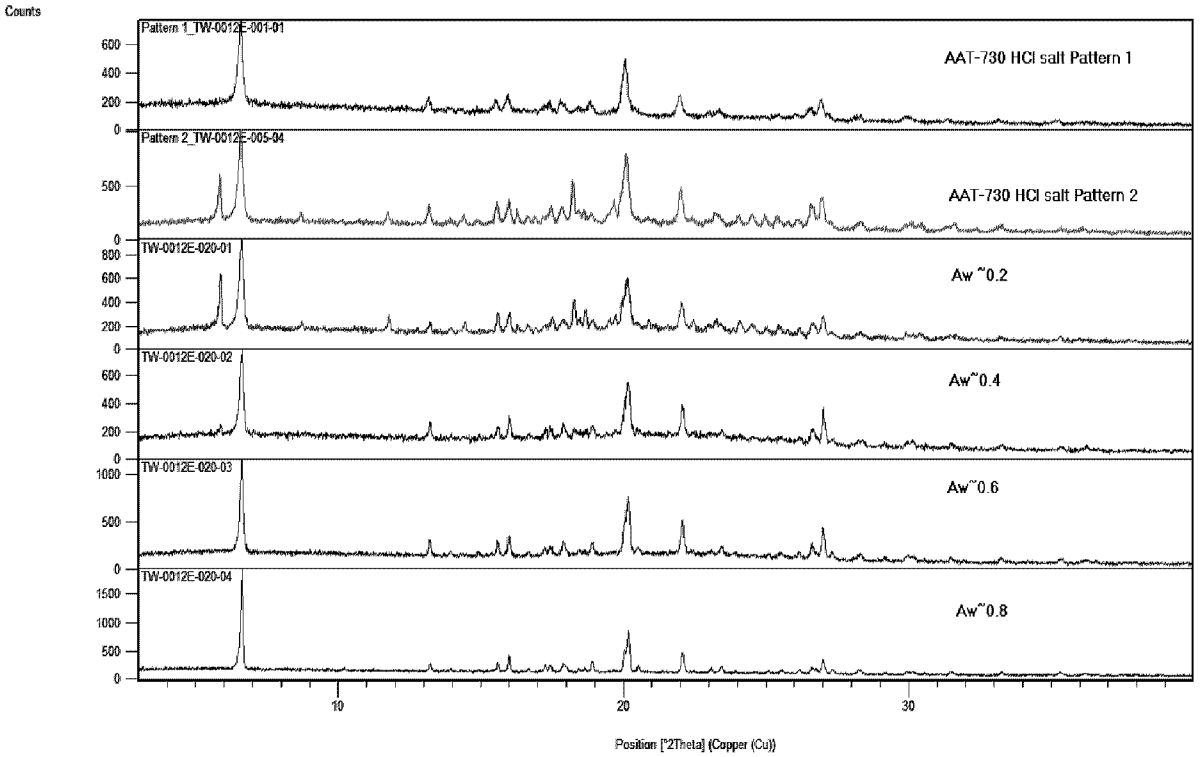
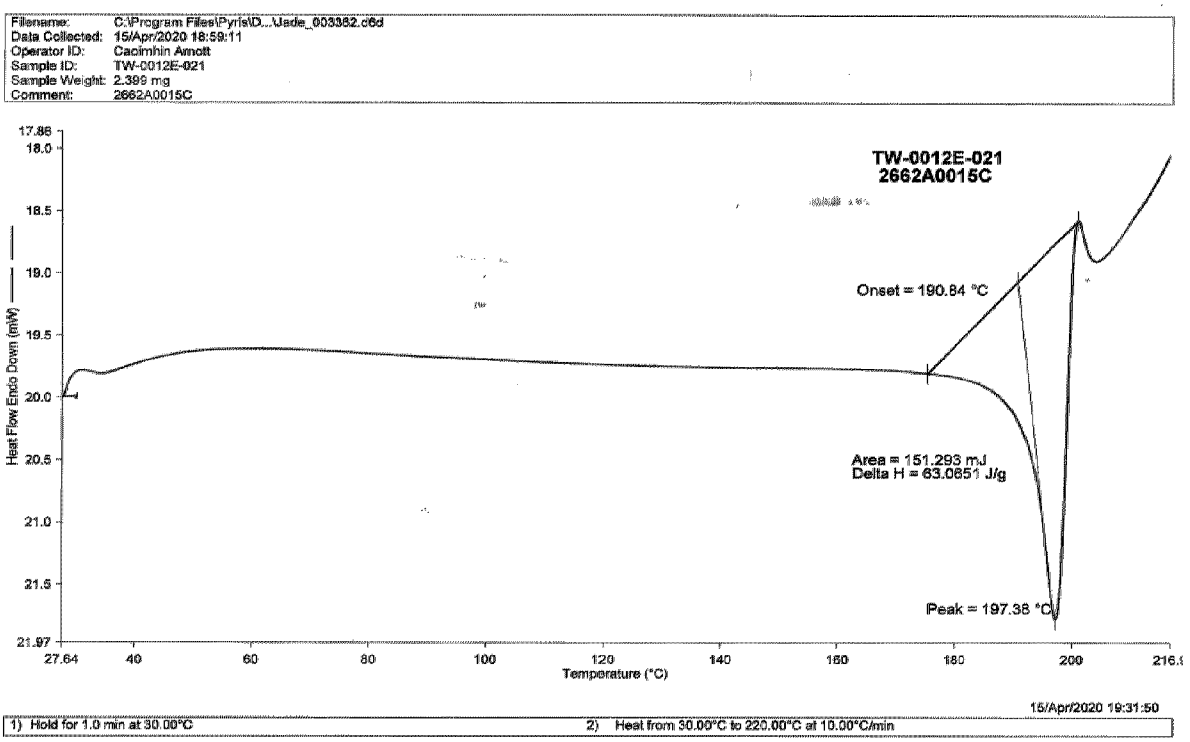
{Fig. 6-14}



{Fig. 6-15}



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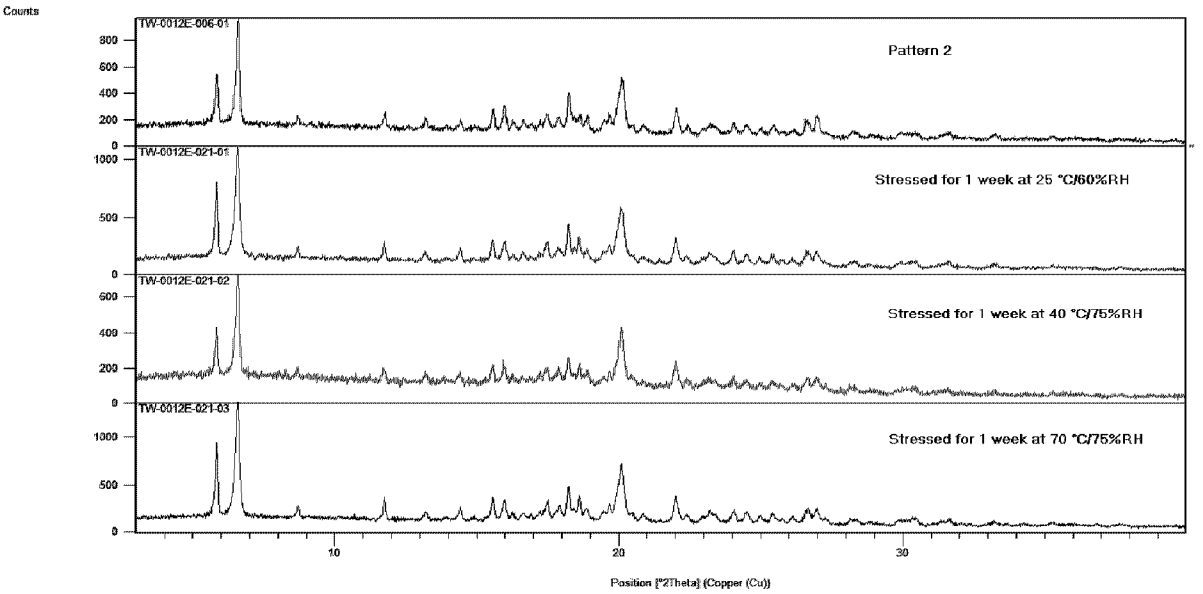
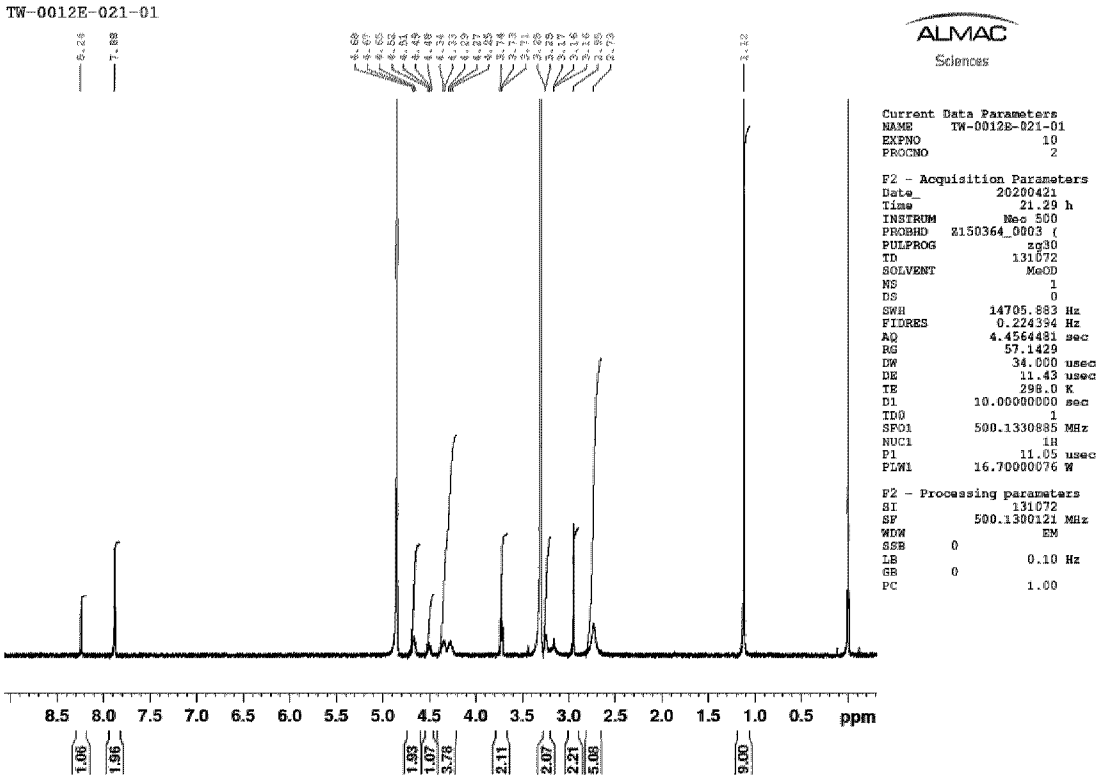
{Fig. 6-16}



{Fig. 6-17}



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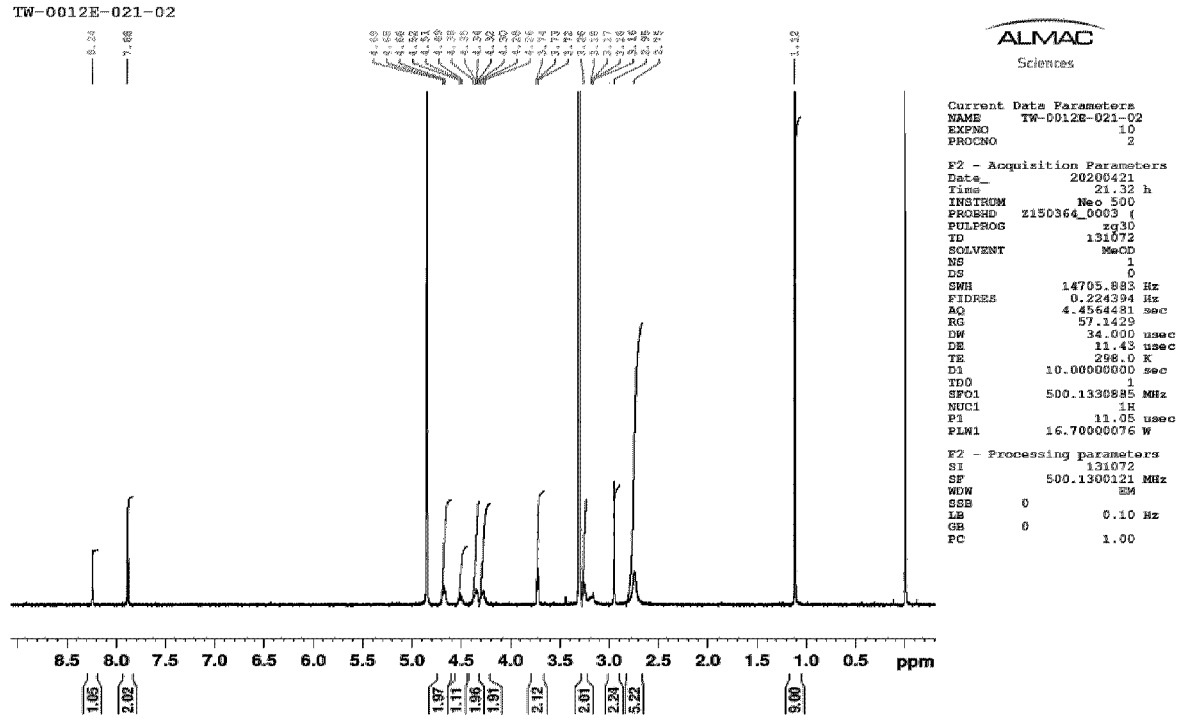
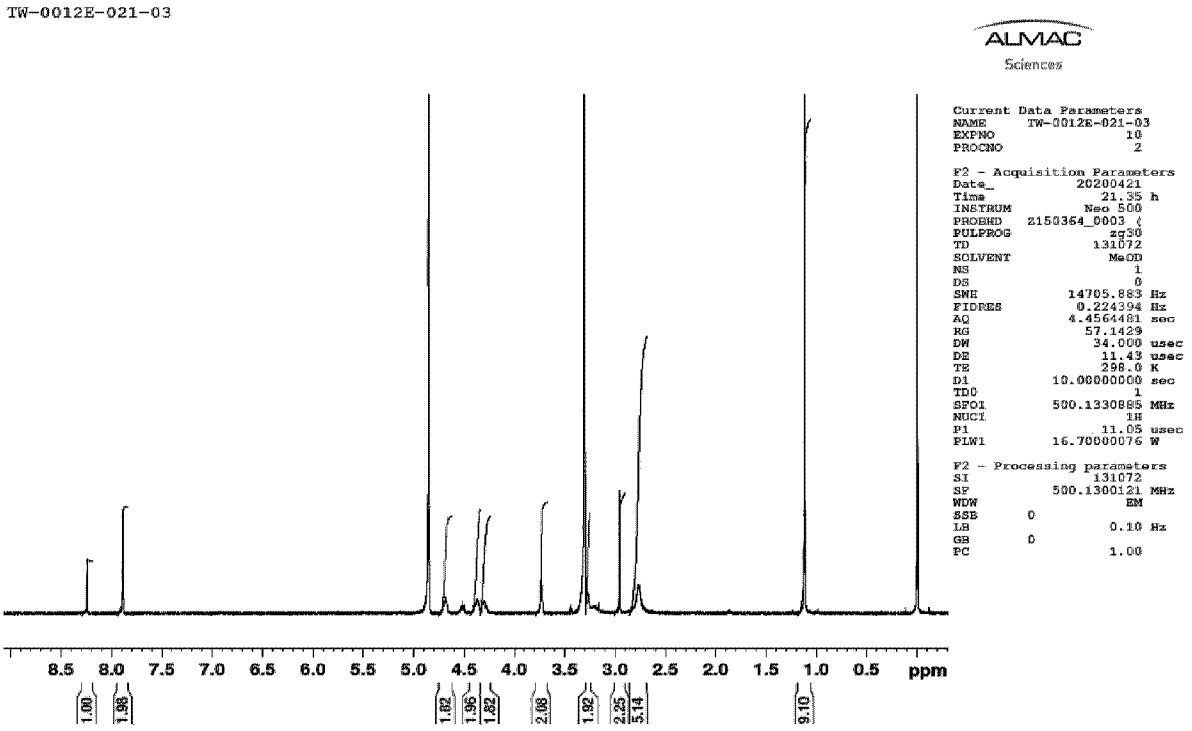
{Fig. 6-18}



{Fig. 6-19}



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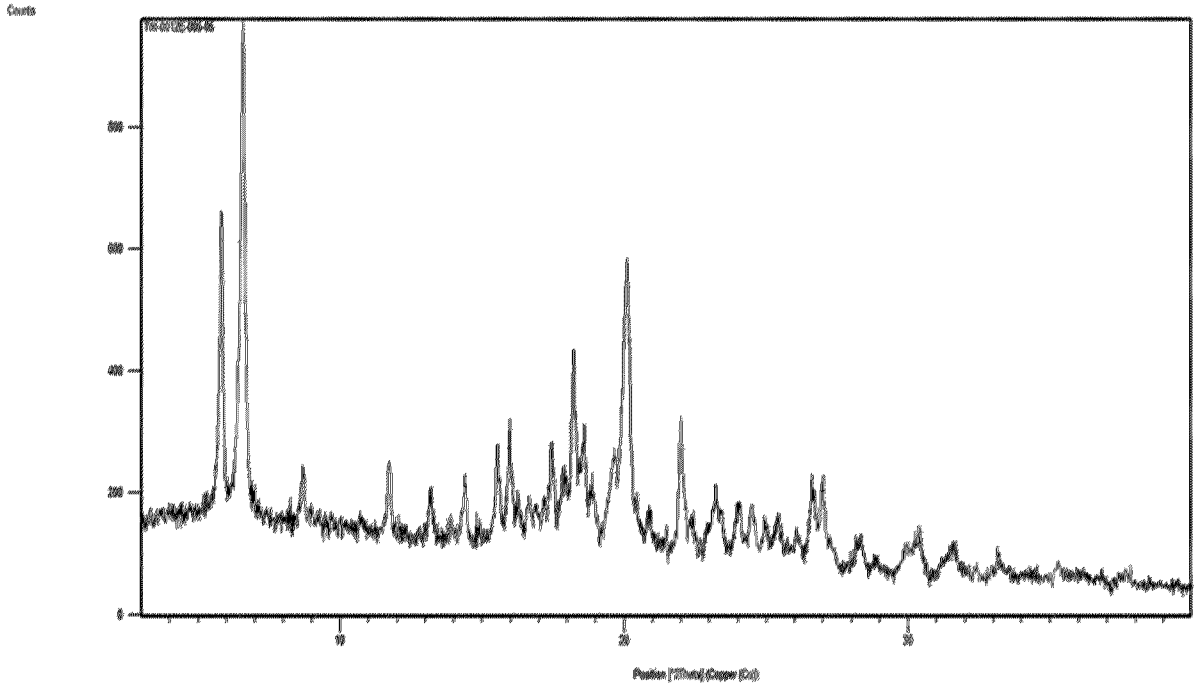
{Fig. 7}



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{Fig. 8}

Appendix Table A: Classifications of the diseases related to CB2 receptors

Class of Disorders*	Indications
Pain	inflammatory pain, nociceptive pain, neuropathic pain, fibromyalgia, chronic pain, visceral pain, migraine, cluster headache, cancer related pain, complex regional pain syndrome, neuralgias (e.g. trigeminal neuralgia)
Neurological & Neurodegenerative	multiple sclerosis, Alzheimer's disease, Parkinson's disease, amyotrophic lateral sclerosis, epilepsy, diabetes neuropathy, human immunodeficiency virus (HIV) polyneuropathy, psychiatric diseases, psychosis, autistic spectrum disorder
Gastrointestinal	irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, Crohn's disease, gastroesophageal reflux disease (GERD), constipation, diarrhoea, functional gastrointestinal disorder
Immune & Inflammatory	arthritis, rheumatoid arthritis, osteoarthritis, atherosclerosis, psoriatic arthritis disease, spondylitides, asthma, allergy, psoriasis, dermatitis, seasonal allergic rhinitis, systemic lupus erythematosus (SLE), acute allograft rejection, gingivitis, encephalitis
Oncology	cutaneous T cell lymphoma, pancreatic cancer
Fibrotic	systemic fibrosis, systemic sclerosis (SSc), vasculitis, liver fibrosis, lung fibrosis, kidney fibrosis, keloids, hypertrophic scars
Lung	acute respiratory distress syndrome (ARDS), reversible airway obstruction, adult respiratory disease syndrome, chronic obstructive pulmonary disease (COPD), cryptogenic fibrosing alveolitis, bronchitis
Eye	glaucoma, age-related macular degeneration (AMD), geographic atrophy, diabetic retinopathy, uveitis, retinal vein occlusion, retinopathy of prematurity, ocular ischemic syndrome
Kidney	glomerulonephritis, renal ischemia, nephritis, diabetic nephropathy, chronic allograft nephropathy,
Liver	hepatitis, acute liver failure, liver cirrhosis, non-alcoholic steatohepatitis (NASH)
Cardiocirculatory	myocardial infarction, cerebral ischemia, ischemia-reperfusion injury, heart failure, stroke, myocardial ischemia, cardiomyopathy, transient ischemic attack
Metabolic	diabetes, osteoporosis, regulation of bone mass, non-alcoholic fatty liver (NAFL)
Psychiatric	attention-deficit hyperactivity disorder (ADHD), anxiety, autistic spectrum disorder, depression, insomnia/sleep disorders, obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD), Tourette's syndrome
Others	malaria, pyrexia

* *Some disorders, despite being localised in certain organs/tissues, may have complex aetiology and potentially classified in different groups.*

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