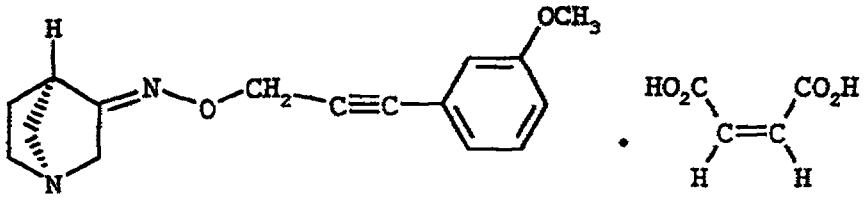
(R)-(Z)-1-AZABICYCLO[2.2.1]HEPTAN-3-ONE,O-[3-(3-METHOXYPHENYL)-2-PROPYNYL]OXIME MALEATE AS A PHARMACEUTICAL AGENT

BACKGROUND OF THE INVENTION

The instant invention is a crystalline salt of (R)-(Z)-1-Azabicyclo[2.2.1]heptan-3-one,O-[3-(3-methoxyphenyl)-2-propynyl]oxime, and maleic acid (1:1 ratio) (the compound) which provides a pharmaceutical form with properties superior to the free base or any of the other pharmaceutically acceptable salt forms of this compound.

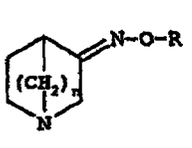
The chemical structure of this salt is



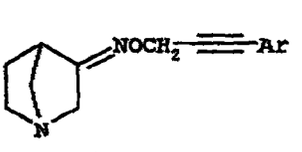
Compounds of Formula I below, and more specifically a subset of compounds of Formula II below, are covered in United States Patent Number 5,306,718 and its continuation-in-part United States Patent Number 5,346,911 as muscarinic agonists, useful agents for the treatment of pain and cognitive decline associated with brain cholinergic deficiency, such as Alzheimer's disease.

Compounds of Formula II where Ar is a phenyl group substituted by one or two methoxy groups possess some of the most interesting profiles of pharmacological activity in vitro (Jaen, et al., Life Sciences, 1995;56:845-852 (Table I of the reference)). One of these compounds in particular (1), which contains a

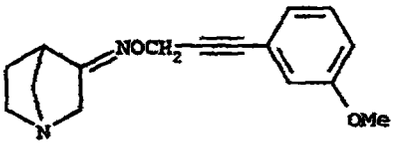
(3-methoxyphenyl)propargyl oxime side chain, was identified in this and earlier publications (Davis R., et al., Prog. Brain Res., 1993;98:439-445) as displaying a very favorable overall profile of pharmacological activity, as illustrated by its high affinity to rat cerebral cortex muscarinic receptors, the ability to displace an agonist radiolabeled ligand (cis-methyldioxolane) from muscarinic receptors at 246 times lower concentrations than those required to displace an antagonist radioligand (quinuclidinyl benzilate), and its ability to selectively stimulate m1-subtype muscarinic receptors without significant stimulation of other non-m1 muscarinic receptors.



I

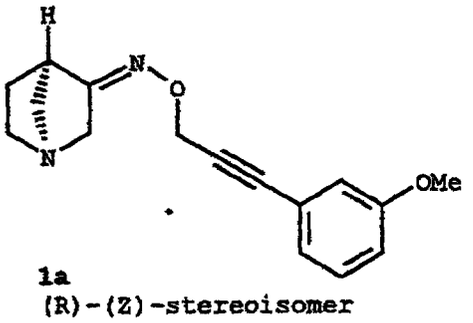


II

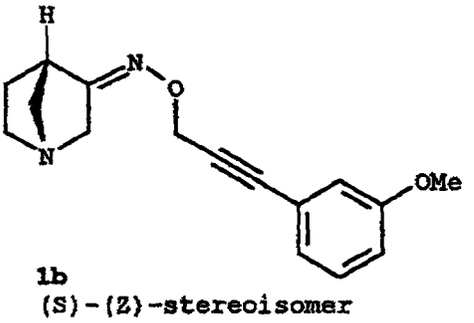


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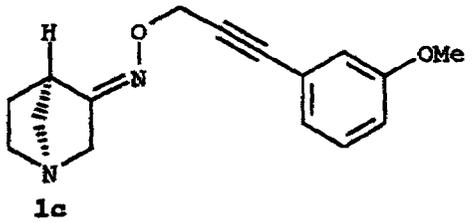
A compound with the chemical structure of 1 above may exist as any of four stereochemical isomers, represented by 1a, 1b, 1c, and 1d below.



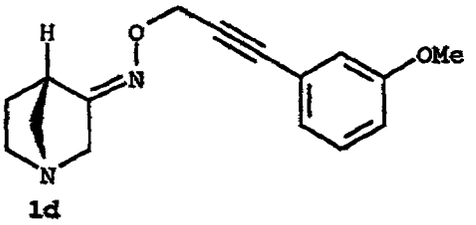
1a
(R)-(Z)-stereoisomer



1b
(S)-(Z)-stereoisomer



1c
(R)-(E)-stereoisomer



1d
(S)-(E)-stereoisomer

Isomers 1a and 1b are enantiomers (i.e., mirror images of each other), the same being true for isomers 1c and 1d. Since the asymmetric center of these molecules is on a bridgehead carbon, which cannot epimerize under any normal conditions, resolution of these enantiomeric pairs (that is, separation of 1a from 1b or separation of 1c from 1d) can be accomplished by synthetic or resolution techniques described in United States Patent Number 5,346,911 and is permanent. This means, for example, that 1a cannot interconvert to its enantiomer 1b and 1c cannot interconvert to 1d. On the other hand, 1a and 1c possess the same absolute stereochemistry at the bridgehead carbon atom but are geometric isomers of each other at the oxime carbon-nitrogen double bond. The same relationship exists between isomers 1b and 1d.

The muscarinic agonist efficacy of oxime 1 resides primarily in isomer 1a (Jaen ibid and Table I below). Tables II and III of the reference indicate that isomer 1a (designated R-8 in the Jaen reference) displays greater m1 receptor subtype selectivity and greater m1 potency than isomer 1b (designated S-8). The small amount of activity displayed by 1b could be due to the presence of small amounts of 1a in the samples of 1b. A comparison between 1a and a mixture of 1c/1d, shown in Table I below, indicates that 1a is more potent and more efficacious as a muscarinic agonist (as determined by the greater ratio of quinuclidinyl benzilate (QNB) to cis-methyldioxolane (CMD) binding for 1a). As a result of these and other experiments, 1a was identified as an optimal compound (high efficacy muscarinic agonist with high selectivity for m1 muscarinic receptor subtypes) for development as a treatment for cognitive malfunction associated with cholinergic deficits, such as Alzheimer's disease.

TABLE I. Muscarinic Receptor Binding

Compound	CMD Binding IC_{50} (nM)	QNB Binding IC_{50} (nM)
1a	25	5300
(1c + 1d)[a]	150	14800

[a] Racemic (E)-oxime was used in these assays.

Some oxime carbon-nitrogen double bonds are relatively stable, while others can undergo facile rearrangement, typically in the presence of acid catalysts. The specific substitution pattern around the oxime moiety typically determines the chemical stability of the oxime (propensity to hydrolyze into its ketone and hydroxylamine components), its stereochemical integrity (the tendency of each geometric isomer to remain in the E or Z configuration), and the exact position of the thermodynamic equilibrium between both stereochemical forms (when chemical conditions are such that an equilibrium can be reached). As shown in Table II below, Compound 1a can undergo acid-catalyzed isomerization to produce its geometric isomer 1c. This equilibration is time- and pH-dependent. We have determined that the thermodynamic equilibrium ratio of 1a:1c in solution is approximately 85:15.

TABLE II. Z:E Peak-Area Ratios as a Function of pH After 24 Hours Incubation of 1a at 37°C

pH	Peak-Area Ratio (1a:1c)
0.1N HCl	85:15
pH 1.97	88:12
pH 4.03	99.3:0.7
>4.03	100:0

There are multiple reasons for not considering an 85:15 mixture of these two isomers as an optimal entity for development as a pharmaceutical drug: The 85:15 ratio of isomers is not always produced in exactly equal amounts from batch to batch, interpretation of the pharmacology, toxicity, and clinical efficacy of such a mixture would be much more difficult than when dealing with a single compound, and the cost of developing a fixed mixture as a clinically useful drug would also be significantly higher; and finally, the physical properties of an 85:15 combination of isomers are less optimal than those of pure **1a** in terms of crystallinity, physical, and chemical stability.

The development of **1a** as a pharmaceutical drug required the identification of a salt form or free base of **1a** with optimal physical and chemical properties. The most critical properties included: Easy and reproducible preparation, crystallinity, non-hygroscopicity, aqueous solubility, stability to visible and ultraviolet light, low rate of degradation under accelerated stability conditions of temperature and humidity, low rate of isomerization of **1a** to its isomer **1c** under these conditions, and safety for long-term administration to humans.

The free base and certain pharmaceutically acceptable salts are covered in United States Patent Number 5,306,718 and continuation-in-part 5,346,911. The salts listed are: hydrochloric, sulfuric, phosphoric, acetic, benzoic, citric, malonic, salicylic, malic, fumaric, oxalic, succinic, tartaric, lactic, gluconic, ascorbic, maleic, aspartic, benzenesulfonic, methane and ethanesulfonic, hydroxymethane- and hydroxyethanesulfonic. There is no teaching or suggestion that the maleate is a superior salt form of the above structure. Clearly the

excellent properties of the maleate salt were not known or appreciated until now.

These two patents are hereby incorporated by reference. We have discovered that not all of the salts are equally useful, as judged by the list of properties described above. In particular, we have discovered the unexpected excellent properties of the maleic acid salt (1:1) of 1a, which clearly distinguishes this salt.

SUMMARY OF THE INVENTION

Of the large number of salts of Compound 1a prepared and examined, quite unexpectedly, only the maleate [1:1] salt satisfied all of the inventors' standards as a pharmaceutically acceptable and desirable salt: ease of preparation without isomerization, consistent and reproducible stoichiometry, crystallinity, aqueous solubility, light stability, non-hygroscopicity, non-toxicity, and general physical and chemical stability. The present invention is, therefore, directed to the [1:1] salt of Compound 1a with maleic acid, its preparation in such a way that large particle size crystals of the salt are obtained, and the method of use of this salt to treat cognitive deficits and pain. The chemical name of this salt is (R)-(Z)-1-azabicyclo[2.2.1]heptan-3-one,O-[3-(3-methoxyphenyl)-2-propynyl]oxime, (Z)-butenedioic acid, [1:1 salt]. The majority of crystal particles are greater than 10 x 10 μm in size; at least half of the particles are larger than 10 x 10 μm.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the separation of 1a and 1c by HPLC.

Figure 2 shows an electron micrograph of 1a maleate crystals recrystallized from ethyl acetate.

Figure 3 shows an electron micrograph of 1a maleate crystals obtained by precipitation from diethyl ether.

Figure 4 shows a comparison of oxalate and maleate salts of 1a in biological activity.

DETAILED DESCRIPTION

The salt selection process for the muscarinic agonist of the instant invention revolved around issues key to pharmaceutical compounds.

The most critical properties included: Easy and reproducible preparation, crystallinity, non-hygroscopicity, aqueous solubility, stability to visible and ultraviolet light, low rate of degradation under accelerated stability conditions of temperature and humidity, low rate of isomerization of 1a to its isomer 1c under these conditions, and safety for long-term administration to humans.

Many counter-ions were evaluated for salt-forming properties. See Table III below. The data presented in Table III answer the following questions: (1) did a solid salt precipitate from ether when free base 1a was treated with each acid?; (2) following collection of the salt by either filtration or evaporation of the ether, what solvents were used to crystallize the salt, and was a crystalline salt obtained from each solvent?; (3) melting point information; and (4) overall rating of each salt, based on considerations of ease of formation and crystallinity.

TABLE III. Evaluation of Acid Addition Salts of (R)-(Z)-1-azabicyclo[2.2.1]heptan-3-one,O-[3-(3-methoxyphenyl)-2-propynyl]oxime

Acid Anion	Results: PPT From Ether	Recrystallization Solvent			Results	Melting Point	Overall Salt Rating
Inorganic							
1. Hydrobromide	Yes	1. Et_2O	Precipitation		Amorphous Solid (very hygroscopic)	—	Low
2. Hydrochloride	Yes	1. Et_2O	Precipitation		White Solid	158-160	High
		2. EtOAc	Recrystallization		White Solid E-Isomer Formation	159-160	
Monocarboxylic							
3. Acetate	No	1. Et_2O	Evaporation		Oil	—	Low
		2. Pet Ether	Trituration		Oil		
		3. IPA/Pet Ether	Crystallization		Oil		
4. Benzoate	No	1. Et_2O	Evaporation		Oil		High
		2. Pentane	Trituration		White Crystals	86-88	
		3. t-Butylmethylether	Crystallization		White Crystals	88-89	
5. *n*-Butyrate[a]	No	1. Et_2O	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
6. *tert*-Butyrate[a]	No	1. Et_2O	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
7. L(+)-Lactate	No (MeOH)	1. MeOH	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
8. 1-Naphthoate	No	1. Et_2O	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
9. 2-Naphthoate	No	1. Et_2O	Evaporation		Gum	—	Low
		2. Pentane	Trituration		Gum		

[a] Racemic oxime was used.

TABLE III (continued)

Acid Anion	Results: PPT From Ether	Recrystallization Solvent			Results	Melting Point	Overall Salt Rating
Monocarboxylic (cont)							
9. 2-Naphthoate (cont)		3.	Toluene	Crystallization	No PPT		
		4.	Acetone	Crystallization	No PPT		
		5.	t-Butylmethylether	Crystallization	No PPT		
		6.	Cyclohexane	Crystallization	Solid = 2-Naphthoic Acid		
10. Propionate	No	1.	Et_2O	Evaporation	Oil	—	Low
		2.	Pentane	Trituration	Oil		
11. Stearate	No	1.	Et_2O	Crystallization	Solid = Stearic acid	—	Low
12. Undecanoate	No	1.	Et_2O	Evaporation	Oil	—	Low
Polycarboxylic							
13. Citrate	Yes	1.	Et_2O	Precipitation	White Amorphous Solid	53-54	Medium
14. Fumarate (0.5 equi)	No (MeOH)	1.	MeOH	Evaporation	Gum		Medium
		2.	EtOAc	Trituration	Solid	79-109	
		3.	EtOAc:Pentane(1:1)	Trituration	Solid	106-108	
		4.	EtOAc	Crystallization	Gum		
		5.	EtOH/Pentane	Crystallization	No PPT		
		6.	IPA/Pentane	Crystallization	No PPT		
		7.	EtOH	Crystallization	No PPT		
		8.	IPA	Crystallization	No PPT		
		9.	Cyclohexane/$CHCl_3$	Crystallization			
15. Fumarate (1 equi)	Yes	1.	Et_2O	Precipitation	Amorphous Solid		Low
		2.	EtOH/Pentane	Crystallization	Oil		

TABLE III (continued)

Acid Anion	Results: PPT From Ether	Recrystallization Solvent			Results	Melting Point	Overall Salt Rating
Polycarboxylic (cont)							
15. Fumarate (1 equi)		3.	IPA/Pentane	Recrystallization	Oil		
		4.	EtOH	Recrystallization	Oil		
		5.	IPA	Recrystallization	Oil		
		6.	EtOAc	Recrystallization	Oil		
16. Maleate	Yes	1.	Et_2O	Evaporation	White Crystals	115-116	High
		2.	EtOAc	Recrystallization	White Crystals	118-119	
		3.	IPA/EtOH/Pentane	Recrystallization	White Crystals	116.5-118	
		4.	EtOH/Pentane	Recrystallization	White Crystals	118.5-121	
		5.	$CHCl_3$/Pentane	Recrystallization	White Crystals	118-119.5	
		6.	EtOH	Recrystallization	White Crystals	115-118	
17. Malate	Yes	1.	Et_2O	Precipitation	White Gum	—	Low
		3.	IPA/EtOH/Pentane	Recrystallization	Oil		
		4.	EtOH/Pentane	Recrystallization	Oil		
18. Oxalate	Yes	1.	Et_2O	Precipitation	White Solid Inconsistent Stoichiometry	Variable 110-113 for 1:1 Salt	Medium
19. Succinate	No (MeOH)	1.	MeOH	Evaporation	Oil		Low
		2.	t-Butylmethylether/Pentane	Recrystallization	Oil		
		3.	Et_2O/Pentane	Crystallization	Oil		
20. Tartrate (L)-(+) (0.5 equi)	No (MeOH)	1.	MeOH	Evaporation	Gum		Low
		2.	Pentane	Trituration	Sticky Gum		
		3.	MeOH/Ether	Crystallization	Amorphous White Solid	58 (Glass)	
		4.	t-Butylmethylether	Crystallization	No PPT		
		5.	EtOAc	Crystallization	Oily PPT		
		6.	EtOAc/Pentane	Crystallization	No PPT		
		7.	EtOH/Pet Ether	Crystallization	No PPT		

TABLE III (continued)

Acid Anion	Results: PPT From Ether	Recrystallization Solvent			Results	Melting Point	Overall Salt Rating
Polycarboxylic (cont)							
21. Tartrate (L)-(+) (1 equi)	No (MeOH)	1. MeOH	Evaporation		Oil	—	Low
		2. EtOH/Pet Ether	Crystallization		No PPT		
22. Tartrate (D)-(-) (0.5 equi)	No (MeOH)	1. MeOH	Evaporation		Gum	—	Low
		2. EtOH/Pet Ether	Crystallization		No PPT		
23. Tartrate (D)-(-) (1 equi)	No (MeOH)	1. MeOH	Evaporation		Gum		Low
Sulfonic							
24. Benzene Sulfonate Sulphonate	No	1. Et_2O	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
Amino Acid							
25. N-acetylglycinate	No (EtOAc/MeOH)	1. EtOAc/MeOH	Evaporation		Oil	—	Low
		2. Et_2O and Pentane	Trituration				
Other							
26. Saccharin	No (MeOH)	1. MeOH	Evaporation		Oil	—	Low
		2. Pentane	Trituration		Oil		
		3. Ether	Trituration		Oil		
		4. t-Butylmethylether	Crystallization		No PPT		
		5. Acetone/Pentane	Crystallization		Oily PPT		

Of the more than 26 salts examined, only four salts provided reasonably crystalline forms: the hydrochloride, the oxalate, the maleate, and the benzoate.

Table IV below shows the moisture uptake of three of these four salts. The HCl salt took up water most rapidly and to the greatest extent; the maleate the least.

Generally, hygroscopicity is an important but not critical factor in salt selection. Precaution can be taken in manufacturing to deal with a wide variety of variables if necessary. On the other hand, other things being equal, a non-hygroscopic form is highly desirable.

For Compound 1a, the fact that the hydrochloride salt is extremely hygroscopic is of major concern because the uptake of moisture lowers the microenvironmental pH of the solid leading to the formation of 1c, even in the solid state. Prior studies have shown that the conversion of 1a to 1c occurs under low pH conditions. In addition, the hydrochloride form is difficult to recrystallize without converting 1a to 1c.

For pharmaceuticals, higher melting points are more desirable than low, as higher melting point compounds tend to be more stable, both physically and chemically, during pharmaceutical processing. Both the maleate and the hydrochloride salts provided these more desirable characteristics.

The oxalate salt, even though less hygroscopic than the hydrochloride, cannot be prepared with a consistent stoichiometry, thus limiting its potential for development. Additionally, significant concerns exist about the toxicity of long-term administration of oxalic acid to patients (The Merk Index, 10th Edition, Merck & Co., Inc., Rahway, New Jersey 1983:6784; and

Gosselin RE, et al., Ed. Clinical Toxicology of Commercial Products. Williams & Wilkins, Baltimore, 4th Edition, 1976; Section III:260-263).

TABLE IV. Hygroscopicity of Salts of Compound 1a

	Benzoate	Oxalate	Maleate	Hydrochloride
Hygroscopicity (%wt ↑)[a]	Not Determined	6.38 ± 1.40	0.32 ± 0.02	27.77 ± 0.40
Melting Point (°C)	89 (DSC)	110	119 (DSC)	158

[a] Hygroscopicity at RT; 81%RH for 16 days using crimped DSC pans

Effect of Temperature, Relative Humidity, and Light on Crystalline Salts of 1a

Table V below summarizes results of stability studies on the least-hygroscopic crystalline salts of 1a. The maleate and benzoate salts were studied in the most detail. No temperature/humidity discrimination occurred with the accelerated condition, 30°C/60%RH after 2 weeks; the maleate and benzoate were both stable at 25°C/60%RH and 30°C/60%RH.

TABLE V. Stability of Crystalline Salts of 1a Under Accelerated Stability Conditions

	Maleate	Benzoate	Oxalate
30°C/60%RH: 2 Weeks	O	O	Not Determined
Xenon: 26 Hours	O	E	E
Fluorescence: 5.5 Months	O	Not Determined	Not Determined

Where: E=presence of 2%-4% 1c. Maleate and benzoate salts were recrystallized from ethyl acetate and t-butyl methyl ether, respectively. Xenon exposure with the Atlas SunChex set for 0.4 ± 0.1 watts/m^2. Fluorescent exposure with 1000- ± 100- ft candles.
O = No E was detected.

Aqueous Solubility of Crystalline Salts of 1a

Compounds such as the muscarinic agonist 1a, which are intended for long-term oral administration usually display better systemic bioavailability following oral administration when they are readily soluble in water. Thus, water solubility is another key consideration in identifying a viable salt of 1a. As shown in Table VI, 1a maleate is about 15 times more soluble in water than 1a benzoate.

TABLE VI. Aqueous Solubility of 1a Maleate and Benzoate Salts

	Maleate	Benzoate
Water Solubility (mg/mL, room temp.)	89	6

As evidenced by all the preceding data, the maleate salt of 1a is the only crystalline salt that meets all the criteria set forth for the optimal pharmaceutical development of 1a. While maleate salts are common in the field of pharmaceuticals, the finding that only the maleate salt of 1a, out of more than 25 salts evaluated, is the only salt with the desired physical and chemical properties to allow the pharmaceutical development of 1a is indeed an unexpected discovery.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGURE 1. Isomer Selective Assay

For analytical purposes, the separation of the Compound 1a from 1c was carried out with a 4.6- × 250-mm Zorbax SBCN 5-μm column (PN 880975.905)

on an HP-1090 system with three solvent reservoirs. Conditions for separation were:

Mobile Phase: A = 80%:50 mM TEA adjusted to pH 3 with H_3PO_4.
B = 10%:CH_3CN.
C = 10%:MeOH.

Mobile Flow Rate: 1.5 mL/min
Temperature: RT
Injection Volume: 100 µL
Draw Speed: 83.3 µL/min

Figure 1 shows a typical separation of a sample of 1a maleate containing some of 1c maleate. The first peak at 3.3 minutes is due to the counter-ion maleate while the peaks at 11.3 and 13.0 are due to 1a and 1c, respectively. These identifications were confirmed by NMR. The chromatogram shows a near equilibrium ratio of 1a to 1c of 85.5:14.5.

FIGURES 2 and 3. Effect of Particle Size

Figures 2 and 3 show the order of magnitude difference in the particle size of an ethyl acetate recrystallized maleate salt of the compound (Figure 2) versus the ether-precipitated product (Figure 3). For Figure 2, the range of particle sizes varied from 150 x 10 µm to less than 10 x 10 µm; for the ether-precipitated product in Figure 3, all particles were less than 10 x 10 µm. This product was formed when the free base form of the compound in diethyl ether was mixed with maleic acid in diethyl ether. This type of in situ salt formation produced very fine particles due to rapid precipitation.

The ether-precipitated product (Figure 3) was deliquescent and reverted to its equilibrium ratio of Z- to E-oxime (85%Z-15%E) after 2 weeks at the accelerated stability condition, 40°C/75%RH. The ethyl acetate recrystallized product (Figure 2) reported in

Table II was more stable. This increased stability of the ethyl acetate crystallized form was most likely due to the relatively small total surface area of the larger recrystallized particles (Figure 2) compared to the smaller precipitated particles (Figure 3).

FIGURE 4. Biological Activity

Figure 4 shows a comparison of the oxalate and maleate salts of **1a** in their ability to improve the performance of hippocampally deficient mice in a mouse water maze test (see Jaen, et al., Life Sci ref. and refs. therein for more details on this test).

This test measures the ability of a compound to decrease the amount of time needed by the mice to find a hidden platform in the water pool.

The graph represents two sets of experiments, each one with its own control group. The data demonstrate that the oxalate salt of Compound **1a**, which had been previously used to evaluate the effects of **1a** in the mouse water maze test, can reduce the time required to find the platform by about 18 seconds (at 1 mg/kg). As a positive control, the acetylcholinesterase inhibitor tacrine (THA) produced about a 27-second improvement. In a separate set of experiments, the maleate salt of **1a**, at 1 mg/kg, produced about 20 seconds latency improvement, while the tacrine control group experienced a 24-second improvement. These data demonstrate that no loss of biological activity is experienced with the maleate salt of **1a**, as compared to other salts that have been evaluated.

To assess the potential for the maleate salt of the compound to form polymorphs, crystallization was studied in five different solvent systems: isopropanol/ethanol/pentane, ethanol/pentane, ethanol, chloroform/pentane, and dichloromethane/pentane. The volume of solvent used, percent yield, mp before

recrystallization, and mp after recrystallization are given in Table VI. For each of the experiments in Table VI, 1.0 g of maleate salt of oxime of the compound was dissolved under ambient conditions into the more polar of the solvents in the solvent system. This was followed by slow, incremental addition of pentane until small particulates could be observed. The mixture was then sealed and stored in the refrigerator overnight, followed by cold filtration, pentane rinse, and subjection to high-vacuum. All products are pure by both elemental and HPLC analyses. Powder x-ray diffraction studies on these lots were carried out and based on the data, the maleate salt of the compound crystallized in a variety of solvents showed the same diffraction pattern and the same crystal form. In general, solvents that allow the slow crystallization of the maleate salt lead to larger particle size material, which is more stable under accelerated stability conditions.

The maleate salt was, as discussed above, identified as significantly superior to all other salt forms considered.

TABLE VI. Room Temperature Recrystallizations

Solvent System	Volume (mL/g)	% Yield	MP Before	MP After
Isopropanol-Ethanol-Pentane	202	77.2	116-119	116.5-118
Ethanol-Pentane	125	85.8	116-118	118.5-121
Ethanol	50	50.1	116-118	114-118
Chloroform-Pentane	32.5	83.1	116-118	118-119.5
Dichloromethane-Pentane	13	64.5	116-118	118-120

The preparation of 1a maleate can be achieved in a variety of ways. For example, the pure 1a isomer can be obtained by column chromatography of the approximately 1:1 mixture of 1a and 1c that is obtained

synthetically (US 5,306,718, US 5,346,911, and Tecle, et al., Bio. Org. Med. Chem. Letters 1995(5):631-636). The free base of 1a is typically obtained as an oil or oily solid. This free base can be stored refrigerated at -4°C for up to several days without noticeable decomposition or isomerization to produce 1c. Preparation of the maleate salt typically involves the dissolution of 1a in an organic solvent and the addition of a solution of approximately one molar equivalent of maleic acid in the same solvent. Useful organic solvents for this purpose are, for example, ether solvents, such as diethyl ether, THF, and the like, ethyl acetate, isopropyl acetate and the like, alcohol solvents such as methanol, ethanol, isopropanol, and the like, hydrocarbon solvents such as hexane, benzene, toluene, and the like, and any other organic solvents that do not react with 1a. Preferred solvents include diethyl ether, ethyl acetate, and ethanol. Depending on the choice of solvent, the salt will precipitate immediately from the organic solvent (such as from diethyl ether), or may be recovered by subsequent addition of a second solvent (such as addition of diethyl ether or hexane to a solution of salt in ethanol) or by evaporation of the solvent under reduced pressure. The salts obtained by these procedures typically possess small particle size crystals. Since small particle size leads to increased hygroscopicity, the initial 1a maleate obtained can be recrystallized from an organic solvent or solvent mixtures, taking care of utilizing solvents that do not require heating to induce solubilization of the salt. Examples of useful solvents for this purpose include ethyl acetate, isopropanol, and diethyl ether, although other non-reactive solvents can be utilized, including water and mixtures of water with water-miscible organic solvents. Recrystallization temperatures are typically

kept at or below room temperature, to minimize the possibility of oxime isomerization. In some cases, such as when using non-protic solvents such as ethyl acetate, the recrystallization temperature can be higher than room temperature.

Alternatively, mixtures of various ratios of **1a** and **1c** free bases can be converted to the corresponding mixtures of maleate salts, by procedures similar to those described above for pure **1a**, and which can be recrystallized from organic or aqueous solvents or mixtures of solvents to yield pure **1a** maleate. Solvents of choice for the recrystallization of **1a**/**1c** maleate mixtures include, for example, isopropanol, ethanol, chloroform, dichloromethane, pentane, hexane, ethyl acetate, and the like.

The physical properties of **1a** maleate influence its chemical stability. Deliquescence appears to be a major initiating event. However, particle size of the salt strongly influences deliquescence, due to the larger surface area for exposure to moisture in smaller particles. In addition, contamination of the higher melting point **1a** maleate with the lower-melting **1c** maleate facilitates deliquescence. Thus, increased stability of solid **1a** maleate can be achieved by minimizing the presence of isomeric **1c** as an impurity and by recrystallizing **1a** maleate in such a way that ensures the production of large particle size crystals.

EXAMPLE 1

Preparation of [1:1] maleate salt of [R-(Z)]-1-aza-bicyclo[2.2.1]heptan-3-one, O-[3-(3-methoxyphenyl)-2-propynyl]oxime

Free base [R-(Z)]-1-azabicyclo[2.2.1]heptan-3-one, O-[3-(3-methoxyphenyl)-2-propynyl]oxime (**1a**) (6.8 g, 0.025 mol) was dissolved in ether. Some insoluble white solid was separated by filtration and discarded.

Maleic acid (2.942 g, 0.025 mol) was dissolved in ether. The maleic acid solution was added dropwise into the ether solution of free base while stirring vigorously. The resulting precipitate was separated by filtration, dried in vacuo at 40°C for 16 hours to give 8.93 g (92% yield) of 1a maleate, mp 116.5-118.0°C;
$[\alpha]$ -10.7° (c=0.646, MeOH);
Mass Spectrum: *m/z* 272 (M+1), 271, 174, 145, 109, 99;
IR (KBr): 2926, 2237, 1697, 1618, 1606, 1576, 1487, 1360, 1294, 1208, 1173, 1055, 1030, 916, 870, 779 cm^{-1};
^1H NMR (DMSO-d_6): δ 7.31 (1H, t, J = 7.7 Hz), 7.00 (m, 3H), 6.04 (s, 2H), 4.92 (s, 2H), 4.09 (dd, 2H, J = 2.4 Hz, J = 16.4 Mz), 3.76 (s, 3H), 3.52 (d, 1H, J = 0.001), 3.36 (m, 6H), 2.24 (m, 1H), 1.75 (m, 1H);
^{13}C NMR (DMSO-d_6): δ 26.0, 51.6, 55.7, 55.8, 59.5, 62.4, 85.9, 86.3, 115.9, 116.8, 123.2, 124.4, 130.4, 136.0, 158.5, 159.6, 167.6;
Elemental analysis ($C_{16}H_{18}N_2O_2 \cdot C_4H_4O_4$)
C, 62.17; H, 5.74; N, 7.25;
Found: C, 61.97; H, 5.77; N, 7.15.
HPLC Analysis: 100% 1a, RT = 6.18 min (Column = Altech altima CN 4.5 × 150 cm, 5 μ; Mobile phase = 15% MeOH:AcCN (1:1) and 85% 50 mmol of Et_3N in H_2O; 1.5 mL/min).

EXAMPLE 2

Recrystallization of 1a from ethyl acetate

The maleate salt of 1a (0.6297 g, 1.6 mmol) was dissolved in 13 mL boiling ethyl acetate. Upon cooling to room temperature, white crystals separated out. This was left in the refrigerator for 14 hours. The resulting white crystals were separated by filtration, dried under high vacuum at 50°C yielding 0.528 g (84% recovery) of the recrystallized material, mp 118-119°C;

HPLC, 99.8% 1a, 0.2% 1c (Column = Zorbax CN 4.5 x 250 cm, 5 μ; Mobile phase = 15% MeOH:AcCN (1:1) and 85% 50 mmol of Et_3N; 1.5 mL/min);
[α] -9.5° (c=0.503, MeOH);
MS m/z 272 (M^{+1}), 174, 145, 99, 82;
IR (KBr): 2926, 2237, 1697, 1618, 1606, 1576, 1487, 1360, 1294, 1208, 1173, 1055, 1030, 916, 870, 779 cm^{-1};
^1H NMR (DMSO-d_6): δ 7.31 (t, 1H, J = 7.7 Hz), 7.00 (m, 3H), 6.04 (s, 2H), 4.92 (s, 2H), 4.09 (dd, 2H, J = 2.4 Hz, J = 16.4 Mz), 3.76 (s, 3H), 3.52 (d, 1H, J = 0.01), 3.36 (m, 5H), 2.24 (m, 1H), 1.75 (m, 1H);
^{13}C NMR (DMSO-d_6): 26.0, 51.6, 55.7, 55.8, 59.5, 62.4, 85.9, 86.3, 115.9, 116.8, 123.2, 124.3, 130.4, 136.1, 158.6, 159.5, 167.6.
Elemental analysis ($C_{16}H_{18}N_2O_2 \cdot C_4H_4O_4$):
C, 62.17; H, 5.74; N, 7.25;
Found: C, 61.98; H, 5.69; N, 7.14.

EXAMPLE 3

Room temperature recrystallization of 1a maleate

The maleate salt of 1a (15.02 g) was dissolved in 800 mL of absolute ethanol with stirring under ambient conditions. Pentane (500 mL) was added in 100 mL increments until visual detection of crystallization. Precipitation of a white crystalline solid ensued rapidly. The mixture was diluted with an additional 600 mL of absolute ethanol with vigorous stirring until homogenous. Pentane (1.25 L) was added incrementally until visual detection of a few small crystals. The crystallization flask was sealed and stored in the freezer overnight.

The white crystals were collected by vacuum filtration and dried in a high-vacuum oven (ca. 10 mm Hg; 40°C) for 2 hours to afford 11.96 g (80% recovery) of 1a as a colorless crystalline solid; mp 118-119°C (dec).

HPLC: 99.93% 1a: 0.07% 1c (Column = Altech altima CN 4.5 x 150 cm, 5 μ; Mobile phase = 15% MeOH:AcCN (1:1) and 85% 50 mmol of Et_3N in H_2O; 1.5 mL/min);
^{1}H-NMR (400 MHz; DMSO-d_6): δ 7.31 (t, 1H, J = 7.7 Hz), 7.04-7.00 (m, 2H), 6.99 (s, 1H), 6.06 (s, 2H), 4.93 (s, 2H), 4.19-4.03 (m, 2H), 3.77 (s, 3H), 3.52 (d, 1H, J = 4.1 Hz), 3.45-3.29 (m, 4H), 2.27-2.20 (m, 1H), 1.78-172 (m, 1H) ppm;
MS (CI) M+1 = 271;
IR (KBr): 2926 (w), 2237 (w), 1697 (w), 1575 (s), 1360 (s), 1293 (m), 1207 (s), 1172 (m), 1054 (m), 1029 (m), 960 (w), 915 (m), 871 (m), 780 (m), 755 (w), 685 (w), 647 (w), 584 (w) cm^{-1};
^{13}C-NMR (100 MHz; DMSO-d_6): δ 167.67, 159.60, 158.62, 136.19, 130.41, 124.37, 123.18, 116.82, 115.87, 86.33, 85.92, 62.40, 59.48, 55.79, 55.69, 51.58, 26.02 ppm.
Elemental analysis ($C_{16}H_{18}N_2O_2 \cdot C_4H_4O_4$):
C, 62.17; H, 5.74; N, 7.25;
Found: C, 62.27; H, 5.86; N, 7.23.

CLAIMS

1. (R)-(Z)-1-Azabicyclo[2.2.1]heptan-3-one,O-[3-(3-methoxyphenyl)-2-propynyl]oxime maleate as a pharmaceutical agent.

2. A compound according to Claim 1 wherein the majority of crystal particles are greater than 10 x 10 μm in size.

3. A pharmaceutical composition useful for alleviating pain in a mammal comprising an analgesically effective amount of a compound according to Claim 1 together with a pharmaceutically acceptable carrier.

4. A pharmaceutical composition useful for treating the symptoms of cognitive impairment comprising a therapeutically effective amount of a compound according to Claim 1 together with a pharmaceutically acceptable carrier.

5. A method of alleviating pain in a mammal which comprises administering to said mammal a compound according to Claim 1.

6. A method of treating the symptoms of cognitive impairment in a mammal which comprises administering to said mammal a compound according to Claim 1.