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(54) **ANTI-INFLUENZA COMPOUNDS**

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(57) **ABSTRACT**

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The present invention provides pyrimidinyl compounds of formula (I) and pharmaceutically acceptable salts thereof. These compounds may be used for the inhibition of influenza. In particular, the compounds of the invention may be used for the treatment or prophylaxis of influenza A, most particularly H1N1 or H5N1 influenza. The compounds of the invention can also be used for the treatment or prophylaxis of a disease caused by *Vibrio cholerae*, *Clostridium perfringens*, *Streptococcus pneumoniae*, *Arthrobacter sialophilus*, an orthomyxovirus, a paramyxovirus, a parainfluenza virus, mumps virus, Newcastle disease virus, fowl plague virus or Sendai virus.

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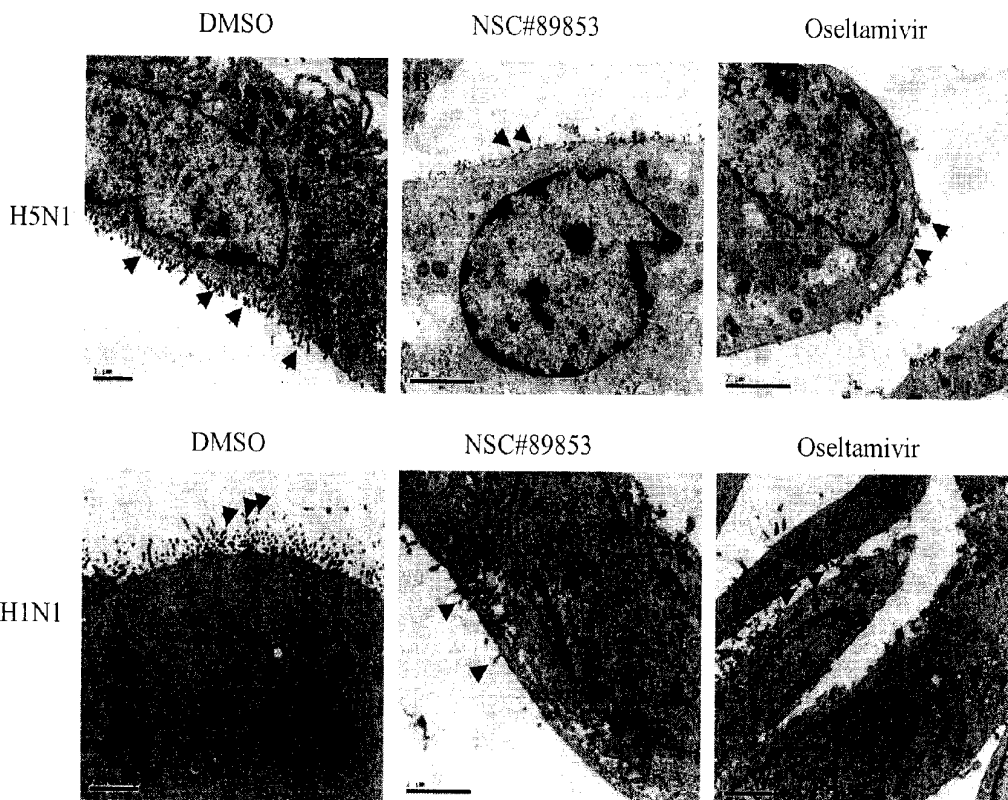


Figure 1

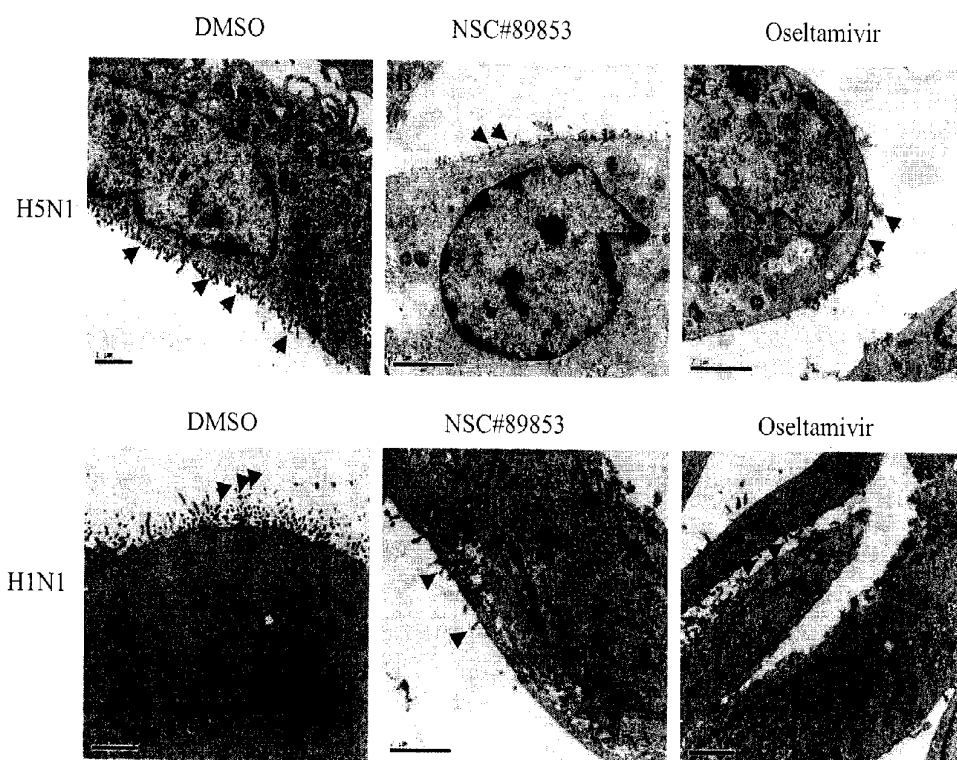
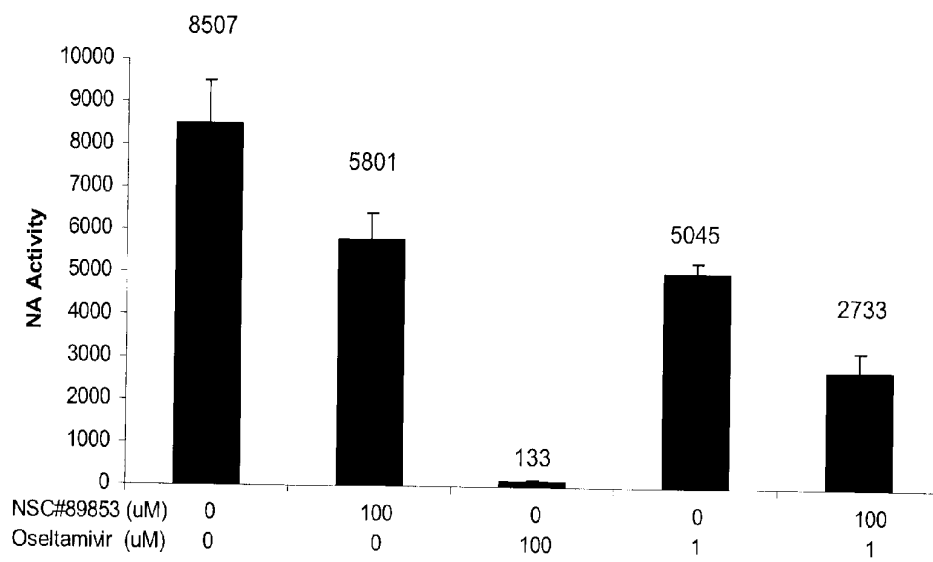


Figure 2



ANTI-INFLUENZA COMPOUNDS

FIELD OF THE INVENTION

[0001] This invention relates to compounds for the treatment of influenza.

BACKGROUND OF THE INVENTION

[0002] The impact of influenza infection is felt globally each year when the disease develops in approximately 20% of the world's population. Influenza A virus, in particular, represents a significant health risk to the public. This is due both to its ability to spread quickly within human populations and the high degree of mortality associated with infection. In the last century, three influenza A pandemics in 1918, 1957 and 1968 killed cumulatively over 50 million people. The highly pathogenic H5N1 strain of influenza A virus is emerging as the most likely cause of the world's next major influenza pandemic.

[0003] Influenza viruses belong to the family Orthomyxoviridae, and are divided into three (3) genera: Influenza A, Influenza B, and Influenza C. Influenza A can cause of epidemics and pandemics in humans and may be transmitted through an avian intermediate host. Influenza B can cause epidemics and has no intermediate host. Influenza C does not occur in epidemics and causes mild disease.

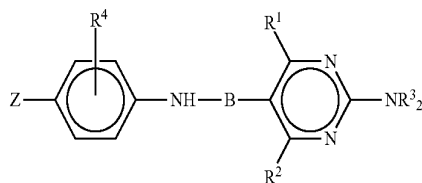
[0004] Influenza A viruses are further classified based on the identity of two surface glycoproteins: hemagglutinin and neuraminidase. Nine subtypes of influenza neuraminidases are known, N1 to N9, and sixteen subtypes of hemagglutinin are known, H1 to H16. Thus, influenza A H5N1 refers to an influenza virus which contains H5 subtype hemagglutinin and N1 subtype neuraminidase.

[0005] Neuraminidase cleaves the specific linkage of the sialic acid receptor in the cell membrane, resulting in the release of the newly formed virions from the infected cells. In addition, neuraminidase may function to facilitate the early process of influenza virus infection of lung epithelial cells. Hence, neuraminidase inhibitors have been an attractive target for the development of novel anti-influenza drugs. Use of effective neuraminidase inhibitors can serve an important role in the early containment of influenza outbreaks in the human population and would complement widespread use of new avian influenza vaccines. Influenza neuraminidases are classified within two categories: group-1 and group-2. Group-1 contains N1, N4, N5, and N8 subtypes, and group-2 contains N2, N3, N6, N7, and N9.

[0006] Existing influenza medicines include oseltamivir (Tamiflu®) and zanamivir (Relenza). These function by inhibiting neuraminidase. However, there have been several documented cases of the emergence of resistance to these drugs by several different sub-strains of avian flu H5N1. Also, the FDA has recently issued a warning label for Tamiflu® after reports of serious psychiatric side-effects in patients receiving the drug, especially children. These factors suggest that there is a significant clinical need for new influenza drugs, particularly to contain the avian flu virus strain H5N1, with improved properties (including efficacy, selectivity and reduced sensitivity to resistance) relative to the current marketed drugs.

SUMMARY OF THE INVENTION

[0007] In one aspect, the present invention provides a compound of formula (I)



wherein

[0008] Z is $-\text{CH}=\text{CHC}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHS}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHP}(=\text{O})\text{Y}_2$, $-\text{OP}(=\text{O})(\text{OH})_2$, or heterocycl, where each Y is independently acyl, alkyl, haloalkyl, hydroxyl, hydroxyalkyl, amino, or alkylamino;

[0009] R^1 and R^2 are independently hydroxyl, alkyl, amino, alkylamino, acyl, or hydroxylalkyl,

[0010] B is alkylene or substituted alkylene, wherein the substituents are $-\text{H}$, $-\text{COOH}$, acyl, $-\text{NO}$, or alkylamino;

[0011] each R^3 is independently $-\text{H}$ or alkyl; and

[0012] R^4 is $-\text{H}$, acyl, amino, alkylamino, or $-\text{COOH}$; and pharmaceutically acceptable salts thereof.

[0013] In one aspect, the invention also encompasses uses of said compounds for the inhibition of influenza. In one embodiment, compounds of the invention may be used for the treatment or prophylaxis of influenza A, in particular H1N1 or H5N1 influenza.

BRIEF DESCRIPTION OF THE DRAWINGS

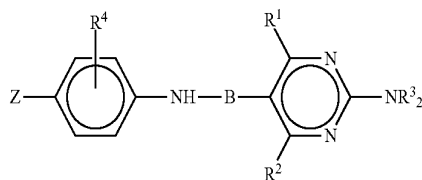
[0014] FIG. 1 shows the transmission electron microscopy of influenza virus infected cells.

[0015] FIG. 2 shows the inhibitory effect of NSC#89853 on the group 1 neuraminidase (NA) activity.

DETAILED DESCRIPTION OF THE INVENTION

Compounds

[0016] In one aspect, the present invention provides a compound of formula (I)



wherein

[0017] Z is $-\text{CH}=\text{CHC}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHS}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHP}(=\text{O})\text{Y}_2$, $-\text{OP}(=\text{O})(\text{OH})_2$, or heterocycl, where each Y is independently acyl, alkyl, haloalkyl, hydroxyl, hydroxyalkyl, amino, or alkylamino;

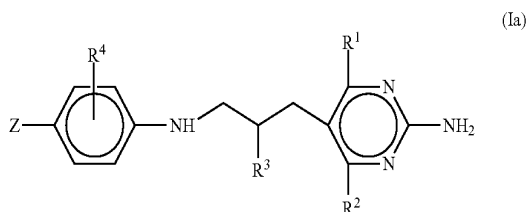
[0018] R^1 and R^2 are independently hydroxyl, alkyl, amino, alkylamino, acyl, or hydroxylalkyl,

[0019] B is alkylene or substituted alkylene, wherein the substituents are $-\text{H}$, $-\text{COOH}$, acyl, $-\text{NO}$, or alkylamino;

[0020] each R³ is independently H or alkyl; and

[0021] R⁴ is H, acyl, amino, alkylamino, or —COOH; and pharmaceutically acceptable salts thereof.

[0022] In one aspect, the present invention provides compounds of formula (Ia)



wherein

[0023] Z is —CH=CHCOCH₂Cl,
—CH=CHCOCH₂CH₃, —CH=CHCOOH,
—CH=CHCONH₂, —CH=CHCONHCH₃,
—CH=CHCOCOH, —CH=CHS(=O)OH,
—CH=CHP(=O)(OH)₂, —OP(=O)(OH)₂, or 2-pyrrolidinone-5-yl;

[0024] R¹ and R² are independently —OH, —CH₃, —NH₂, —COH, or —CH(OH)₂,

[0025] R³ is —COH, —NO, or —H; and

[0026] R⁴ is —COOH, —COH, COCH₃, COCH₂CH₃, —N(CH₃)₂, or —H;

and pharmaceutically acceptable salts, solvents, and hydrates thereof.

[0027] Examples of such compounds are shown in Table 2.

[0028] The compound 4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one is previously known from Baker, B R and Jordaan, J H, *J. Med. Chem.* 1965 Jan (8): 35-41, and was reported therein to be an inhibitor of dihydrofolic reductase. However, its use for treating influenza is novel.

[0029] “Acyl” means a radical —C(O)R where R is hydrogen or alkyl. Examples include formyl, acetyl, ethylcarbonyl, and the like.

[0030] “Alkyl” means a linear saturated monovalent hydrocarbon radical of one to eight carbon atoms or a branched saturated monovalent hydrocarbon radical of three to eight carbon atoms. It may include a linear monovalent hydrocarbon radical of one to four or one to three carbon atoms. Examples include methyl, ethyl, propyl, 2-propyl, n-butyl, iso-butyl, tert-butyl, pentyl, and the like.

[0031] “Alkylamino” means means a radical —NHR or —NR₂ where each R is independently an alkyl or hydroxyalkyl group. Examples include methylamino, (1-methylethyl) amino, hydroxymethylamino, dimethylamino, methylethylamino, di(1-methylethyl)amino, (methyl)(hydroxymethyl) amino, and the like.

[0032] “Alkylene” means a linear saturated divalent hydrocarbon radical of one to six carbon atoms or a branched saturated divalent hydrocarbon radical of three to six carbon atoms. It may include a linear divalent hydrocarbon radical of one to four or one to three carbon atoms. Examples include methylene, ethylene, 2,2-dimethylethylene, propylene, 2-methylpropylene, butylene, pentylene, and the like.

[0033] “Halo” means fluoro, chloro, bromo, or iodo, such as bromo and chloro.

[0034] “Haloalkyl” means alkyl substituted with one or more same or different halo atoms, e.g., —CH₂Cl, —CH₂Br, —CF₃, —CH₂CH₂Cl, —CH₂CCl₃, and the like.

[0035] “Heterocyclyl” means a saturated or unsaturated non-aromatic cyclic radical of 3 to 8 ring atoms in which one or two ring atoms are heteroatoms selected from N, O, or S(O)_n (where n is an integer from 0 to 2), the remaining ring atoms being C, where one or two C atoms may optionally be replaced by a carbonyl group. The heterocyclyl ring may be optionally substituted independently with one, two, or three substituents selected, for example, from alkyl, haloalkyl, halo, nitro, cyano, cyanoalkyl, hydroxy, alkoxy, amino, and alkylamino. More specifically the term heterocyclyl includes, but is not limited to, tetrahydropyranyl, piperidino, N-methylpiperidin-3-yl, piperazino, N-methylpyrrolidin-3-yl, 3-pyrrolidino, morpholino, thiomorpholino, thiomorpholino-1-oxide, thiomorpholino-1,1-dioxide, 4-(1,1-dioxo-tetrahydro-2H-thiopyranyl), pyrrolinyl, imidazolyl, N-methanesulfonyl-piperidin-4-yl, 2-pyrrolidinone-5-yl, and the derivatives thereof.

[0036] “Hydroxyalkyl” means an alkyl radical as defined herein, substituted with one or more, preferably one, two or three hydroxy groups. Representative examples include, but are not limited to, hydroxymethyl, 2-hydroxyethyl, 2-hydroxypropyl, 3-hydroxypropyl, 1-(hydroxymethyl)-2-methylpropyl, 2-hydroxybutyl, 3-hydroxybutyl, 4-hydroxybutyl, 2,3-dihydroxypropyl, 2-hydroxy-1-hydroxymethylethyl, 2,3-dihydroxybutyl, 3,4-dihydroxybutyl and 2-(hydroxymethyl)-3-hydroxy-propyl, preferably 2-hydroxyethyl, 2,3-dihydroxypropyl and 1-(hydroxymethyl) 2-hydroxyethyl.

Salts, Solvates, and Hydrates:

[0037] The compounds of this invention optionally comprise salts of the compounds herein.

[0038] Particular mention may be made of the pharmacologically acceptable salts of inorganic and organic acids customarily used in pharmacy. Those suitable are water-soluble and water-insoluble acid addition salts with acids such as, for example, hydrochloric acid, hydrobromic acid, phosphoric acid, nitric acid, sulfuric acid, acetic acid, citric acid, D-gluconic acid, benzoic acid, 2-(4-hydroxybenzoyl)benzoic acid, butyric acid, sulfosalicylic acid, maleic acid, lauric acid, malic acid, fumaric acid, succinic acid, oxalic acid, tartaric acid, embonic acid, stearic acid, toluenesulfonic acid, methanesulfonic acid or 3-hydroxy-2-naphthoic acid. Salts with bases are also suitable, including salts with alkali metal (lithium, sodium, potassium) or calcium, aluminum, magnesium, titanium, ammonium, meglumine or guanidinium salts.

[0039] It is known to the person skilled in the art that the compounds according to the invention, and also their salts, may contain varying amounts of solvents, for example when they are isolated in crystalline form. The invention therefore also embraces all solvates and in particular all hydrates of the compounds of the formula I, and also all solvates and in particular all hydrates of the salts of the compounds of the formula I.

Stereoisomers:

[0040] Certain compounds of the invention contain chiral centres. Both racemic and diastereomeric mixtures, as well as the individual optical isomers isolated or synthesized, substantially free of their enantiomeric or diastereomeric partners, are all within the scope of the invention. The racemic

mixtures may be separated into their individual, substantially optically pure isomers through well-known techniques, such as the separation of diastereomeric salts formed with optically active adjuncts, e.g., acids or bases followed by conversion back to the optically active substances. The desired optical isomer may be synthesized by means of stereospecific reactions, beginning with the appropriate stereoisomer of the desired starting material.

Prodrugs:

[0041] Prodrugs of the compounds of the invention are also contemplated. The terms “pro-drug” and “prodrug” are used interchangeably herein and refer to any compound which releases an active parent drug according to Formula I or Ia in vivo when such prodrug is administered to a mammalian subject. Prodrugs of a compound of Formula I or Ia are prepared by modifying one or more functional group(s) present in the compound of Formula I or Ia in such a way that the modification(s) may be cleaved in vivo to release the parent compound. Prodrugs include compounds of Formula I or Ia wherein a hydroxy, amino, carboxy or carbonyl group in a compound of Formula I or Ia is bonded to any group that may be cleaved in vivo to regenerate the free hydroxyl, or amino group, respectively. Examples of prodrugs include, but are not limited to, esters (e.g., acetate, dialkylaminoacetates, formates, phosphates, sulfates, and benzoate derivatives) and carbamates (e.g., N,N-dimethylamino carbonyl) of hydroxy functional groups, esters groups (e.g. ethyl esters, morpholinoethanol esters) of carboxyl functional groups, N-acyl derivatives (e.g. N-acetyl) N-Mannich bases, Schiff bases and enamines of amino functional groups, oximes, acetals, ketals and enol esters of ketone and aldehyde functional groups in compounds of Formula I or Ia, and the like. See Bundgaard, H. “Design of Prodrugs” p. 1-92, Elsevier, New York-Oxford (1985).

Pharmaceutical Formulations and Routes of Administration:

[0042] The compositions of the present invention may be formulated in a conventional manner using one or more pharmaceutically acceptable carriers. Thus, the active compounds of the invention may be formulated for oral, buccal, intranasal, parenteral (e.g., intravenous, intramuscular or subcutaneous), topical or rectal administration or in a form suitable for administration by inhalation.

[0043] For oral administration, the pharmaceutical compositions may take the form of, for example, tablets or capsules prepared by conventional means with pharmaceutically acceptable excipients such as binding agents (e.g., pregelatinized maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose); fillers (e.g., lactose, microcrystalline cellulose or calcium phosphate); lubricants (e.g., magnesium stearate, talc or silica); disintegrants (e.g., potato starch or sodium starch glycolate); or wetting agents (e.g., sodium lauryl sulphate). The tablets may be coated by methods well known in the art. Liquid preparations for oral administration may take the form of, for example, solutions, syrups or suspensions, or they may be presented as a dry product for constitution with water or other suitable vehicle before use. Such liquid preparations may be prepared by conventional means with pharmaceutically acceptable additives such as suspending agents (e.g., sorbitol syrup, methyl cellulose or hydrogenated edible fats); emulsifying agents (e.g., lecithin or acacia); non-aqueous vehicles (e.g., almond oil, oily esters

or ethyl alcohol); and preservatives (e.g., methyl or propyl p-hydroxybenzoates or sorbic acid).

[0044] For buccal administration, the composition may take the form of tablets or lozenges formulated in a conventional manner.

[0045] The compounds of the invention can also be formulated for sustained delivery according to methods well known to those of ordinary skill in the art. Examples of such formulations can be found in U.S. Pat. Nos. 3,538,214, 4,060,598, 4,173,626, 3,119,742, and 3,492,397, which are herein incorporated by reference in their entirety.

[0046] The compounds of the invention may be formulated for parenteral administration by injection, including using conventional catheterization techniques or infusion. Formulations for injection may be presented in unit dosage form, e.g., in ampoules or in multi-dose containers, with an added preservative. The compositions may take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and may contain formulating agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient may be in a powder form for reconstitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

[0047] The compounds of the invention may also be formulated in rectal compositions such as suppositories or retention enemas, e.g., containing conventional suppository bases such as cocoa butter or other glycerides.

[0048] For intranasal administration or administration by inhalation, the active compounds of the invention are conveniently delivered in the form of a solution, dry powder formulation or suspension from a pump spray container that is squeezed or pumped by the patient or as an aerosol spray presentation from a pressurized container or a nebulizer, with the use of a suitable propellant, e.g., dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, heptafluoroalkanes, 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 or nebulizer may contain a solution or suspension of the active compound. Capsules and cartridges (made, for example, from gelatin) for use in an inhaler or insufflator may be formulated containing a powder mix of a compound of the invention and a suitable powder base such as lactose or starch.

[0049] The compound of the invention including pharmaceutically acceptable salts and solvates thereof may be used on their own but will generally be administered in the form of a pharmaceutical composition in which the compound (active ingredient) is in association with a pharmaceutically acceptable adjuvant, diluent or carrier. Depending on the mode of administration, the pharmaceutical composition will preferably comprise from 0.05 to 99% w (percent by weight), more preferably from 0.10 to 70% w, of active ingredient, and, from 1 to 99.95% w, more preferably from 30 to 99.90% w, of a pharmaceutically acceptable adjuvant, diluent or carrier, all percentages by weight being based on total composition.

[0050] “Pharmaceutically acceptable excipient” means an excipient that is useful in preparing a pharmaceutical composition that is generally safe, non-toxic and neither biologically nor otherwise undesirable, and includes excipient that is acceptable for veterinary use as well as human pharmaceutical use. A “pharmaceutically acceptable excipient” as used in the specification and claims includes both one and more than one such excipient.

Uses of the Compounds:

[0051] The compounds of this invention are useful in the prophylaxis of influenza infections or treatment of existing

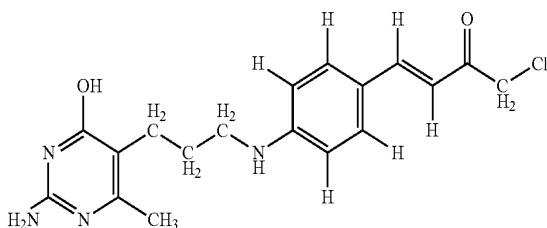
influenza infections in animals such as duck, rodents, or swine, or in man. This includes influenza A (such as the group-1 type neuraminidases including H1N1 and H5N1, and the group-2 neuraminidase including H1N2, H3N2, H7N3, H7N7, and H9N2), influenza B, and influenza C. The compounds may be especially useful in instances of drug-resistance to other influenza medications, such as adamantanes (e.g. amantadine and rimantadine) and neuraminidase inhibitors (e.g. oseltamivir and zanamivir).

[0052] The compounds disclosed herein may be used to inhibit neuraminidases. Organisms that contain neuraminidase include bacteria (*Vibrio cholerae*, *Clostridium perfringens*, *Streptococcus pneumoniae*, and *Arthrobacter sialophilus*) and viruses (especially orthomyxoviruses or paramyxoviruses such as influenza virus A and B, parainfluenza virus, mumps virus, Newcastle disease virus, fowl plague virus, and Sendai virus). Inhibition of neuraminidase activity obtained from or found within any of these organisms is within the scope of this invention.

Experimental

4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one
(Referred to herein as NSC#89853)

[0053]



[0054] This compound was obtained from the National Cancer Institute, USA. However, this compound can be prepared in accordance with Baker, B R and Jordaan, J H, *J. Med. Chem.* 1965 Jan. 8, pp. 35-41.

[0055] Cell viability test: Primary human blood macrophages or MDCK cells were seeded at 2×10^6 /ml in a 96-well plate for 16-24 hours. 100 μ M of NSC#89853 was added to the cells. 100 μ M of DMSO was added to the cells as a control. Cells were incubated at 37° C. and 5% CO₂ for 72 hours, and then Thiazolyl Blue Tetrazolium Bromide (MTT) was added to a final concentration of 0.1 mg/ml. After two hours, the culture supernatant was removed and each well was replenished with isopropanol. The MTT metabolic product, formazan, was dissolved in isopropanol for five minutes with shaking. The optical densities of formazan and background were measured at 560 nm and 670 nm, respectively. The degree of cytotoxicity was calculated as follows:

$$\frac{(\lambda 560_{\text{sample1}} - \lambda 670_{\text{sample1}})}{(\lambda 560_{\text{DMSO}} - \lambda 670_{\text{DMSO}})}$$

NSC#89853 does not display cytotoxicity in MDCK cells as well as in primary macrophages at 100 μ M compared with those treated with DMSO.

ASL no.	Macrophage	MDCK
NSC#89853	1.1	2.2
DMSO	1.0	1.0

[0056] Viral infection: Avian influenza H5N1 virus, A/Vietnam/1203/04, and human influenza H1N1 virus, A/HK/54/98, were prepared as described in previous reports (Lee D C, Cheung C Y, Law A H, Mok C K, Peiris M, Lau A S., *J. Virol.* 2005 August; 79(16):10147-54; and Mok C K, Lee D C, Cheung C Y, Peiris M, Lau A S., *J Gen Virol.* 2007 April; 88 (Pt 4):1275-80). Madin-Darby canine kidney (MDCK) cells were infected with viruses at a multiplicity of infection (m.o.i.) of 2 for 30 min and the virus containing supernatants were removed and washed once with PBS. Serum Free Medium supplemented with N-tosyl-L-phenylalanyl chloromethyl ketone (TPCK)-trypsin and compounds were used to replenish the cell culture. The supernatants and virus-infected cells were harvested for TCID₅₀ assays and electron microscopy examination, respectively.

[0057] Tissue culture infective dose (TCID₅₀) determination: Prior to TCID assays, MDCK cells were seeded at 2×10^4 cells per well on the 96-well plates. Culture supernatants were harvested from virus-infected cells at 48-hour post-infection. Serial two-fold dilutions of the supernatant samples were prepared and the diluted samples were incubated with the MDCK cells for one hour (37° C., 5% CO₂) for virus adsorption. The virus inoculum was then removed. Cells were washed once and replenished with minimum essential medium (MEM), supplemented with 1 μ g/ml N-tosyl-L-phenylalanyl chloromethyl ketone (TPCK)-treated trypsin. After four days of incubation (37° C., 5% CO₂), cells were fixed with 10% formaldehyde for 30 minutes and stained with 0.5% crystal violet to determine the virus-induced cytopathic effects. TCID₅₀ titers were calculated using the Reed-Muench formula (Methods and Techniques in Virology (1993), edited by Payment P and Trudel M, Marcel Dekker Inc. pp. 32-33). The dosage effects of NSC#89853 on influenza viral titers is shown in Table 1.

TABLE 1

Dosage effects of NSC#89853 on influenza viral titers.		
Concentration (μ M)	TCID ₅₀ /ml	
	H5N1 virus ^a	H1N1 virus ^b
0	1.51×10^8	7.796×10^6
5	3.98×10^7	9.74×10^5
10	4.68×10^7	5.79×10^5
20	1.95×10^7	7.28×10^5
50	5.89×10^6	3.64×10^5
100	2.63×10^6	2.44×10^5
100 (oseltamivir)	2.46×10^6	N/A

^aMDCK cells were infected with H5N1 virus at a m.o.i of 2. Cells were then incubated with NSC#89853 at various concentrations as indicated, or with oseltamivir (control drug) at 100 μ M as the standard antiviral agent. Culture supernatants were collected at 48-hour post-infection. Viral titers (TCID₅₀) were measured by titration in MDCK cells. (Representative results from three experiments).

^bResults on H1N1 virus. MDCK cells were infected with H1N1 virus at a m.o.i of 2. Cells were then incubated with NSC#89853 at various concentrations as indicated. Culture supernatants were collected at 48-hour post-infection. Viral titers (TCID₅₀) were measured by titration in MDCK cells. (Representative results from three experiments).

[0058] The TCID₅₀ results demonstrate that NSC#89853 inhibits the replication of the H5N1 and H1N1 viruses in a significant manner, and at a level comparable to that of oseltamivir.

[0059] Transmission electron microscopy: At 18 hour post-infection, the culture supernatant was removed and cells were fixed with 2.5% glutaraldehyde in cacodylate buffer (0.1 M sodium cacodylate-HCl buffer, pH 7.4) for 15 minutes on ice. Cells were then scraped from the culture dish and the pellet was harvested by centrifugation at 5000 rpm for 3 minutes. Cells were fixed with 2.5% glutaraldehyde in cacodylate buffer at 4° C. overnight and then resuspended in cacodylate buffer with 0.1 M sucrose. After washings with cacodylate buffer, cells were fixed in 1% osmium tetroxide in cacodylate buffer for 30 minutes at room temperature. Cells were washed three times and then dehydrated with graduated ethanol. After two washings with propylene oxide, cell pellets were embedded in epoxy resin. Ultra-thin sections with a thickness of 100 nm were cut. Ultrastructural features of cells were examined under a transmission electron microscope (Philips EM208S).

[0060] FIG. 1 shows the results of the transmission electron microscopy of influenza virus infected cells. MDCK cells were infected with H5N1 (A-C) or H1N1 (D-F) virus at a m.o.i. of 2. Cells were then treated with NSC#89853 (100 uM), oseltamivir (100 uM) or DMSO. At 18-hour post-infection, the cells were collected for ultrastructural examination by transmission electron microscopy. Arrows indicate the virions. Magnification: A, 14000×; B-F, 8900×.

[0061] Consistent with the results of TCID₅₀, the levels of H5N1 or H1N1 viruses found on the surface of MDCK cells were lower on the cells treated with NSC#89853 or oseltamivir compared with that of the DMSO-treated cells.

[0062] Neuraminidase Assay: Neuraminidase inhibitory activity was determined using the NA-Star Influenza Neuraminidase Inhibitor Resistance Detection Kit (Applied Biosystems P/N: 4374422). Briefly, 25 µl of the compounds NSC#89853 or oseltamivir at 2× the desired final concentration was added in triplicates to each well of the Star Detection 96-well microplate. H1N1 virus (TCID₅₀=2×10⁷/ml) was diluted five-fold with NA-Star Assay Buffer. 25 µl of the diluted virus was added per well and mixed with the compounds. The microplate was agitated and incubated at 37° C. for 20 minutes. The substrate was diluted at 1:1000 in the assay buffer immediately before use. 10 µl of diluted NA-Star Substrate was added to each well and briefly agitated on a plate shaker and incubated at room temperature for 30 minutes. 60 µl of NA-Star Accelerator was added to each well followed by immediate measurement of the chemiluminescent signal by Envison™ (Perkin Elmer). The results are shown in FIG. 2.

TABLE 2-continued

Examples of compounds of the invention

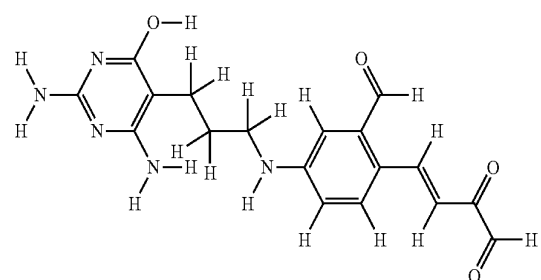
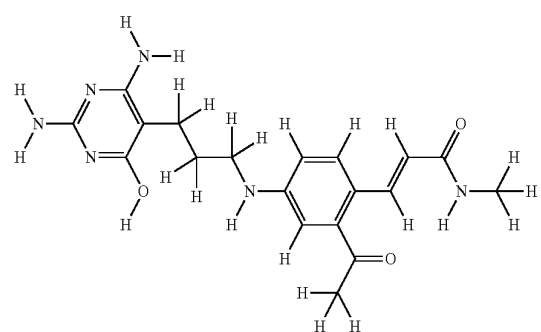
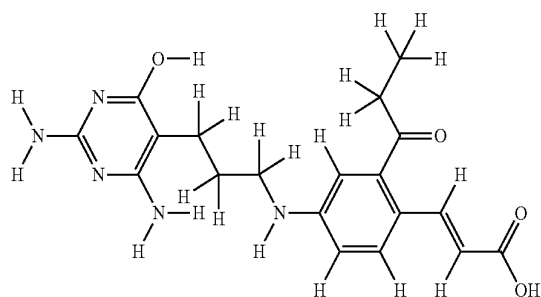
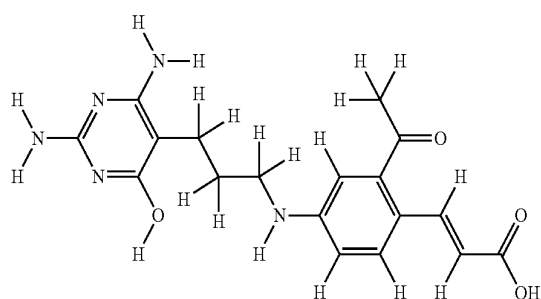
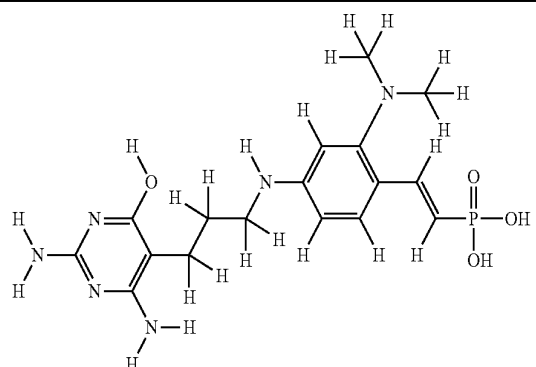


TABLE 2

Examples of compounds of the invention

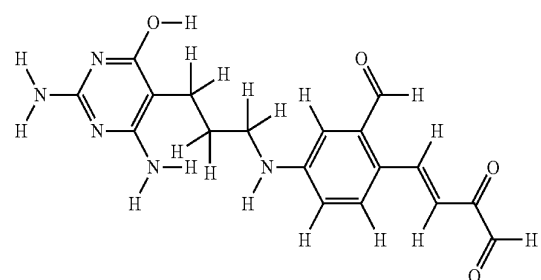
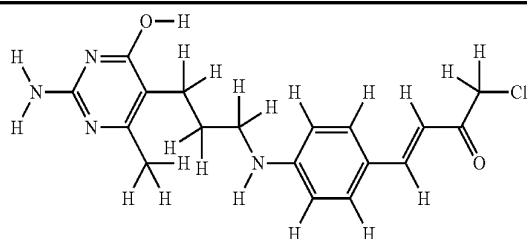


TABLE 2-continued

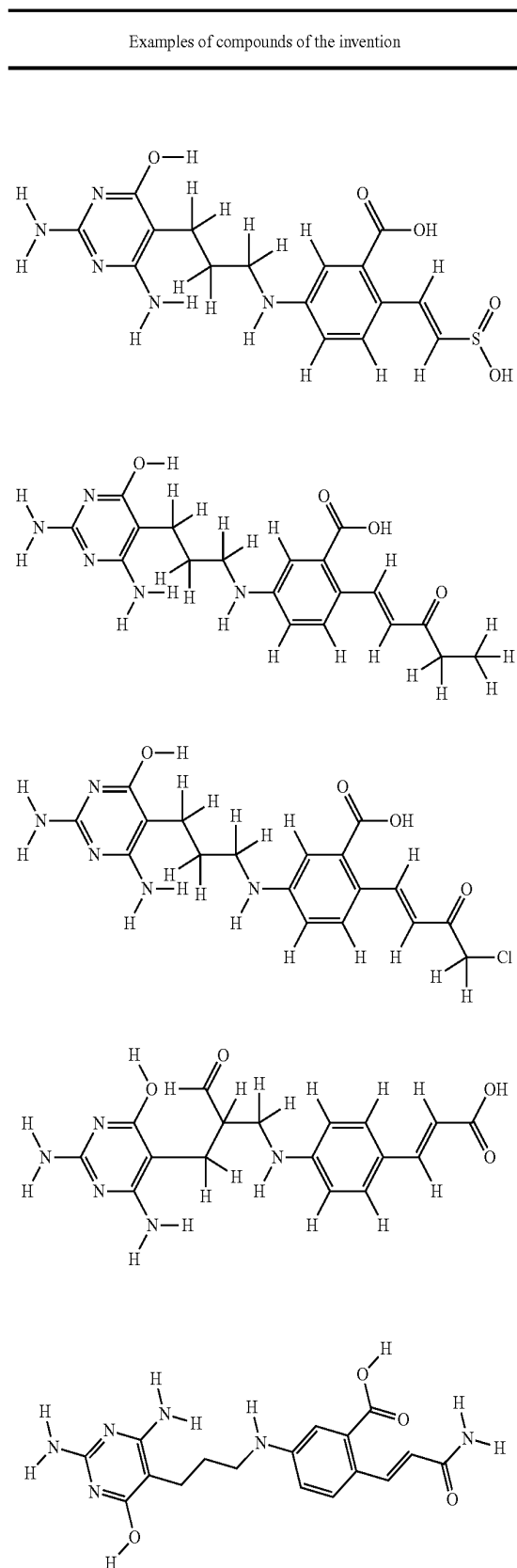
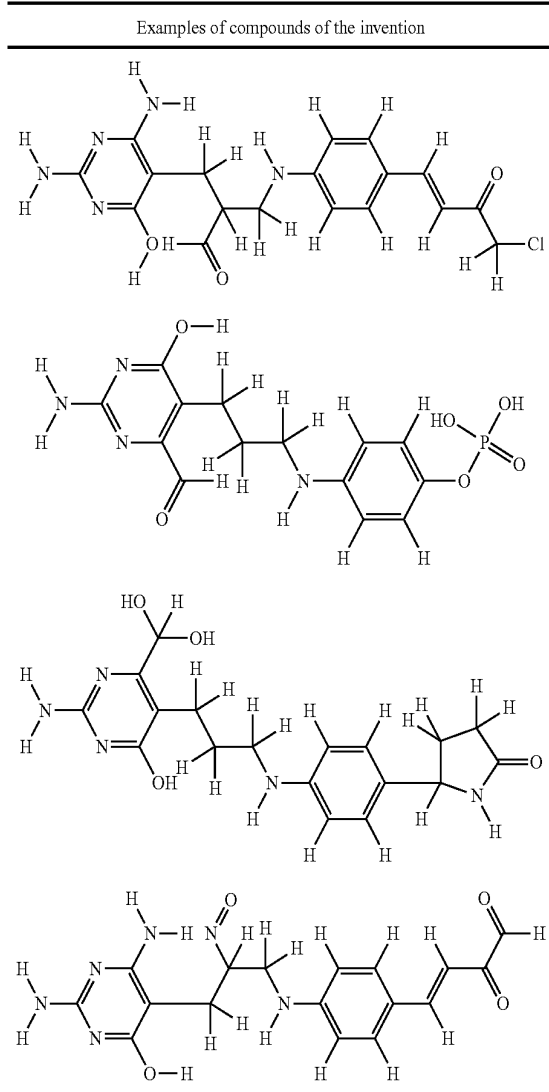
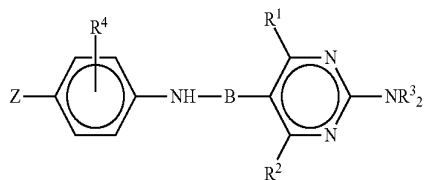


TABLE 2-continued



1. A compound of formula (I)



wherein

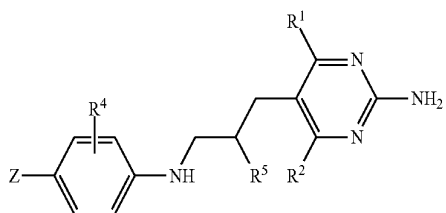
Z is $-\text{CH}=\text{CHC}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHS}(=\text{O})\text{Y}$, $-\text{CH}=\text{CHP}(=\text{O})\text{Y}_2$, $-\text{OP}(=\text{O})(\text{OH})_2$, or heterocycl, where each Y is independently acyl, alkyl, haloalkyl, hydroxyl, hydroxyalkyl, amino, or alkylamino;

R¹ and R² are independently hydroxyl, alkyl, amino, alkylamino, acyl, or hydroxylalkyl,

B is alkylene or substituted alkylene, wherein the substituents are $-\text{H}$, $-\text{COOH}$, acyl, $-\text{NO}$, or alkylamino;

each R³ is independently H or alkyl; and
 R⁴ is H, acyl, amino, alkylamino, or —COOH;
 and pharmaceutically acceptable salts thereof;
 with the proviso that 4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one is excluded.

2. The compound of claim 1, wherein the compound has formula (Ia)

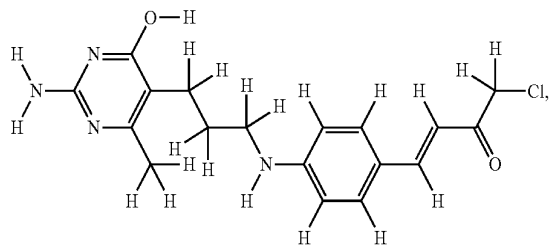


(Ia)

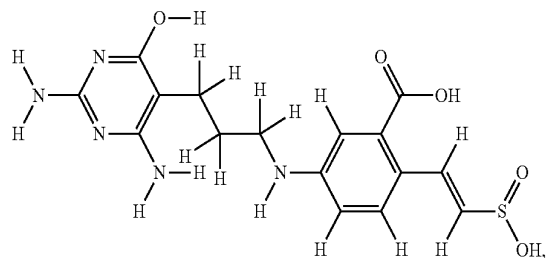
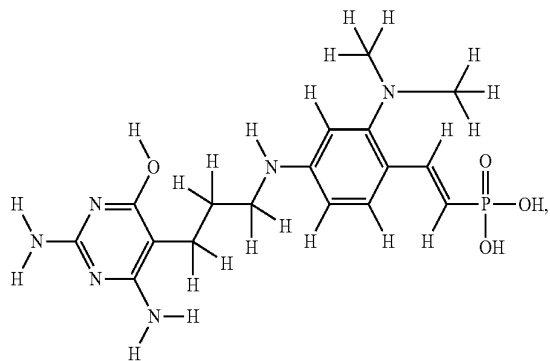
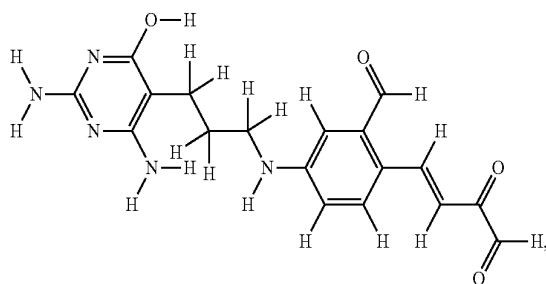
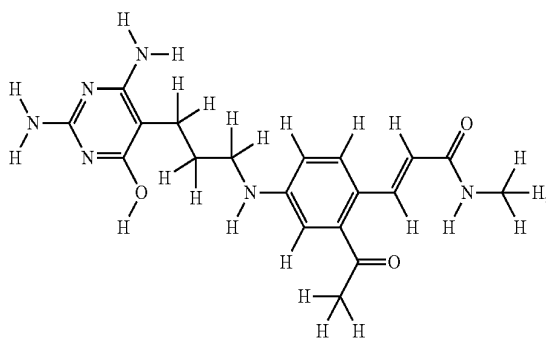
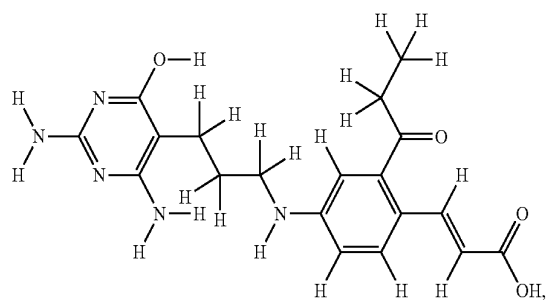
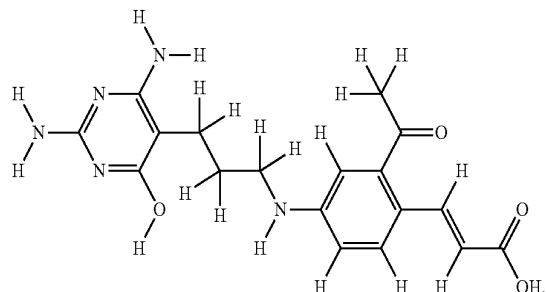
wherein

- Z is —CH=CHCOCH₂Cl, —CH=CHCOCH₂CH₃,
 —CH=CHCOOH, —CH=CHCONH₂,
 —CH=CHCONHCH₃, —CH=CHCOCO₂H,
 —CH=CHS(=O)OH, —CH=CHP(=O)(OH)₂,
 —OP(=O)(OH)₂, or 2-pyrrolidinone-5-yl;
 R¹ and R² are independently —OH, —CH₃, —NH₂,
 —COH, or —CH(OH)₂;
 R⁴ is H, —COOH, —COH, —COCH₃, —COCH₂CH₃, or
 —N(CH₃)₂; and
 R⁵ is H, —NO, or —COH.

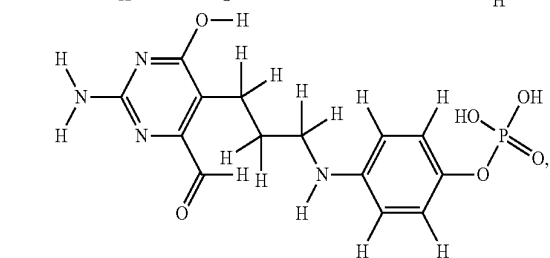
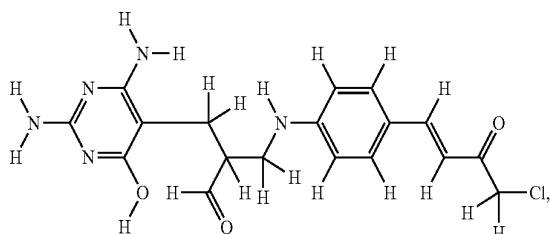
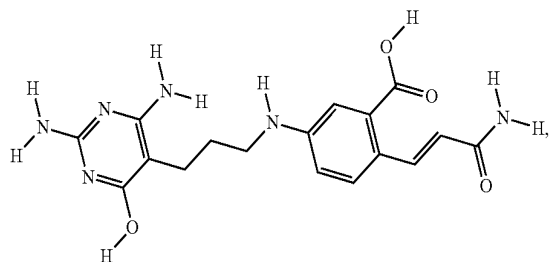
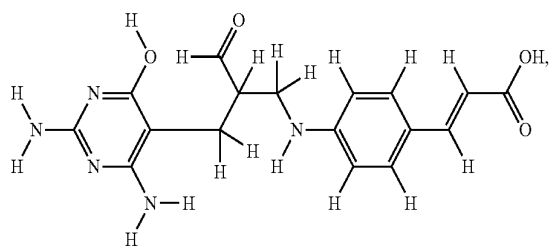
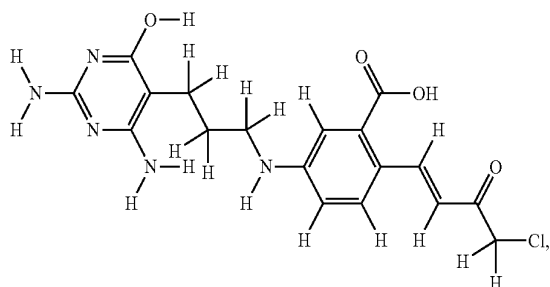
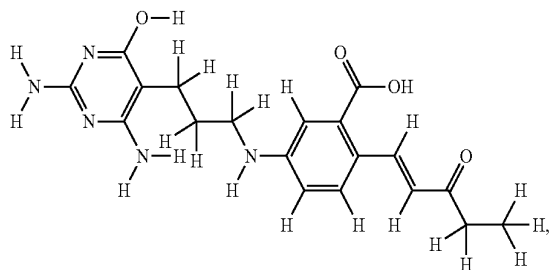
3. A compound consisting of:



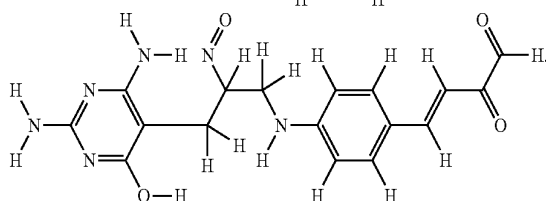
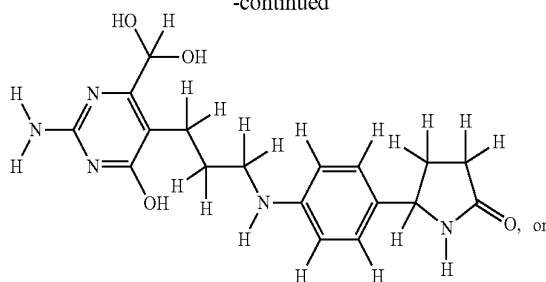
-continued



-continued



-continued



4. A pharmaceutical composition comprising the compound of claim 1, in admixture with a suitable pharmaceutically acceptable diluent or carrier.

5. The pharmaceutical composition of claim 4, in admixture with a medication for the treatment of influenza.

6. The pharmaceutical composition of claim 5, wherein the medication for the treatment of influenza is oseltamivir, zanamivir, amantadine, or rimantadine.

7. (canceled)

8. (canceled)

9. (canceled)

10. (canceled)

11. (canceled)

12. (canceled)

13. (canceled)

14. (canceled)

15. (canceled)

16. (canceled)

17. (canceled)

18. (canceled)

19. (canceled)

20. (canceled)

21. (canceled)

22. (canceled)

23. A method for treating or preventing influenza in a subject, comprising administering to said subject an effective amount of the compound of claim 1.

24. A method for treating or preventing influenza in a subject, comprising administering to said subject an effective amount of 4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one.

25. The method of claim 23, wherein the influenza is influenza A or B.

26. The method of claim 23, wherein the influenza is influenza type A.

27. The method of claim 23, wherein the influenza is influenza type C.

28. The method of claim 23, wherein the influenza is type A group-1.

29. The method of claim 23, wherein the influenza is type A group-2.

30. The method of claim 23, wherein the influenza is H1N1, H1N2, H3N2, H5N1, H9N2, H7N3, or H7N7.

31. The method of claim **23**, wherein the influenza is Type A H5N1 influenza.

32. The method of claim **23**, wherein the influenza is Type A H1N1 influenza.

33. The method of claim **23**, wherein the influenza is a drug-resistant strain of influenza.

34. The method of claim **33**, wherein drug-resistant strain is resistant to oseltamivir or zanamivir.

35. A method for treating or preventing a disease caused by *Vibrio cholerae*, *Clostridium perfringens*, *Streptococcus pneumoniae*, *Arthrobacter sialophilus*, an orthomyxovirus, a paramyxovirus, a parainfluenza virus, mumps virus, Newcastle disease virus, fowl plague virus, or Sendai virus in a subject, comprising administering to said subject an effective amount of the compound of claim **1**.

36. A method for inhibiting endogenous mammalian sialidases in a subject, comprising administering to said subject an effective amount of the compound of claim **1**.

37. A method for treating or preventing a disease caused by *Vibrio cholerae*, *Clostridium perfringens*, *Streptococcus pneumoniae*, *Arthrobacter sialophilus*, an orthomyxovirus, a paramyxovirus, a parainfluenza virus, mumps virus, Newcastle disease virus, fowl plague virus, or Sendai virus in a subject, comprising administering to said subject an effective amount of 4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one.

38. A method for inhibiting endogenous mammalian sialidases in a subject, comprising administering to said subject an effective amount of 4-(4-((3-(2-amino-4-hydroxy-6-methyl-5-pyrimidinyl)propyl)amino)phenyl)-1-chloro-3-buten-2-one.

* * * * *