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(57) Abstract

The invention provides a slow release vitreous system comprising a water soluble glass having a softening point of less than 320°C and preferably less than 200°C wherein said water soluble glass has dissolved or admixed therein an active agent such as a pharmaceutical which is stable at the melting point of the glass and which releases to an aqueous environment of use over a predetermined time period.

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SLOW RELEASE VITREOUS SYSTEMS

The present invention relates to slow-release vitreous systems particularly for the release of biologically active materials to an aqueous environment of use over a predetermined time period.

Slow-release systems are well known in the art but tend to be specialised becaused of their inherent expense. Slow-release systems are for example used in the pharmaceutical industry for the administration of biologically active agents to a patient over a predetermined time span at a constant or varying rate depending upon the circumstances. Other slow-release systems are known for other purposes, but all suffer from the inherent expense or lack of flexibility of the slow-release vehicle.

Glass is a relatively cheap material, and the glasses which are water soluble are known. Indeed phosphate glasses have been used to release inorganic substances which are thermostable since the softening point of phosphate glasses is for example 400 - 500^{o}C. These

phosphate glasses have a widely varying dissolution rate depending upon the precise constitution of the watersoluble glass chosen and are hence able to transmit inorganic salts to an environment of use over a predetermined time period.

Low melting point water soluble glasses for example the acetate glasses have been described in The Journal of the American Ceramic Society Vol 52, No. 4 April 1969 Pages 224-225. Further nitrate glasses have been described, as such, in the Journal of The Chemical Society 1969 pages 2398 et seq. It has not however been appreciated that the combination of the low softening point of the acetate and other carboxylates and nitrate type glasses combined with their variable water solubility provides an excellent slow release vehicle for heat-sensitive substances, such as biologically active substances, to an aqueous environment of use.

GB-A-2,182,034 discloses a vitreous system in which organic materials are incorporated in a water soluble glass by forming a sintered porous body and filling the same with an organic material in liquid form.

This disclosure teaches against incorporating organic materials directly into the glass.

According therefore to the present invention there is provided a slow release vitreous system comprising a water soluble glass having a softening point of less than 320°C characterised in that said water soluble glass has dissolved, or admixed therein, an active agent which releases to an aqueous environment of use over a predetermined time period.

Where "glass" describes amorphous material derived for example from carboxylates and nitrates. The active agents, which can be biologically active or nonbiologically active, need be stable only to the temperature of the softening point of the glass (see Table 1). This illustrates the advantages of these glasses: compounds with low decomposition temperatures can be safely entrapped or dissolved with little decomposition.

In a preferred form of the invention the water soluble glass is a carboxylate, nitrate, sulphate or bisulphate glass having a low softening point, e.g. below 200°C.

The glass may be selected from a compound of the formula

$$R^1\ M^1 : R^2\ M^2$$

wherein R^1 and R^2 are the same or different and are selected from

$$(\text{alkyl -COO-})_x$$

wherein x has a value of 1 - 3;

and wherein M^1 and M^2 are the same or different and are selected from H, an alkali metal or an alkaline earth metals or a chemically appropriate metal such as lead or zinc.

In a preferred embodiment of the foregoing formula; R^1 and R^2 may be CH_3 COO-; the preferred substituent for M^1 and M^2 are lithium, sodium, potassium, calcium, lead or zinc.

In a further aspect of the invention the glass selected is made from either a single salt or a mixture of salts or a mixture of salts and acids having general formula

$$m_1(M^1A^1{}_a):m_2(M^2A^2{}_b):m_3(M^3A^3_c):\ldots$$

wherein M^1 , M^2, M^3... are the same or different and are selected from H, alkali metals or alkaline earth metals or a chemically appropriate metal such as zinc or lead wherein A^1, A^2 , A^3 ... are the same or different and are selected from carboxylates preferably chiral carboxylates, such as tartrates nitrate, sulphate or bisulphate; wherein a, b, c ... depend on the valencies of M^1, M^2, M^3... and A^1, A^2, A^3 ...; wherein m_1, m_2, m_3 ... are the same or

different.

The invention is further characterised by a method for the production of a slow-release system which method comprises;

selecting a water soluble glass having an appropriate softening point below 320°C and preferably below 200°C; carefully heating said selected glass to its softening temperature,

causing said softened glass to come into intimate contact with an active agent thereby to cause the active agent to be dissolved by, or be admixed therein,

subsequently cooling said system; whereby on exposure of the cooled system to an aqueous environment of use, the glass dissolves to release the active agent over a predetermined time period.

The glasses as just described may be coated with a coating material to further modify the slow-release rate of the active agent to the environment of use. The shape and geometry of the water soluble glass may also be adjusted to alter the release rates.

The coating material as just described may be a phosphate glass or any selected polymeric material so chosen as to give a desired rate of agent release (see Table 2 below).

The geometry of the system in accordance with the present invention is important. It will be appreciated that the larger the system particle, the smaller the total surface area and hence the slower the release rate in aqueous environment of use. Thus physically relatively large slow-release systems in accordance with the present invention will release the active agent to the environment of use slower than small particles. Thus the constant release rate to an environment of use can be achieved over a long time period by not only selecting the materials from which the release systems are made, but also by altering the

relative particle sizes in a mixture applied to an environment of use.

Further the geometry of the slow-release system in accordance with the present invention may be configured to adjust the output rate of the active agent to an environment of use by altering the rate at which readily soluble glass is exposed for dissolution. Thus for example it is possible to form a multi-layer system wherein layers of the water soluble glass in accordance with the present invention are overlaid by a phosphate glass or other polymeric material. It will be appreciated that the relative thicknesses of the layers can be adjusted to achieve a desired dissolution rate.

Alternatively a multi-layer system may be achieved by providing a central core of the water soluble glass in accordance with the present invention, overlaid by, for example, a coating of a phosphate glass. The relative diameter of the central core which need not be uniform throughout its length, can be adjusted to provide a desired predetermined dissolution rate.

The active agents in accordance with the present invention may for example be pharmaceutically active agents such as hormones and amino-acids, for administration to agriculturally significant animals for example to ruminants. Alternatively the active agents may be any suitable pharmaceutical agent such as an antibiotic which can be administered to a patient for slow-release.

Alternatively slow-release systems of the present invention can be provided with pheromones which can be utilized to attract specific insects to a specific site. By way of example the pheromones can be specific to an insect which is a pest on a particular crop. Tomatoes for example can be cleared of insect pests in a closed tomato growing area without application of toxic materials to the plants themselves. Since pheromones are specific to insects of a particular sex as well as a particular type, it is also possible to separate males and females of a particular species by this method.

In a further aspect of the invention for which a nitrate glass may be used, fertilizers are formed with nitrogen, phosphorus, and potassium for administration to a crop in a seed bed preferably in a single pass operation. Further the slow-release systems in accordance with the present invention of this type may also include insecticides, fungicides, or other pesticides in general which act to protect the crop during its growing season, (about three or four months), without the necessity for regular spraying.

It is envisaged that slow-release systems in accordance of this type will be incoporated into the seed bed at the same time as the seed are sown thereby providing long term protection from pest attack as well as fertilization throughout its growing period.

The invention is also suitable for the slow-release of descaling agents for pipes and boilers and for the slow-release of bactericidal agents to water storage systems for the prevention, for example, of Legionella . The systems in accordance with the

present invention may also be utilized as wood preservatives for in situ applications.

The invention will now be described, by way of illustration only in the following examples of the invention.

Example 1

Carboxylate glasses were formed by standard methods to have the following consitution as shown in Table 1.

Table 1

Carboxylate Glasses

Glass	Mole Ratio	Softening Temperature °C
$CH_3CO_2Li:CH_3CO_2Na$	1.33:1	160
$CH_3CO_2K:(CH_3CO_2)_2Ca$	1:1	270
$CH_3CO_2Na:(CH_3CO_2)_2Ca$	1:1	310
" "	2:1	-
$CH_3CO_2K:(CH_3CO_2)_2Ca$	2:1	-
$CH_3CO_2Li:(CH_3CO_2)_2Pb$	1:1	-
$(CH_3CO_2)_2Pb:CH_3CO_2K$	3:1	-
$CH_3CO_2Na:(CH_3CO_2)_2Zn$	1:1	180
$CH_3CO_2K:(C_2H_5CO_2)_2Ca:C_4H_9CO_2Na$	1:1:1	150
$CH_3CO_2K:(CH_3CO_2)_2Ca:C_7H_{15}CO_2Na$	2:2:1	150
$(CH_3CO_2)_2Ca:C_{15}H_{31}CO_2Na$	3:4	150

Glasses of this type were softened to their softening temperatures and active lactones and esters were incorporated thereinto. These were subsequently recovered from the carboxylate glasses so formed by dissolving the same in an aqueous solution and extracting the target substance from the solution so formed. It was found that the lactones and esters were substantially recoverable.

Selected carboxylate glasses of Table 1 in the form of a rod were then coated with a phosphate glass in accordance with Table 2.

Table 2

Examples of Phosphate coatings

Glass Composition	Ratio	Softening Temperature ^{o}C	Dis-solution Rate*
$Na_2O:P_2O_5$	1:1	440	24 mins
$Na_2O:CaO:P_2O_5$	2:2:3	-	8 hrs 20 mins
$K_2O:CaO:P_2O_5$	2:2:3	560	5 days
$K_2O:CaO:P_2O_5$	4:2:5	480	1 hr 10 mins
$K_2O:Na_2O:P_2O_5$	1:2:2	-	14 mins
$Li_2O:ZnO:P_2O_5$	1:3:6	<400	31 days
$Li_2O:ZnO:P_2O_5$	2:1:7		4.9 days
$Li_2O:ZnO:MgO.P_2O_5$	2:1:0.2:6.8	<400	25 hrs
$Li_2O:ZnO:BaO:NaF:P_2O_5$	1.95:0.65:0.65:0.25:6.5	370	
$Na_2O:CaO:MgO:P_2O_5$	4.4:0.6:0.5:4.5	320	No significant loss in weight after 20 hours
$Na_2O:ZnO:P_2O_5$	2:1.5:6.5	370	69 days
$Li_2O:ZnO:Na_2O:P_2O_5$	1:1.5:1.5:6	380	No significant loss in weight after 20 hrs
$MgO:ZnO:P_2O_5$	0.5:0.5:9	-	-
$K_2O:MgO:ZnO:P_2O_5$	-	-	-

* Rate at which a tablet of glass (1 g, 450-550 mm^2) dissolves to 50% of its original mass in 200 mls of water.

The rod was exposed to the atmosphere at each end of the structure so formed. By selection of the phosphate glasses as shown, a dissolution rate could be adjusted to be between 24 minutes and 70 days. Since the dissolution rate of the acetate glasses is faster than that of the phosphate glasses in general it will be noted that the slow-release system can be adjusted to release its bolus within any desired time frame. Further by altering the relative geometry of the coating and the core it is possible to release more or less active agent to the enviroment of use over a predetermined portion of the time frame.

The invention therefore comprehends not only a slow-release system and a method for the production thereof, but a method of administering an active agent to an environment of use, said enviroment of use being agricultural, veterinary, human or industrial.

CLAIMS

1. A slow release vitreous system comprising a water soluble glass having a softening point of less than 320°C;

characterised in that said water soluble glass has dissolved or admixed therein an active agent which is stable at the melting point of the glass and which releases to an aqueous environment of use over a predetermined time period.

2. A system according to claim 1 characterised in that the glass is a carboxylate, nitrate, sulphate or bisulpate glass having a softening point below 200°C.

3. A system according to either of claims 1 or 2 characterised in that the glass is selected from a compound of the formula

$$R^1 M^1 : R^2 M^2$$

wherein R^1 and R^2 are the same or different and are selected from (alkyl -COO-)$_x$ wherein x has a value of 1 - 3,

and wherein M^1 and M^2 are the same or different and are selected from H, an alkali metal or an alkaline earth metal or a chemically appropriate metal.

4. A system according to claim 3 characterised in that the chemically appropriate metal is lead or zinc.

5. A system according to either of claims 1 or 2 characterised in that the glass is selected from a single salt or mixture of salts with or without acids of the general formula:

$$m_1(M^1A^1{}_a):m_2(M^2A^2{}_b):m_3(M^3A^3_c):\ldots$$

wherein M^1, M^2, M^3... are the same or different and are selected from H, alkali metals or alkaline earth metals or a chemically appropriate metal

wherein A^1, A^2 , A^3 ... are the same or different and are selected from carboxylates nitrates, sulphates or bisulphates and

wherein a, b, c ... depend upon the valencies of M and A and wherein m_1, m_2, m_3 ... are the same or different.

6. A system according to any preceding claim characterised in the vitreous glass as defined is coated with a phosphate glass having a predetermined solution rate.

7. A system according to any preceding claim characterised in that the geometry of the vitreous system is configured to adjust the output rate of the active agent to the aqueous environment of use by adjusting the rate at which readily soluble glass is exposed for dissolution.

8. A system according to claim 7 characterised in that the system is a multilayer system comprising layers of water soluble glass according to any of

claims 1 to 5 overlaid by a phosphate glass of claim 6 or other polymeric material; thereby to adjust rates of dissolution to a desired pattern.

9. A system according to claim 7 characterised in that the system is formed of a central core coated with a phosphate class of claim 6.

10. A system according to any preceding claim characterised in that the active agent is selected from a hormone, an amino acid, an antibiotic, a bacteriocide or an agricultural chemical.

11. A method for the controlled release an agricultural, horticultural, or pharmaceutical active agent to an environment of use which comprises delivering such an agent to said environment when dissolved or intimatedly admixed in a vitreous system according to any of claims 1 to 10.

12. A method for the production of a slow-release vitreous system which method comprises:-

selecting a water soluble glass having an appropriate softening point below 320°C, carefully heating said selected glass to its softening temperature,

causing said softened glass to come into intimate contact with an active agent thereby to cause the active agent to be dissolved by, or be admixed therein,

subsequently cooling said system; whereby on exposure of the cooled system to an aqueous environment of use, the glass dissolves to release the active agent over a predetermined time period.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/00497

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[5]: A 61 K 9/20, C 03 C 4/00, C 03 C 3/12

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[5]	A 61 K, C 03 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	EP, A, 0009338 (INTERNATIONAL STANDARD ELECTRIC CORPORATION) 2 April 1980 see claims 1,2,3; page 4, lines 10-14; example 1 --	1-5
X	FR, A, 2521835 (UNIVERSITY OF LEEDS INDUSTRIAL SERVICES) 26 August 1983 see claim 1 --	1
A	Chemical Abstracts, vol. 108, 1988 (Columbus, Ohio, US) see page 322, abstract no. 61225x, & SU, A, 1351978 (URAL POLYTECHNIC INSTITUTE) 15 November 1987 --	5
A	US, A, 3649551 (R.F. BARTHOLOMEW) 14 March 1972 see claims 1-7; column 4, lines 5,6 --	3,4 ./.

* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
31st July 1990	06 SEP 1990
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	Mme N. KUIPER

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,X	Glass Technology, vol. 30, no. 5, October 1989 (Sheffield, GB) J.A. Blair et al.: "Acetate glasses for the slow release of thermally unstable materials", pages 190-191, see page 190	1-5,10,11

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9000497 SA 35709

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 28/08/90
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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