CO-CRYSTALS AND PHARMACEUTICAL COMPOSITIONS COMPRISING THE SAME

CROSS-REFERENCE

[001] This application claims priority to U.S. Application No. 60/903,587, filed on February 27, 2007, the content of which is incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

[002] Infection by hepatitis C virus ("HCV") is a compelling human medical problem. HCV is recognized as the causative agent for most cases of non-A, non-B hepatitis, with an estimated human prevalence of 3% globally [A. Alberti et al., "Natural History of Hepatitis C," *J. Hepatology*, 31 (Suppl. 1), pp. 17-24 (1999)]. Nearly four million individuals may be infected in the United States alone [M.J. Alter et al., "The Epidemiology of Viral Hepatitis in the United States, *Gastroenterol. Clin. North Am.*, 23, pp. 437-455 (1994); M. J. Alter "Hepatitis C Virus Infection in the United States," *J. Hepatology*, 31 (Suppl. 1), pp. 88-91 (1999)].

[003] Upon first exposure to HCV, only about 20% of infected individuals develop acute clinical hepatitis while others appear to resolve the infection spontaneously. In almost 70% of instances, however, the virus establishes a chronic infection that persists for decades [S. Iwarson, "The Natural Course of Chronic Hepatitis," *FEMS Microbiology Reviews*, 14, pp. 201-204 (1994); D. Lavanchy, "Global Surveillance and Control of Hepatitis C," *J. Viral Hepatitis*, 6, pp. 35-47 (1999)]. This usually results in recurrent and progressively worsening liver inflammation, which often leads to more severe disease states such as cirrhosis and hepatocellular carcinoma [M.C. Kew, "Hepatitis C and Hepatocellular Carcinoma", *FEMS Microbiology Reviews*, 14, pp. 211-220 (1994); I. Saito et al., "Hepatitis C Virus Infection is Associated with the Development of Hepatocellular Carcinoma," *Proc. Natl. Acad. Sci. USA*, 87, pp. 6547-6549 (1990)]. Unfortunately, there are no broadly effective treatments for the debilitating progression of chronic HCV.

[004] The HCV genome encodes a polyprotein of 3010-3033 amino acids [Q.L. Choo, et al., "Genetic Organization and Diversity of the Hepatitis C Virus," *Proc. Natl. Acad. Sci. USA*, 88, pp. 2451-2455 (1991); N. Kato et al., "Molecular Cloning of the Human Hepatitis C Virus Genome From Japanese Patients with Non-A, Non-B Hepatitis," *Proc. Natl. Acad. Sci. USA*, 87, pp. 9524-9528 (1990); A. Takamizawa et al., "Structure and Organization of the Hepatitis C Virus Genome Isolated From Human Carriers," *J. Virol.*, 65, pp. 1105-1113 (1991)]. The HCV nonstructural (NS) proteins are presumed to provide the essential catalytic

machinery for viral replication. The NS proteins are derived by proteolytic cleavage of the polyprotein [R. Bartenschlager et al., "Nonstructural Protein 3 of the Hepatitis C Virus Encodes a Serine-Type Proteinase Required for Cleavage at the NS3/4 and NS4/5 Junctions," *J. Virol.*, 67, pp. 3835-3844 (1993); A. Grakoui et al., "Characterization of the Hepatitis C Virus-Encoded Serine Proteinase: Determination of Proteinase-Dependent Polyprotein Cleavage Sites," *J. Virol.*, 67, pp. 2832-2843 (1993); A. Grakoui et al., "Expression and Identification of Hepatitis C Virus Polyprotein Cleavage Products," *J. Virol.*, 67, pp. 1385-1395 (1993); L. Tomei et al., "NS3 is a serine protease required for processing of hepatitis C virus polyprotein", *J. Virol.*, 67, pp. 4017-4026 (1993)].

[005] The HCV NS protein 3 (NS3) is essential for viral replication and infectivity [Kolykhalov, *J. Virology*, Volume 74, pp. 2046 -2051 2000 "Mutations at the HCV NS3 Serine Protease Catalytic Triad abolish infectivity of HCV RNA in Chimpanzees]. It is known that mutations in the yellow fever virus NS3 protease decrease viral infectivity [Chambers, T.J. et al., "Evidence that the N-terminal Domain of Nonstructural Protein NS3 From Yellow Fever Virus is a Serine Protease Responsible for Site-Specific Cleavages in the Viral Polyprotein", *Proc. Natl. Acad. Sci. USA*, 87, pp. 8898-8902 (1990)]. The first 181 amino acids of NS3 (residues 1027-1207 of the viral polyprotein) have been shown to contain the serine protease domain of NS3 that processes all four downstream sites of the HCV polyprotein [C. Lin et al., "Hepatitis C Virus NS3 Serine Proteinase: Trans-Cleavage Requirements and Processing Kinetics", *J. Virol.*, 68, pp. 8147-8157 (1994)].

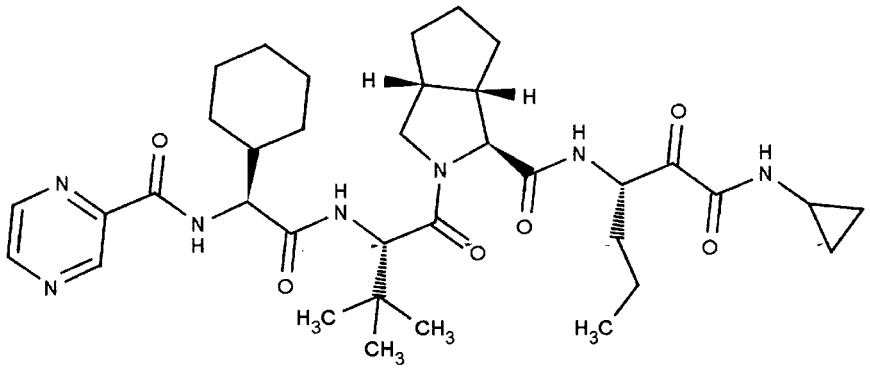
[006] The HCV NS3 serine protease and its associated cofactor, NS4A, help process all of the viral enzymes, and is thus considered essential for viral replication. This processing appears to be analogous to that carried out by the human immunodeficiency virus aspartyl protease, which is also involved in viral enzyme processing. HIV protease inhibitors, which inhibit viral protein processing, are potent antiviral agents in man indicating that interrupting this stage of the viral life cycle results in therapeutically active agents. Consequently, HCV NS3 serine protease is also an attractive target for drug discovery.

[007] Until recently, the only established therapy for HCV disease was interferon treatment. However, interferons have significant side effects [M. A. Wlaker et al., "Hepatitis C Virus: An Overview of Current Approaches and Progress," *DDT*, 4, pp. 518-29 (1999); D. Moradpour et al., "Current and Evolving Therapies for Hepatitis C," *Eur. J. Gastroenterol. Hepatol.*, 11, pp. 1199-1202 (1999); H. L. A. Janssen et al. "Suicide Associated with Alfa-Interferon Therapy for Chronic Viral Hepatitis," *J. Hepatol.*, 21, pp. 241-243 (1994); P.F.

Renault et al., "Side Effects of Alpha Interferon," *Seminars in Liver Disease*, 9, pp. 273-277 (1989)] and induce long term remission in only a fraction (~ 25%) of cases [O. Weiland, "Interferon Therapy in Chronic Hepatitis C Virus Infection", *FEMS Microbiol. Rev.*, 14, pp. 279-288 (1994)]. Recent introductions of the pegylated forms of interferon (PEG-INTRON® and PEGASYS®) and the combination therapy of ribavirin and interferon (REBETROL®) have resulted in only modest improvements in remission rates and only partial reductions in side effects. Moreover, the prospects for effective anti-HCV vaccines remain uncertain.

[008] Thus, there is a need for more effective anti-HCV therapies. Such inhibitors would have therapeutic potential as protease inhibitors, particularly as serine protease inhibitors, and more particularly as HCV NS3 protease inhibitors. Specifically, such compounds may be useful as antiviral agents, particularly as anti-HCV agents.

[009] VX-950, an HCV inhibitor with its structure shown below is such a compound in need. VX-950 is described in PCT Publication Number WO 02/18369, which is incorporated herein by reference in its entirety.



SUMMARY OF THE INVENTION

[0010] In general, the present invention relates to compositions containing the HCV inhibitor VX-950 and a specific co-crystal former. A co-crystal former is a pharmacologically inert excipient that alters the crystal form of a solid drug through the formation of co-crystals, clathrates, or other crystalline solid forms. It is within the meaning of "co-former" used herein. Under certain circumstances, VX-950 and a co-crystal former together may form a crystalline composition, i.e., a co-crystal. Compared to their free forms, specific VX-950 co-crystals are advantageous as they possess improved dissolution, higher aqueous solubility, and greater solid state physical stability than amorphous VX-950 dispersions. The specific VX-950 co-crystals provide a reduced mass of the dosage form and therefore lower pill burden since the VX-950 co-crystals also exhibit higher bulk densities relative to amorphous forms. Further, VX-950 co-crystals provide manufacturing advantages relative to amorphous forms which require spray drying, melt extrusion, lyophilization, or precipitation.

[0011] In one aspect, the compositions provided by this invention each contain VX-950 and as a co-crystal former compound. In one embodiment, VX-950 and the co-crystal former (i.e., 4-hydroxybenzoic acid) together are in the crystalline form in the composition (i.e., forming a co-crystal). In some embodiments, the molar ratio of VX-950 and 4-hydroxybenzoic acid is in the range of about 5:1 to about 1:5 (e.g., about 1:1). In some embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 17.61, 18.07, 18.87, 19.68, and 20.75, each with a standard deviation of about +/- 0.3° 2-Theta. In some embodiments, the co-crystal has a peak in its DSC thermogram at about 191.19 °C, with a standard deviation of about +/- 5 °C. In other embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 17.6, 18.0, 18.9, 19.7, and 20.8, each with a standard deviation of about +/- 0.3° 2-Theta. In still other embodiments, the co-crystal has a peak in its DSC thermogram at about 191 °C, with a standard deviation of about +/- 5 °C.

[0012] In another aspect, the invention provides composition containing VX-950; a co-crystal former selected from the group consisting of 4-amino salicylic acid and 4-hydroxybenzoic acid; and a solvent selected from the group consisting of acetonitrile, ethyl acetate, ethanol, acetone, dichloromethane, and methyl tert-butyl ether. In some embodiments, VX-950, the co-crystal former, and the solvent together may take the crystalline form (i.e., forming a co-crystal). Due to the presence of the solvent, the co-crystal may be a solvate. In some other embodiments, the solvent is acetonitrile. In some other embodiments, the co-crystal former is

4-amino salicylic acid. In some embodiments, the molar ratio of VX-950 and 4-amino salicylic acid is in the range of about 5:1 to about 1:5 (e.g., about 1:1). In some embodiments, the molar ratio of VX-950 and acetonitrile is in the range of about 1:0.05 to about 1:1 (e.g., about 1:0.34). In some embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 7.711, 8.631, 9.723, and 9.959 °2-Theta, each with a standard deviation of about +/- 0.3° 2-Theta. In some embodiments, the co-crystal has a DSC peak in its DSC thermogram at about 184.71 °C with a standard deviation of about +/- 5 °C. In other embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 7.7, 8.6, 9.7, and 10.0 °2-Theta, each with a standard deviation of about +/- 0.3° 2-Theta. In still other embodiments, the co-crystal has a DSC peak in its DSC thermogram at about 185 °C with a standard deviation of about +/-5 °C.

[0013] In still some further embodiments, the co-crystal former is 4-hydroxybenzoic acid. In some further embodiments, the molar ratio of VX-950 and 4-hydroxybenzoic acid is in the range of about 5:1 to about 1:5 (e.g., about 1:1). In some further embodiments, the solvent is acetonitrile. And still in some further embodiments, the molar ratio of VX-950 and acetonitrile is about 1:0.05 to about 1:0.5 (e.g., about 1:0.14). In some further embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 7.684, 8.599, 9.605, 9.938 °2-Theta, each with a standard deviation of about +/- 0.3 °2-Theta. In some embodiments, the co-crystal has a DSC peak in its DSC thermogram at about 190.78 °C with a standard deviation of about +/- 5 °C. In some further embodiments, the co-crystal has at least two of the four X-ray powder diffraction peaks at about 7.7, 8.6, 9.6, 9.9 °2-Theta, each with a standard deviation of about +/- 0.3 °2-Theta. In some embodiments, the co-crystal has a DSC peak in its DSC thermogram at about 191 °C with a standard deviation of about +/- 5 °C.

[0014] In another aspect, the invention provides composition containing VX-950 and a co-crystal former selected from the group consisting of phenyl alanine, threonine, tartaric acid, and adipic acid. In some embodiments, VX-950 and the co-crystal former together take the crystalline form (i.e., forming a co-crystal). In some embodiments, the molar ratio of VX-950 and the co-crystal former is in the range of about 5:1 to about 1:5 (e.g., about 1:1).

[0015] In another aspect, the invention provides composition containing VX-950 and a co-former selected from the group consisting of succinic acetate and proline. In some embodiments, VX-950 and the co-former together form a co-form (e.g., by taking the crystalline form and thus forming a co-crystal). As used herein, the term "co-form" refers to

a crystalline single phase substance containing an active pharmaceutical ingredient and one or more inactive ingredients (such as the "co-former" used herein) in a fixed stoichiometric proportion. The term "co-form" encompass "co-crystal" as used herein. In some embodiments, the molar ratio of VX-950 and the co-former is in the range of about 5:1 to about 1:5 (e.g., about 1:1).

[0016] In another aspect, the invention provides composition containing VX-950 and a co-former selected from the group consisting of methyl 4-hydroxybenzoate, anthranilic acid, d-Biotin, and tartaric acid. In some embodiments, VX-950 and the co-former together form a co-form (e.g., by taking the crystalline form and thus forming a co-crystal). In some embodiments, the molar ratio of VX-950 and the co-former is in the range of about 5:1 to about 1:40.

[0017] These compositions may have applications, among others, in treating diseases implicated by or associated with HCV. As such, also within the scope of the invention are pharmaceutical compositions each containing VX-950 and a co-crystal former identified above, in an appropriate molar ratio. The pharmaceutical composition may optionally contain a solvent (e.g., acetonitrile, ethyl acetate, ethanol, or acetone) for forming a solvate. Additionally, the pharmaceutical compositions may further contain a diluent, solvent, excipient, carrier, or solubilizing agent.

[0018] Still also within the scope of this invention is a method for making a co-crystal described above. The method may include the steps of **(a)** providing VX-950, **(b)** providing a co-crystal former selected from the group consisting of 4-hydroxybenzoic acid, 4-amino salicylic acid (optionally in a solvent, e.g., acetonitrile for forming a solvate), phenylanaline, threonine, tartaric acid, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, and d-Biotin, **(c)** grinding, heating, co-subliming, co-melting, or contacting in solution VX-950 with the co-crystal former under crystallization condition so as to form the co-crystal in solid phase, and **(d)** optionally isolating the co-crystal formed by step (c).

[0019] Still within the scope of this invention is a method for modulating a chemical or physical of interest of a co-crystal described above. The method may include the steps of **(a)** measuring the chemical or physical property of interest for VX-950 and a co-crystal former selected from the group consisting of 4-hydroxybenzoic acid, 4-amino salicylic acid, phenylalanine, threonline, tartaric acid, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, and d-Biotin, **(b)** determining the mole fraction of the VX-950 and the co-crystal former that will result in the desired modulation of the chemical or

physical property of interest, and **(c)** preparing the co-crystal with the molar fraction determined in step **(b)**.

[0020] The compositions and co-crystals of this invention can be used for treating diseases implicated by or associated with HCV. Thus, also within the scope of this invention is a method of treating such diseases, which comprising administering to a subject in need thereof a therapeutically effective amount of a co-crystal of this invention or a composition of this invention.

[0021] The compositions and co-crystals of this invention can also be used as seeds to prepare additional co-crystals containing an active ingredient that can be the same as or different from VX-950, and a co-crystal former that can also be the same as or different from the group consisting of 4-hydroxybenzoic acid, 4-amino salicylic acid, phenylalanine, threonline, tartaric acid, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, and d-Biotin. For instance, a small amount of a co-crystal of this invention can be placed into a solution containing the desired active ingredient and the co-crystal former and the mixture is allowed to sit so that an additional co-crystal can be formed with and grown out of the existing co-crystal.

[0022] Additionally, the compositions and co-crystals of this invention can be used as research tools. For instance, they can be used to study the pharmacological properties (such as bioavailability, metabolism, and efficacy) of VX-950 in different form and under condition, or to develop various VX-950 formulations for best delivery and absorption.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 shows a representative HPLC chromatograph used to determine the progress of forming the co-crystal of VX-950 and 4-hydroxybenzoic acic.

[0024] FIG. 2 shows a ^{1}H-NMR spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0025] FIG. 3 shows XRPD of the co-crystal of VX-950 and 4-aminosalicylic acid as an acetonitrile solvate.

[0026] FIG. 4 shows a DSC spectrum of the co-crystal of VX-950 and 4-amino salicylic acid as an acetonitrile solvate.

[0027] FIG. 5 shows a TGA spectrum of the co-crystal of VX-950 and 4-amino salicylic acid as an acetonitrile solvate.

[0028] FIG. 6 shows a TGA spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0029] FIG. 7 shows a DSC spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0030] FIG. 8 shows an XRD pattern of the co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0031] FIG. 9 shows an XRD pattern of the co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate.

[0032] FIG. 10 shows a DSC spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate.

[0033] FIG. 11 shows a TGA spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate.

[0034] FIG. 12 shows an FTIR spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid.

DETAILED DESCRIPTION OF THE INVENTION

[0035] Methods for preparing and characterizing a co-crystal are well documented in the literature. See, e.g., Trask et al., *Chem. Commun.*, 2004, 890-891; and O. Almarsson and M.J. Zaworotko, *Chem. Commun.*, 2004, 1889-1896. These methods in general are also suitable for preparing and characterizing co-crystals of this invention.

[0036] Additionally, the following specific methods can be used to identify co-crystal formers suitable for making co-crystals, particularly the co-crystals of this invention.

[0037] Initial identification of or screening for a possible co-crystal former for VX-950 can be conducted on a scale of a few milligrams in a 96-well plate. Visual comparison of the XRPD results to the known crystalline VX-950 diffraction pattern can be used as a screen for new crystal forms and/or altered crystal lattice dimensions that could indicate incorporation of a co-crystal former into a crystal. Oxalic acid, 4-amino salicylic acid, and salicylic acid, etc. have been identified by this initial screening as possible candidates for forming co-crystals with VX-950.

[0038] The results of the initial screening can be used for modeling work to identify additional co-crystal formers for VX-950. For instance, due to better physical and chemical properties, 4-amino salicylic acid can be used as a lead molecule in identifying other possible

co-crystal formers for VX-950 via molecular modeling. Specifically, a model of 4-ASA can be built using the Quanta software package (Accelrys Inc., San Diego, CA) and be complexed with the structure of a single molecule of VX-950 obtained by single crystal x-ray diffraction. The 4-ASA molecule can be placed manually at different positions around VX-950 to form the maximum number of hydrogen bonds between the two molecules. The positional coordinates of the 4-ASA molecule are energy-minimized while the VX-950 molecule is held fixed. An adopted-basis Newton-Raphson method available in Quanta can be used for energy minimization using default settings and a distance-dependent dielectric. AutoNom software (MDL Information Systems, GmbH) can be used to convert the names of chemical compounds in the FDA's EAFUS (Everything Added to Food, US) and GRAS (Generally Regarded As Safe) lists into 2D structures in SMILES format to produce a database of structures. The database can then be searched for new co-crystal formers that fit the pharmacophore identified with 4-ASA. Acceptable pharmacophores have local energy minima similar to that of VX-950 and 4-ASA.

[0039] DSC can also be used for screening co-crystal formers. In screening by DSC, physical mixtures of co-crystal formers with VX-950 that showed evidence of solid-phase interactions during DSC (i.e., the formation of eutectic melts) are probably more likely to form co-crystals. To detect an interaction between VX-950 and the co-crystal former, the components can be blended in a 1:1 molar ratio and subjected to a DSC temperature ramp method from the room temperature to, e.g., 300 °C in 10 °C increments. Blends showing a new thermal-event (i.e., an endotherm) that differs in temperature from endotherms of the pure components are selected. When the new thermal transition is observed in addition to that of the one of original components, the molar ratio between VX-950 and the co-crystal former can then be adjusted in an attempt to yield the new thermal transition only. The observed transition temperatures can be plotted as a function of composition to produce phase diagrams for the binary mixtures. Combinations of VX-950 and co-crystal former that produce new thermal transitions on DSC can then be scaled up to produce larger quantities (e.g., grams) as described above.

[0040] Mixtures of VX-950 and co-crystal formers with new thermal transitions can be produced in large quantity (i.e., scaled-up), e.g., by using the ball-milling, solvent-evaporation, melting with and without solvents, slurry conversion, blending, sublimation, or modeling. Some of these methods are described in detail below. The products thus prepared can be analyzed or characterized by such known methods as XRPD, TGA, and DSC, and their solubility and stability in an aqueous medium can also be measured by methods known

in the art.

[0041] *Ball-milling:* Equi-molar amounts of VX-950 and a co-crystal former are mixed with an appropriate solvent. The mixture is then milled using a ball-mill apparatus, e.g., Retsch MM200 (GlenMills Inc., Clifton, NJ) for 3 hours at a frequency of 15 Hz. The mixture is then placed in the milling compartment made of sintered corundum. After milling, the material is placed in a screw cap scintillation vials (uncapped) and dried under vacuum at the room temperature. XRPD and DSC analyses can be performed to characterize the resulting mixture.

[0042] *Melting in a Reaction Block:* Equi-molar amounts of VX-950 and the co-crystal former are mixed, with or without a solvent. The mixture is then placed in a reaction block, e.g., Model RR98072 by Radleys Discovery Technologies (Essex, UK) with the lid closed and heated to the temperature identified by DSC of the new thermal transition. The mixture is then held for a period of time at the transition temperature before the reaction block is opened and the resulting mixture cooled under ambient conditions.

[0043] *Solvent Evaporation*: VX-950 and a potential co-crystal former are dissolved separately into a volatile solvent (e.g., dichloromethane or methyl tert-butyl ether) or a solvent mixture (e.g., 50:50 toluene:acetonitrile). Dissolution can be aided by agitation and sonication until a clear solution is obtained. The VX-950 solution is then mixed with the co-crystal former solution in a screw cap scintillation vials at the desired molar ratio. The vials are placed uncapped under reduced pressure and solvent allowed to evaporate to dryness, typically over a period of several days. Solid (crystalline) material is obtained and analyzed.

[0044] As mentioned above, co-crystals of this invention can be analyzed by methods known in the art for characterizing solid or crystalline materials. Examples of characterization methods include thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), X-ray powder diffraction (XRPD), solubility analyses, dynamic vapor sorption, infrared off-gas analysis, and suspension stability. TGA can be used to investigate the presence of residual solvents in a co-crystal sample, and to identify the temperature at which decomposition of each co-crystal sample occurs. DSC can be used to look for thermo-transitions occurring in a co-crystal sample as a function of temperature and determine the melting point of each co-crystal sample. XRPD can be used for structural characterization of the co-crystal. Solubility analysis can be performed to reflect the changes in the physical state of each co-crystal sample. And suspension stability analysis can be used to determine the chemical stability of a co-crystal sample in a solvent. Described in great detail are some

of such methods.

[0045] *X-ray Powder Diffraction (XRPD)*: XRPD can be used to characterize the physical form of the material by recording its original pattern and monitoring changes in the pattern with time. The XRPD pattern can be obtained at the room temperature in reflection mode, e.g., by using a Bruker D8 Discover diffractometer that is equipped with a sealed tube source and a Hi-Star area detector (Bruker AXS, Madison, WI, USA). A copper target X-ray tube (Siemens) can be operated, e.g., at 40 kV and 35 mA. Graphite monochromator and 0.5 mm collimator provided by Bruker can be used to produce parallel, monochromatic beam (CuKa, $\lambda = 1.5418$ Å). The distance between the sample and the detector can be approximately 30 cm. The sample can be placed on a Si zero-background wafer (e.g., from The Gem Dugout, State College, PA) which is then positioned and centered on XYZ platform. Data can bee acquired using GADDS software for Windows NT, version 4.1.16 (Bruker AXS, Madison, WI, USA). Two frames can be registered with an exposure time of 120 seconds per frame each at 2 different 2θ angles: 8 ° and 26 °2-Theta. The sample is oscillated in both X and Y directions with an amplitude of 1 mm during the exposure. The data can then be subsequently integrated over the range of 3 ° to 41 °2-Theta with a step size of 0.02 °2-Theta and merged into one continuous pattern. Corundum plate (NIST standard 1976) can be used to calibrate the instrument.

[0046] *Differential Scanning Calorimetry (DSC)*: DSC can be used to detect thermal transitions occurring in the sample as a function of temperature and to determine the melting point of crystalline materials. It is performed, e.g., using an MDSC Q100 differential scanning calorimeter (TA Instruments, New Castle, DE) calibrated with indium. The samples can be prepared in aluminum pans crimped with a single pinhole with the sample size being, e.g., approximately 2 mg. Each run is initially equilibrated to 25 °C followed by a ramp of 10 °C/minute to 300 °C. VX-950 degrades upon melting, degradation onset is about 240 °C. The data can be collected by Thermal Advantage Q Series™ software and analyzed by Universal Analysis software (TA Instruments, New Castle, DE).

[0047] *Thermogravimetric Analysis (TGA)*: TGA can be used to investigate the presence of residual solvents in the samples, and to identify the temperature at which decomposition of the sample occurs. For instance, a Model Q500 Thermogravimetric Analyzer (TA Instruments, New Castle, DE) can be used for TGA measurement. The sample can weigh in the range of about 3-8 mg, and be heated at the rate of about 10 °C/minute to a final temperature of, e.g., 300 °C. The data can be, e.g., collected by Thermal Advantage Q

Series™ software and analyzed by Universal Analysis software (TA Instruments, New Castle, DE).

[0048] *Fourier Transform Infrared (FT-IR) Spectrometry:* FT-IR can be used to investigate hydrogen bonding in blends of VX-950 with a co-crystal former at different molar ratios. Infrared transmission spectra can be obtained, e.g., from KBr pellets with Nexus 670 spectrometer (Thermo Electron Corp.; Madison, WI) from 4000 to 625 cm^{-1}.

[0049] *Solubility Determination:* Solubility can be expressed in VX-950 equivalents. It can be measured to reflect the changes in the physical state of the material, and to monitor progress toward the goal of enhancing VX-950 solubility. Specifically, an aliquot of the material can be placed in an aqueous mediumwith a target solubility of 10 mg/ mL. At set time points, an aliquot of supernatant is withdrawn, filtered through a 0.45 micron filter (e.g., Millex; Millipore, Billerica, MA) and analyzed using HPLC (e.g., Agilent 1100; Palo Alto, CA). The samples are run isocratically with the detector, e.g., set at 270 nm and a flow rate of 1 mL/min on an XTerra® Phenyl column 150 mm x 4.6 mm, 3.5 μm particle size (P/N 186001144) (Waters Corp., Milford, MA). The mobile phase contained potassium phosphate buffer (10 mM, pH = 7.0) and methanol in a 60:40 (v/v) ratio. The concentrations of VX-950 can be determined by comparing chromatographic peak areas with a calibration curve produced using standards of known concentration.

[0050] *Hotstage Microscopy:* Microscope images can be taken, e.g., with an Olympus BX51 confocal microscope with polarized films, an SLMPlan 50x infinity corrected objective, a C-5050 digital camera, and an Instec hotstage with a variable temperature controller. The experimental procedure consists of a linear heating ramp between different temperature steps in which the samples are allowed to equilibrate for several minutes. Digital images are collected manually throughout the ramp to capture any transitions that occurred.

[0051] An effective amount of co-crystals or compositions of this invention, each including VX-950 and a co-crystal former (e.g., 4-hydroxybenzoic acid, 4-amino salicylic acid (with acetonitrile), phenyl alanine, threonine, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, d-Biotin, or tartaric acid) can be used to treat diseases implicated or associated with the HCV. An effective amount is the amount which is required to confer a therapeutic effect on the treated subject, e.g. a patient. The effective amount of a co-crystal of VX-950 and the co-crystal former is between about 0.1 mg/kg to about 150 mg/kg (e.g., from about 1 mg/kg to about 60 mg/kg). Effective doses will also vary, as recognized by those skilled in the art, dependent on route of administration, excipient usage,

and the possibility of co-usage with other therapeutic treatments including use of other therapeutic agents and/or therapy.

[0052] The co-crystals or pharmaceutical compositions of this invention can be administered to the subject in need thereof (e.g., cells, a tissue, or a patient (including an animal or a human)) by any method that permits the delivery of the compound VX-950, e.g., orally, intravenously, or parenterally. For instance, they can be administered via pills, tablets, capsules, aerosols, suppositories, liquid formulations for ingestion or injection or for use as eye or ear drops, dietary supplements, and topical preparations.

[0053] The pharmaceutical compositions can include diluents, solvents, excipients and carriers such as water, Ringer's solution, isotonic saline, 5% glucose, and isotonic sodium chloride solution. In another embodiment, the pharmaceutical composition can further include a solubilizing agent such as cyclodextrin. Additional examples of suitable diluents, solvents, excipients, carriers, and solubilizing agents can be found, e.g., in U.S. Pharmacopeia 23/National Formulary 18, Rockville, MD, U.S. Pharmacopeia Convention, Inc., (1995); Ansel HC, Popovich NG, Allen Jr LV. Pharmaceutical Dosage Forms and Drug Delivery Systems, Baltimore MD, Williams &Wilkins, (1995); Gennaro AR., Remingtons: The Science and Practice of Pharmacy, Easton PA, Mack Publishing Co., (1995); Wade A, Weller PJ. Handbook of Pharmaceutical Excipients, 2nd Ed, Washington DC, American Pharmaceutical Association, (1994); Baner GS, Rhodes CT. Modern Pharmaceutics, 3rd Ed., New York, Marcel Dekker, Inc., (1995); Ranade VV, Hollinger MA. Drug Delivery Systems. Boca Raton, CRC Press, (1996).

[0054] The pharmaceutical compositions can also include aqueous solutions of the co-crystal, in an isotonic saline, 5% glucose or other well-known pharmaceutically acceptable excipient(s). Solubilizing agents such as cyclodextrins, or other solubilizing agents well-known to those familiar with the art, can be utilized as pharmaceutical excipients for delivery of the therapeutic compound VX-950. As to route of administration, the co-crystals or pharmaceutical compositions can be administered orally, intranasally, transdermally, intradermally, vaginally, intraaurally, intraocularly, buccally, rectally, transmucosally, or via inhalation, or intravenous administration. The compositions may be delivered intravenously via a balloon catheter. The compositions can be administered to an animal (e.g., a mammal such as a human, non-human primate, horse, dog, cow, pig, sheep, goat, cat, mouse, rat, guinea pig, rabbit, hamster, gerbil, ferret, lizard, reptile, or bird).

[0055] The co-crystals or pharmaceutical compositions of this invention also can be delivered

by implantation (e.g., surgically) such with an implantable device. Examples of implantable devices include, but are not limited to, stents, delivery pumps, vascular filters, and implantable control release compositions. Any implantable device can be used to deliver the compound VX-950 as the active ingredient in the co-crystals or pharmaceutical compositions of this invention, provided that 1) the device, compound VX-950 and any pharmaceutical composition including the compound are biocompatible, and 2) that the device can deliver or release an effective amount of the compound to confer a therapeutic effect on the treated patient.

[0056] Delivery of therapeutic agents via stents, delivery pumps (e.g., mini-osmotic pumps), and other implantable devices is known in the art. See, e.g., "Recent Developments in Coated Stents" by Hofma et al., published in *Current Interventional Cardiology Reports,* 2001, **3:** 28-36, the entire contents of which, including references cited therein, are incorporated herein. Other descriptions of implantable devices, such as stents, can be found in U.S. Patent Nos. 6,569,195 and 6,322,847, and PCT International Publication Numbers WO 04/0044405, WO 04/0018228, WO 03/0229390, WO 03/0228346, WO 03/0225450, WO 03/0216699, and WO 03/0204168, each of which (as well as other publications cited herein) is incorporated herein in its entirety.

[0057] Described below are examples of preparing and characterizing co-crystals of this invention, which are meant to be only illustrative and not to be limiting in any way.

Example 1. Preparation by Ball-milling Method

[0058] VX-950 and an equal molar equivalent of a co-crystal former (e.g., 4-hydroxybenzoic acid) can be mixed with a solvent (e.g., methyl ethyl ketone or ethyl acetate). The components can then be milled using a Wig-L-Bug apparatus, e.g., Retsch MM200 (GlenMills Inc, Clifton, NJ) for 10 minutes at the frequency of 15 Hz. After milling, a batch is dried, e.g., in a vacuum oven at 75 °C for 2 hours, to give a co-crystal of the invention.

Example 2. Preparation by Melting Method

[0059] VX-950 and an equal molar equivalent of a co-crystal former (e.g., 4-hydroxybenzoic acid) can be mixed, e.g., by vortex for 5 minutes, with or without a solvent. The mixture is then placed in a reaction block (e.g., RR 98072 from Radley Discovery Technologies) with the lid closed and heated to the endotherm. The mixture is held for 30 minutes at the endotherm temperature, and then the resulting mixture was cooled off under ambient conditions with the lid off, and the solvent, when used, removed to give a co-crystal of the

invention.

Example 3. Preparation by Solvent-evaporation Method

[0060] ***4-Hydroxybenzoic Acid***: 160 mg of VX-950 and 80 mg of 4-hydroxybenzoic acid (Sigma Chemicals Co., St. Louis, MO, USA) were heated in 50 mL of ethyl acetate until both dissolved and a clear solution was obtained. The solution was filed into an open beaker and the solvent was allowed to evaporate under reduced pressure at the room temperature for about 12 hours. A crystalline material was observed in the beaker and removed therefrom to give 180 mg of a co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0061] ***4-Hydroxybenzoic Acid with Acetonitrile***: 160 mg of VX-950 and 80 mg of 4-hydroxybenzoic acid (Sigma Chemicals Co., St. Louis, MO, USA) were heated in 50 mL of acetonitrile until both dissolved and a clear solution was obtained. The solution was filed into an open beaker and the solvent was allowed to evaporate under reduced pressure at the room temperature for about 12 hours. A crystalline material was observed in the beaker and removed therefrom to give 190 mg of a co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate.

[0062] ***4-Aminosalicylic Acid with Acetonitrile***: 180 mg of VX-950 and 80 mg of 4-aminosalicilic acid (Sigma Chemicals Co., St. Louis, MO, USA) were heated in 50 mL of acetonitrile until both dissolved and a clear solution was obtained. The solution was filed into an open beaker and the solvent was allowed to evaporate under reduced pressure at the room temperature for about 12 hours. A crystalline material was observed in the beaker and removed therefrom to give 200 mg of a co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate.

Example 4. Preparation by Crystallization

[0063] The co-crystal of VX-950 and 4-hydroxybenzoic acid was also prepared by first dissolving 1 molar of VX-950 in 3 volume of dichloromethane. To the VX-950 solution was then added, while stirring, 5 volume of methyl tertiary-butyl ether (MTBE) solution containing 1.4 molar equivalents of 4-hydroxybenzoic acid. The mixture thus obtained was allowed to sit for approximately 1 to 3 hours before crystallization started to occur. The crystallization process was allowed to proceed for 5 to 6 hours and a solid material was observed. The solid material was filtered and washed with fresh mother liquid (i.e., a mixture of MTBE and dichloromethane at a 5:3 ratio by volume). The material was then dried in a vacuum oven at 15 to 75 °C for 6 hours to 3 days, with or without nitrogen sweep, to give the

co-crystal of VX-950 and 4-hydroxybenzoic acid.

[0064] Alternative, the co-crystal of VX-950 and 4-hydroxybenzoic acid was prepared under the following conditions. Under the nitrogen atmosphere, VX-950 (1.00 equivalent) was added to a first reactor, followed by the addition of dichloromethane (3 volumes) to the same reactor. The temperature of the batch for this first reactor was adjusted to 20-25 °C and VX-950 was observed dissolving in dichloromethane. 4-Hydroxybenzoic acid (1.30 equivalents) was added to the second reactor, followed by the addition of methyl tert-butyl ether (5 volumes). The temperature of the batch for this second reactor was also adjusted to 20-25 °C and 4-hydroxybenzoic acid was observed dissolved in methyl tert-butyl ether. The solution of 4-hydroxybenzoic acid in methyl tert-butyl ether was then transferred from the second reactor to the solution of VX-950 in dichloromethane in the first reactor over 90 to 120 minutes, while the batch temperature for the first reactor was maintained at 20-25 °C. The solution thus obtained was agitated at 20-25 °C, and it was sampled and analyzed with HPLC every 2 hours until the reaction for forming the co-crystal of VX-950 and 4-hydroxybenzoic acid was completed. Shown in FIG. A is a representative HPLC spectrum showing peaks for 4-hydroxybenzoic acid and VX-950 still in the solution, which were then converted to their remaining concentrations or amounts. Upon completion of reaction, the resulting slurry was filtered and the filter cake was washed with 2 volumes of a mixture of dichloromethane and methyl tert-butyl ether (at the 3:5 ratio). The washing was repeated using 2 volumes of a mixture of dichloromethane and methyl *tert*-butyl ether (at the ratio of 3:5). The co-crystal of VX-950 and 4-hydroxybenzoic acid thus obtained was dried under vacuum at 15 to 75 °C for 6 hours to 3 days, with or without nitrogen sweep.

Example 5: Single crystal diffraction

[0065] Single crystal diffraction was performed on a Bruker APEX II CCD diffractometer at 100K using Cu Kα radiation by using single crystals picked from mother liquors and mounted on glass fibers. The crystals are cooled to 100K in a nitrogen flow system and oscillation photos were taken around ω axis at 4 φ angles. The data were indexed, integrated, and scaled with the APEX software. The structures were solved and refined with the SHELX-TL package.

[0066] The co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate showed orthorhombic cell with the space group $P2_12_12_11$. The unit cell dimensions were a = 9.4143Å, b = 11.9529 Å, c = 39.474 Å, α= 90°, β= 90°, γ = 90°. The cell dimension may deviate +/- 0.1 Å. R factors R1 = 0.0273, wR2 = 0.0688. The data show that the co-crystal

contained one VX-950, one 4-hydroxybenzoic acid, and 0.143 acetonitrile in the asymmetric unit.

[0067] The co-crystal of VX-950 and 4-aminosalicylic acid as an acetonitrile showed orthorhombic cell with the space group $P2_12_12_11$. The unit cell dimensions were a = 9.3889Å, b = 12.2292Å, c = 39.7436Å, α= 90°, β= 90°, γ = 90°. The cell dimension may deviate +/- 0.1 Å. R factors R1 = 0.0574, wR2 = 0.1445. The data show that the co-crystal contained one VX-950, one 4-aminosalicylic acid, and 0.337 acetonitrile in the asymmetric unit.

Example 6. Thermogravimetric Analysis (TGA)

[0068] TGA of each sample was performed using a Model Q500 Thermogravimetric Analyzer (TA Instruments, New Castle, DE, USA), which uses its control Thermal Advantage Q Series™ software, Version 2.2.0.248, Thermal Advantage Release 4.2.1 (TA Instruments-Water LLC), with the following components: QAdv.exe version 2.2 build 248.0; RhDII.dII version 2.2 build 248.0; RhBase.dII version 2.2 build 248.0; RhComm.dII version 2.2 build 248.0; TaLicense.dII version 2.2 build 248.0; and TGA.dII version 2.2 build 248.0. In addition, the analysis software used was Universal Analysis 2000 software for Windows 2000/XP, version 4.1 D build 4.1.0.16 (TA Instruments).

[0069] For all of the experiments, the basic procedure for performing TGA included transferring an aliquot (about 3-8 mg) of a sample into a platinum sample pan (Pan: Part No. 952018.906, TA Instruments). The pan was placed on a loading platform and was then automatically loaded into the Q500 Thermogravimetric Analyzer using the control software. Thermograms were obtained by individually heating the sample at 10 °C/minute across a temperature range (generally from the room temperature to 400 °C under flowing dry nitrogen (compressed nitrogen, grade 4.8 (BOC Gases, Murray Hill, NJ, USA), with a sample purge flow rate of 90 L/minute and a balance purge flow rate of 10 L/minute. Thermal transitions (e.g. weight changes) were viewed and analyzed using the analysis software provided with the instrument.

[0070] As in FIG. 5, the TGA spectrum of the co-crystal of VX-950 and 4-aminosalicylic acid (molar ratio being 1) as an acetonitrile solvate showed approximate 10.4% weight loss up to 220 °C.

[0071] As in FIG. 6, the TGA spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ratio also being 1) showed continuous weight loss from approximately 160 °C.

[0072] As in FIG. 11, the TGA spectrum of the co-crystal of VX-950 and 4-hydroxybenzoic acid as an acetonitrile solvate showed continuous weight loss from approximately 140 °C.

Example 7. Differential Scanning Calorimetry (DSC)

[0073] DSC analysis was performed using an MDSC Q100 Differential Scanning Calorimeter (TA Instruments), which uses its control Thermal Advantage Q Series™ software, version 2.2.0.248, Thermal Advantage Release 4.2.1, with the following components: QAdv.exe version 2.2 build 248.0; RhDII.dII version 2.2 build 248.0; RhBase.dII version 2.2 build 248.0; RhComm.dII version 2.2 build 248.0; TaLicense.dII version 2.2 build 248.0; and DSC.dII version 2.2 build 248.0. In addition, the analysis software used was Universal Analysis 2000 software for Windows 2000/ XP, version 4.1 D build 4.1.0.16 (TA Instruments). The instrument was calibrated with indium.

[0074] For all DSC analysis, an aliquot of a sample (approximately 2 mg) was weighed into an aluminum sample pan (Pan: Part No. 900786.901; and Lid: Part No. 900779.901, TA Instruments). The sample pan was closed by crimping with a single pinhole, allowed to equilibrate at 30 °C, and then loaded into the Q100 Differential Scanning Calorimeter which was equipped with an autosampler. A thermogram was obtained by individually heating each sample at a rate at 50 °C/minute across a temperature range (generally from the room temperature to 400 °C) under flowing dry nitrogen (compressed nitrogen, grade 4.8 (BOC Gases, Murray Hill, NJ, USA), with a sample purge flow rate of 60 L/minute and a balance purge flow rate of 40 L/minute. An empty aluminum pan prepared the same way as the pan with the sample was used a reference. Thermal transitions were viewed and analyzed using the analysis software provided with the instrument.

[0075] As in FIG. 4, the DSC thermogram shows the co-crystal of VX-950 and 4-aminosalicylic acid (molar ratio being 1:1) as an acetonitrile solvate melt at approximately 184.71 °C.

[0076] As in FIG. 7, the DSC thermogram shows the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ratio being 1:1) melt at approximately 191.19 °C.

[0077] As in FIG. 10, the DSC thermogram shows the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ratio being 1:1) as an acetonitrile solvate melt at about 190.78 °C

Example 8. X-ray Powder Diffraction (XRPD)

[0078] The XRPD pattern was obtained at the room temperature in reflection mode by using a Bruker D8 Discover diffractometer that was equipped with a sealed tube source and a Hi-

Star area detector (Bruker AXS, Madison, WI, USA). A copper target X-ray tube (Siemens) was operated at 40 kV and 35 mA. Graphite monochromator and 0.5 mm collimator provided by Bruker were used to produce parallel, monochromatic beam (CuKa, λ = 1.5418 Å). The distance between the sample and the detector was approximately 30 cm. The sample was placed on a Si zero-background wafer (The Gem Dugout, State College, PA) which was then positioned and centered on XYZ platform. Data were acquired using GADDS software for Windows NT, version 4.1.16 (Bruker AXS, Madison, WI, USA). Two frames were registered with an exposure time of 120 seconds per frame each at 2 different 2θ angles: 8° and 26°. . The sample was oscillated in both X and Y directions with an amplitude of 1 mm during the exposure. The data were subsequently integrated over the range of 3° to 41° 2-Theta with a step size of 0.02° and merged into one continuous pattern. Corundum plate (NIST standard 1976) was used to calibrate the instrument.

[0079] As shown in FIG. 3, the XRPD pattern of the co-crystal of VX-950 and 4-aminosalicylic acid (molar ratio being 1:1) as an acetonitrile solvate showed peaks at about 7.711, 8.631, 8.949, 9.723, 9.959, 11.564, 11.968, 12.984, 13.354, 13.717, 14.615, 14.910, 16.342, 17.235, 17.584, 18.004, 19.040, 19.274, 19.631, 20.173, 20.715, 21.406, 22.013, 23.018, 24.245, 24.855, 26.552, 28.445, 30.020, 32.768, and 34.392 °2-Theta.

[0080] As shown in FIG. 8, the XRPD pattern of the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ratio being 1:1) showed peaks at about 17.33, 17.61, 18.07, 18.87, 19.34, 19.68, 20.75, and 26.76 °2-Theta, with relative intensity of 0.74, 0.93, 1.00, 0.96, 0.67, 0.77, 0.79, and 0.65, respectively.

[0081] As shown in FIG. 9, the XRPD pattern of the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ratio being 1:1) as an acetonitrile solvate showed peaks at about 7.684, 8.599, 9.605, 9.938, 11.502, 11.895, 12.892, 13.317, 14.864, 16.282, 17.199, 17.581, 18.051, 18.868, 19.252, 19.616, 20.074, 20.712, 21.435, 23.090, 24.417, 26.752, and 28.643 °2-Theta.

Example 9. Solubility Analyses

[0082] An aliquot of a co-crystal of this invention was placed in a tube and then an aqueous medium is added. At set time points, an aliquot of supernatant was withdrawn, filtered through 0.45 PTFE micron filter (Millex, LCR, Millipore) and processed for high performance liquid chromatography (HPLC) analysis (Agilent 1100; Palo Alto, CA, USA). The system is equipped with an autosampler set at 25 °C. For the sample handling, an aliquot of the co-crystal can be diluted with acetonitrile at 1 to 1 by v/v ratio. The samples can be

run isocratically with the detector set at 270 nm with a column being XTerra® Phenyl column 150 mm x 4.6 mm, 3.5 μm Particle Size (P/N 186001144) (Waters, Milford, MA, USA). The mobile phase can be potassium phosphate buffer (10 mM, pH = 7.0):methanol at 60:40 (v/v) ratio. The run can be done at the flow-rate of 1 mL/minute and completed within 15 minutes.

[0083] The water solubility data were determined at ambient conditions by equilibrating the co-crystal with water on a shaking bed for 24 hours followed by centrifugation and separation of the saturated solution. The solubility in simulated gastric and intestinal fluids (both fed and fasted) was determined at room temperature by adding the co-crystal to the simulated fluid under continuous stirring for 24 hours. At selected time points, samples were filtered and the filtrate was assayed by HPLC.

[0084] The solubility of the co-crystal of VX-950 and 4-hydroxybenzoic acid (molar ration being 1:1) is as follows: 0.0148 mg/mL in water, 0.109 mg/ml in simulated gastric fluid (Fed), 0.145 mg/mL in simulated gastric fluid (Fasted), 0.0227 mg/mL in simulated intestinal fluid (Fed), and 0.133 mg/mL in simulated intestinal fluid (Fasted).

Example 10. Suspension Stability

[0085] The physical stability of a co-crystal of this invention upon suspension in aqueous media can also evaluated. Specifically, the co-crystal powder can be slurried, e.g., in (1) unbuffered, deionized water and (2) a 1% (w/w) solution of HPMC (low viscosity grade) at 25 °C at a nominal concentration of approximately 6 mg/mL. Slurries can then then mixed using a magnetic stir bar and plate. The samples of the solid can be isolated by filtration, e.g., at time intervals of 1, 2, 6 and 24 hours.

OTHER EMBODIMENTS

[0086] It is to be understood that while the invention has been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A co-crystal comprising VX-950 and 4-hydroxybenzoic acid.
2. The co-crystal of claim 1, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is in the range of about 5:1 to about 1:5.
3. The co-crystal of claim 2, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is about 1:1.
4. The co-crystal of claim 3, having at least two of the four X-ray powder diffraction peaks at about 17.61, 18.07, 18.87, 19.68, and 20.75 °2-Theta, each with a standard deviation of about +/- 0.3 °2-Theta.
5. The co-crystal of claim 3, having a peak in its DSC thermogram at about 191.19 °C with a standard deviation of about +/- 5 °C.
6. A co-crystal comprising VX-950; a co-crystal former selected from the group consisting of 4-amino salicylic acid and 4-hydroxybenzoic acid; and a solvent selected from the group consisting of acetonitrile, ethyl acetate, ethanol, and acetone.
7. The co-crystal of claim 6, wherein the solvent is acetonitrile.
8. The co-crystal of claim 7, wherein the co-crystal former is 4-amino salicylic acid.
9. The co-crystal of claim 8, wherein the molar ratio of VX-950 and 4-amino salicylic acid is in the range of about 5:1 to about 1:5.
10. The co-crystal of claim 9, wherein the molar ratio of VX-950 and 4-amino salicylic acid is about 1:1.
11. The co-crystal of claim 10, wherein the molar ratio of VX-950 and acetonitrile is in the range of about 1:0.05 to about 1:1.
12. The co-crystal of claim 11, wherein the molar ratio of VX-950 and acetonitrile is about 1:0.34.
13. The co-crystal of claim 12, having at least two of the four X-ray powder diffraction peaks at about 7.711, 8.631, 9.723, and 9.959 °2-Theta, each with a standard deviation of about +/- 0.3 °2-Theta.
14. The co-crystal of claim 12, having a DSC peak in its DSC thermogram at about 184.71 °C with a standard deviation of about +/-5 °C.
15. The co-crystal of claim 7, wherein the co-crystal former is 4-hydroxybenzoic acid.

16. The co-crystal of claim 15, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is in the range of about 5:1 to about 1:5.

17. The co-crystal of claim 16, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is about 1:1.

18. The co-crystal of claim 17, wherein the solvent is acetonitrile.

19. The co-crystal of claim 18, wherein the molar ratio of VX-950 and acetonitrile is about 1:0.05 to about 1:0.5.

20. The co-crystal of claim 19, wherein the molar ratio of VX-950 and acetonitrile is about 1:0.14.

21. The co-crystal of claim 20, having at least two of the four X-ray powder diffraction peaks at about 7.684, 8.599, 9.605, 9.938 °2-Theta, each with a standard deviation of about +/- 0.3 °2-Theta.

22. The co-crystal of claim 20, having a DSC peak in its DSC thermogram at about 190.78 °C with a standard deviation of about +/- 5 °C.

23. A co-crystal comprising VX-950 and a co-crystal former selected from the group consisting of phenyl alanine, threonine, tartaric acid, and adipic acid.

24. The co-crystal of claim 23, wherein the molar ratio of VX-950 and the co-crystal former is in the range of about 5:1 to about 1:5.

25. The co-crystal of claim 24, wherein the molar ratio of VX-950 and the co-crystal former is about 1:1.

26. A co-form comprising VX-950 and a co-former selected from the group consisting of succinic acetate and proline.

27. The co-form of claim 26, wherein the molar ratio of VX-950 and the co-former is in the range of about 5:1 to about 1:5.

28. The co-form of claim 27, wherein the molar ratio of VX-950 and the co-former is about 1:1.

29. A co-form comprising VX-950 and a co-former selected from the group consisting of methyl 4-hydroxybenzoate, anthranilic acid, d-Biotin, and tartaric acid.

30. The co-form of claim 29, wherein the molar ratio of VX-950 and the co-former is in the range of about 5:1 to about 1:40.

31. A pharmaceutical composition comprising VX-950 and 4-hydroxybenzoic acid.

32. The pharmaceutical composition of claim 31, wherein VX-950 and 4-hydroxybenzoic acid together are in the crystalline form.

33. The pharmaceutical composition of claim 32, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is in the range of about 5:1 to about 1:5.

34. The pharmaceutical composition of claim 33, wherein the molar ratio of VX-950 and 4-hydroxybenzoic acid is about 1:1.

35. The pharmaceutical composition of claim 31, further comprising a diluent, solvent, excipient, carrier, or solubilizing agent.

36. A pharmaceutical composition comprising VX-950, a co-crystal former selected from the group consisting of 4-amino salicylic acid and 4-hydroxybenzoic acid; and a solvent selected from the group consisting of acetonitrile, ethyl acetate, ethanol, acetone, dichloromethane, and methyl *tert*-butyl ether.

37. The pharmaceutical composition of claim 36, wherein VX-950, the co-crystal former, and the solvent together are in the crystalline form.

38. The pharmaceutical composition of claim 37, wherein the solvent is acetonitrile.

39. The pharmaceutical composition of claim 38, wherein the molar ratio of VX-950 and the co-crystal former is in the range of about 5:1 to about 1:5.

40. The pharmaceutical composition of claim 39, wherein the molar ratio of VX-950 and the co-crystal former is about 1:1.

41. The pharmaceutical composition of claim 40, wherein the molar ratio of VX-950 and acetonitrile is in the range of about 1:0.01 to about 1:1.

42. The pharmaceutical composition of claim 41, wherein the co-crystal former is 4-hydroxybenzoic acid, and the molar ratio of VX-950 and acetonitrile is about 1:0.14.

43. The pharmaceutical composition of claim 41, wherein the co-crystal former is 4-amino salicylic acid, and the molar ratio of VX-950 and acetonitrile is about 1:0.34.

44. The pharmaceutical composition of claim 36, further comprising a second solvent, a diluent, an excipient, a carrier, or a solubilizing agent.

45. A pharmaceutical composition comprising VX-950 and a co-crystal former selected from the group consisting of phenylanaline, threonine, tartaric acid, and adipic acid.

46. The pharmaceutical composition of claim 45, further comprising a solvent, diluent, excipient, carrier, or solubilizing agent.

47. A pharmaceutical composition comprising VX-950 and a co-crystal former selected from the group consisting of succinic acetate and proline.

48. The pharmaceutical composition of claim 47, further comprising a solvent, diluent, excipient, carrier, or solubilizing agent.

49. A pharmaceutical composition comprising VX-950 and a co-crystal former selected from the group consisting of methyl 4-hydroxybenzoate, anthrnilic acid, d-Biotin, and tartaric acid.

50. The pharmaceutical composition of claim 49, further comprising a solvent, diluent, excipient, carrier, or solubilizing agent.

51. A method of making a co-crystal of any of claims 1-30, comprising:
    a. providing VX-950,
    b. providing a co-crystal former selected from the group consisting of 4-hydroxybenzoic acid, 4-amino salicylic acid, phenylanaline, threonine, tartaric acid, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, and d-Biotin,
    c. grinding, heating, co-subliming, co-melting, or contacting in solution VX-950 with the co-crystal former under crystallization condition so as to form the co-crystal in solid phase, and
    d. optionally isolating the co-crystal formed by step (c).

52. A method for modulating a chemical or physical of interest of a co-crystal of any of claims 1-30, comprising:
    a. measuring the chemical or physical property of interest for VX-950 and a co-crystal former selected from the group consisting of 4-hydroxybenzoic acid, 4-amino salicylic acid, phenylalanine, threonline, tartaric acid, adipic acid, succinic acetate, proline, methyl 4-hydroxybenzoate, anthranilic acid, and d-Biotin.
    b. determining the mole fraction of the VX-950 and the co-crystal former that will result in the desired modulation of the chemical or physical property of interest, and
    c. preparing the co-crystal with the molar fraction determined in step (b).