

ESTTA Tracking number: **ESTTA820050**

Filing date: **05/10/2017**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

Notice of Opposition

Notice is hereby given that the following parties oppose registration of the indicated application.

Opposers Information

Name	Federal Cartridge Company
Granted to Date of previous extension	05/10/2017
Address	900 Ehlen Drive Anoka, MN 55303 UNITED STATES

Name	Vista Outdoor Operations LLC
Granted to Date of previous extension	05/10/2017
Address	262 North University Drive Farmington, UT 84025 UNITED STATES

Attorney information	Stephen R. Baird Winthrop & Weinstine, P.A. 225 South Sixth Street Capella Tower Suite 3500 Minneapolis, MN 55402 UNITED STATES trademark@winthrop.com Phone:612-604-6585
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Applicant Information

Application No	85947962	Publication date	01/10/2017
Opposition Filing Date	05/10/2017	Opposition Period Ends	05/10/2017
Applicant	Hodgdon Powder Company, Inc. 6430 Vista Dr Shawnee, KS 66218 UNITED STATES		

Goods/Services Affected by Opposition

Class 013. First Use: 2008/07/01 First Use In Commerce: 2008/07/01
All goods and services in the class are opposed, namely: Preformed gunpowder charges for muzzle-loading firearms

Grounds for Opposition

The mark is merely descriptive	Trademark Act Section 2(e)(1)
The mark comprises matter that, as a whole, is functional	Trademark Act Section 2(e)(5)

No use of mark in commerce before application or amendment to allege use was filed	Trademark Act Sections 1(a) and (c)
Failure to function as a mark	Trademark Act Sections 1, 2 and 45
The mark is not inherently distinctive and has not acquired distinctiveness	Trademark Act Sections 1, 2 and 45; and Section 2(f)

Attachments	Notice of Opposition Hodgdon Powder Company Inc. 18748-2747.pdf(112385 bytes) Exhibits Notice of Opposition Hodgdon Powder 18748-2747.pdf(2486120 bytes)
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Signature	/Timothy D. Sitzmann/
Name	Timothy D. Sitzmann
Date	05/10/2017

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD**

In the matter of Application Serial No.: 85/947,962
Filed: May 31, 2013
Published in the *Trademark Official Gazette* on January 10, 2017

Vista Outdoor Operations LLC and
Federal Cartridge Company

Opposers,

v.

Opposition No. _____

Hodgdon Powder Company, Inc.

Applicant.

NOTICE OF OPPOSITION

Vista Outdoor Operations LLC (“Vista Outdoor”) and Federal Cartridge Company (“Federal Cartridge”) (Vista Outdoor and Federal Cartridge are collectively referred to herein as “Opposers”) believe that they will be damaged by registration of the claimed mark shown in Application Serial No. 85/947,962 (the “Application”) and hereby oppose the same.

The grounds for opposition are as follows:

Vista Outdoor and Federal Cartridge

1. Opposers Federal Cartridge and Vista Outdoor are related companies.
2. Opposers develop, market, and sell gunpowder, ammunition, ammunition components, and other hunting and shooting products.
3. Applicant and Opposers are competitors in the hunting and shooting industry.

Applicant and the Application

4. Upon information and belief, Hodgdon Powder Company, Inc. (“Applicant”) develops, manufactures, and sells a variety of gunpowder products.

5. Applicant filed the Application on May 31, 2013 seeking to register its claimed mark “the color white applied to gunpowder” in connection with “Preformed gunpowder charges for muzzleloading firearms” (“Applicant’s Goods”) in International Class 13.

6. Applicant describes its claimed mark in the Application as “the color white applied to gunpowder” (“Applicant’s Claimed Mark”).

7. The Application does not identify any specific shade of white.

8. The Application was published for opposition in the *Trademark Official Gazette* on January 10, 2017.

9. On February 9, 2017, Vista Outdoor filed a Request for Extension of Time to Oppose the Application. The Board granted this request on February 9, 2017, extending the filing period to May 10, 2017.

10. On February 9, 2017, Federal Cartridge filed a Request for Extension of Time to Oppose the Application. The Board granted this request on February 9, 2017, extending the filing period to May 10, 2017.

11. This Notice of Opposition is timely filed.

Gunpowder and Applicant’s Claimed Goods

12. The traditional constituents of gunpowder are saltpeter, sulfur, and a carbon source such as charcoal.

13. In traditional gunpowder, sulfur and carbon act as fuels.

14. In traditional gunpowder, saltpeter acts as an oxidizer.

15. Saltpeter for gunpowder is white in appearance.

16. Another name for saltpeter is potassium nitrate.

17. Potassium nitrate is white in appearance.

18. Sulfur for gunpowder is yellow in appearance.
19. Elemental carbon for gunpowder is a shade of black in appearance.
20. Charcoal for gunpowder is a shade of black in appearance.
21. The presence of sulfur in gunpowder causes corrosive residue in gun barrels.
22. The presence of charcoal or other carbon sources in gunpowder may cause black residue in gun barrels.
23. The color white is synonymous with cleanliness.
24. The color white communicates cleanliness.
25. The color white indicates cleanliness.
26. Upon information and belief, consumers likely believe that products having a white color are cleaner than products having a black color.
27. The color white creates a visual contrast with materials that are darkly colored.
28. The barrels of guns are often dark colors.
29. White gunpowder creates a visual contrast with dark colored gun barrels.
30. White gunpowder is more easily visible in a gun barrel than black powder.
31. Upon information and belief, Applicant removed sulfur and carbon from the three traditional constituents of gunpowder to create the composition for the goods Applicant sells in connection with Applicant's Claimed Mark.
32. Upon information and belief, in manufacturing the goods Applicant sells in connection with Applicant's Claimed Mark, Applicant has omitted sulfur and carbon.
33. Upon information and belief, in manufacturing the goods Applicant sells in connection with Applicant's Claimed Mark, Applicant has omitted sulfur and carbon in favor of other ingredients.

34. Upon information and belief, the “other ingredients” referenced in Paragraph 33 are colorless or white in appearance.

35. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is dextrin.

36. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is potassium nitrate.

37. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is potassium perchlorate.

38. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is tricalcium phosphate.

39. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is sodium benzoate.

40. Upon information and belief, one of the “other ingredients” referenced in Paragraph 33 is sodium m-nitrobenzoate.

41. Attached as Exhibit A is a true and correct printout of the website available at <https://en.wikipedia.org/wiki/Dextrin>.

42. Page 1 of the printout attached as Exhibit A identifies the appearance of dextrin to be a white or yellow powder.

43. Dextrin is a white or yellow powder in appearance.

44. Some dextrin is white in appearance.

45. Upon information and belief, the dextrin used in producing Applicant’s preformed gunpowder charges featuring Applicant’s Claimed Mark is white in appearance.

46. Attached as Exhibit B is a true and correct printout of the website available at https://en.wikipedia.org/wiki/Potassium_nitrate.

47. Page 1 of the printout attached as Exhibit B identifies the appearance of potassium nitrate to be a white solid.

48. Potassium nitrate is white in appearance.

49. Attached as Exhibit C is a true and correct printout of the website available at https://en.wikipedia.org/wiki/Potassium_perchlorate.

50. Page 2 of the printout attached as Exhibit C identifies the appearance of potassium perchlorate to be a colourless/ white crystalline powder.

51. Potassium perchlorate is colorless or white in appearance.

52. Upon information and belief, the potassium perchlorate used in producing Applicant's preformed gunpowder charges featuring Applicant's Claimed Mark is white in appearance.

53. Attached as Exhibit D is a true and correct printout of the website available at https://en.wikipedia.org/wiki/Tricalcium_phosphate.

54. Page 1 of the printout attached as Exhibit D identifies the appearance of tricalcium phosphate to be a white amorphous powder.

55. Tricalcium phosphate is white in appearance.

56. Attached as Exhibit E is a true and correct printout of the website available at https://en.wikipedia.org/wiki/Sodium_benzoate.

57. Page 1 of the printout attached as Exhibit E identifies the appearance of sodium benzoate to be a white or colorless crystalline powder.

58. Sodium benzoate is white or colorless in appearance.

59. Upon information and belief, the sodium benzoate used in producing Applicant's preformed gunpowder charges featuring Applicant's Claimed Mark is white in appearance.

60. Sodium m-nitrobenzoate is white or colorless in appearance.

61. Upon information and belief, the sodium m-nitrobenzoate used in producing Applicant's preformed gunpowder charges featuring Applicant's Claimed Mark is white or colorless in appearance.

62. Upon information and belief, each of the ingredients for the goods Applicant sells in connection with Applicant's Claimed Mark is colorless or white in appearance.

63. Upon information and belief, the required ingredients for the goods Applicant sells in connection with Applicant's Claimed Mark are all colorless or white in appearance.

64. Upon information and belief, the natural result of combining the chosen ingredients for the goods Applicant sells under Applicant's Claimed Mark is a product that is white in appearance.

65. Upon information and belief, the natural result of combining the chosen ingredients for the goods Applicant sells under Applicant's Claimed Mark is a product that is white in color.

66. Upon information and belief, Applicant has not introduced a dye to the goods Applicant sells under Applicant's Claimed Mark.

67. Upon information and belief, Applicant has not introduced a colored dye to the goods Applicant sells under Applicant's Claimed Mark.

68. Upon information and belief, Applicant has not introduced a coloring agent to the goods Applicant sells under Applicant's Claimed Mark.

69. Upon information and belief, Applicant has not introduced a colorant to the goods Applicant sells under Applicant's Claimed Mark.

70. Upon information and belief, Applicant has not introduced a pigment to the goods Applicant sells under Applicant's Claimed Mark.

71. Upon information and belief, Applicant has not included a dye in the goods Applicant sells under Applicant's Claimed Mark.

72. Upon information and belief, Applicant has not included a colored dye in the goods Applicant sells under Applicant's Claimed Mark.

73. Upon information and belief, Applicant has not included a coloring agent in the goods Applicant sells under Applicant's Claimed Mark.

74. Upon information and belief, Applicant has not included a colorant in the goods Applicant sells under Applicant's Claimed Mark.

75. Upon information and belief, Applicant has not included a pigment in the goods Applicant sells under Applicant's Claimed Mark.

76. Upon information and belief, Applicant has not applied a dye to the goods Applicant sells under Applicant's Claimed Mark.

77. Upon information and belief, Applicant has not applied a colored dye to the goods Applicant sells under Applicant's Claimed Mark.

78. Upon information and belief, Applicant has not applied a coloring agent to the goods Applicant sells under Applicant's Claimed Mark.

79. Upon information and belief, Applicant has not applied a colorant to the goods Applicant sells under Applicant's Claimed Mark.

80. Upon information and belief, Applicant has not applied a pigment to the goods Applicant sells under Applicant's Claimed Mark.

81. Upon information and belief, Applicant has not applied the color white to the goods Applicant sells under Applicant's Claimed Mark.

Applicant's Utility Patent

82. Applicant is the owner of U.S. utility patent 7,914,633 (the "Patent").

83. Attached hereto as Exhibit F are true and correct copies of excerpts of the Patent.

84. The invention identified in the Patent is entitled WHITE PROPELLANT COMPOSITIONS.

85. Gunpowder is a type of propellant.

86. Blackpowder is a type of propellant.

87. The invention identified in the Patent covers a composition that can be used to manufacture "preformed gunpowder charges for muzzleloading firearms."

88. The Patent includes the following statement in Column 2, lines 36-41 "At the same time, the need remains for propellant compositions which solve the many disadvantages and drawbacks of corrosiveness and cleaning difficulty associated with blackpowder and conventional blackpowder substitutes such as Pyrodex powder."

89. The Patent includes the following statement in Column 2, lines 55-59: "Another object of the invention is to provide a propellant composition of the character described which is white in color and free of elemental carbon to eliminate the presence of black residues associated with conventional blackpowder and blackpowder substitutes."

90. The Patent includes the following statement in Column 6, lines 38-44 "A small amount of carbon black may serve as a colorant in the propellant formulations. Blackpowder traditionalists and muzzleloading enthusiasts expect substitute powders to have a pleasing black color. Accordingly, an appropriate color shade may be achieved by adding up 0.5% by weight carbon black to the propellant formulations of this invention."

91. The Patent includes the following statement in Column 57, lines 66-67 and Column 58, lines 62-65 “Thus, two of the three traditional constituents of blackpowder can be omitted utilizing our new formulations. Sulfur and carbon have accounted for many of the problems associated with blackpowder since the products of combustion form corrosive sulfur compounds and black carbonaceous residues.”

92. The Patent includes the following statement in Column 73, lines 56-63 “Having thus described our invention, we claim: 1. A white propellant composition free of elemental sulfur and elemental carbon.”

93. The invention identified in the Patent includes as an aspect of the invention propellants that are white in color.

94. Upon information and belief, gunpowder manufactured pursuant to the invention identified in the Patent only becomes a non-white color if colorants or coating agents are added.

95. Colorants add additional steps to the manufacturing process.

96. Coating agents add additional steps to the manufacturing process.

97. Applicant did not disclose the Patent during prosecution of the Application.

Count I: Functionality

98. Opposers restate and incorporate by reference the allegations in Paragraphs 1-97.

99. Upon information and belief, Applicant’s Claimed Mark is covered by a utility patent.

100. One aspect of the invention identified in the Patent is a white propellant composition free of elemental sulfur and elemental carbon.

101. Upon information and belief, the white appearance of the propellant composition sold under Applicant's Claimed Mark is the natural result of manufacturing Applicant's Goods according to the invention disclosed in the Patent.

102. Upon information and belief, the propellant composition Applicant sells under Applicant's Claimed Mark omits two traditional constituents of gunpowder that are not white in appearance.

103. Upon information and belief, the propellant composition Applicant sells under Applicant's Claimed Mark omits two traditional constituents of gunpowder that are not white in color.

104. Upon information and belief, the propellant composition Applicant sells under Applicant's Claimed Mark removes the traditional constituents for gunpowder that are not white.

105. Upon information and belief, manufacturing non-white propellants according to the invention identified in the Patent requires additional manufacturing steps.

106. Upon information and belief, manufacturing non-white propellants according to the invention identified in the Patent requires additional material.

107. Upon information and belief, manufacturing non-white propellants according to the invention identified in the Patent results in additional cost.

108. Upon information and belief, manufacturing white propellants according to the invention identified in the Patent is simpler than manufacturing non-white propellants pursuant to the invention identified in the Patent.

109. Upon information and belief, manufacturing white propellants according to the invention identified in the Patent is cheaper than manufacturing non-white propellants pursuant to the Patent.

110. Upon information and belief, the color of gunpowder could affect the quality of the gunpowder.

111. Upon information and belief, the color of gunpowder could affect the cost of the gunpowder.

112. Gunpowder that has a white color creates a visual contrast with dark colored gun barrels.

113. White gunpowder is more easily visible in a gun barrel than black powder.

114. Applicant has touted gunpowder featuring Applicant's Claimed Mark in advertisements as "clean burning."

115. Applicant has touted gunpowder featuring Applicant's Claimed Mark in advertisements as providing "easy clean-up."

116. Upon information and belief, gunpowder featuring Applicant's Claimed Mark provides utilitarian advantages over gunpowder that is not white in color.

117. Upon information and belief, consumers may prefer white gunpowder over other colors of gunpowder for non-reputation related reasons.

118. Upon information and belief, manufacture of gunpowder featuring Applicant's Claimed Mark affects the cost of Applicant's gunpowder.

119. Upon information and belief, manufacture of gunpowder featuring Applicant's Claimed Mark affects the quality of Applicant's gunpowder.

120. Upon information and belief, it is easier to change the color of a white propellant composition for use with muzzleloading rifles than it is to change the color of traditional gunpowder or black powder.

121. Upon information and belief, it is easier to modify the color of a white propellant composition for use with muzzleloading rifles than it is to modify the color of traditional gunpowder or black powder.

122. Upon information and belief, it is easier to alter the color of a white propellant composition for use with muzzleloading rifles than it is to alter the color of traditional gunpowder or black powder.

123. Upon information and belief, gunpowder that is white in color enables greater variety of product options.

124. Granting to Applicant federal registration of Applicant's Claimed Mark for Applicant's Goods would put Opposers and competitors of Applicant at a significant non-reputational related disadvantage.

125. The mark comprises matter that, as a whole, is functional and is therefore barred from registration under Section 2(e)(5) of the Lanham Act.

Count II: Applicant's Claimed Mark Fails to Function as a Mark

126. Opposers restate and incorporate by reference the allegations in Paragraphs 1-125.

127. Upon information and belief, the color white communicates information to consumers that is not source identifying.

128. Upon information and belief, consumers understand the color white to indicate cleanliness.

129. Upon information and belief, white is the symbolic opposition of black.

130. Upon information and belief, consumers will perceive Applicant's Claimed Mark as improving cleanliness rather than indicating a particular source.

131. Upon information and belief, consumers encountering Applicant's Goods featuring Applicant's Claimed Mark will not perceive the color white as a source-identifier.

132. Applicant's Claimed Mark fails to function as an indicator of source.

133. Applicant's Claimed Mark is not perceived as an indicator of source.

134. Applicant's Claimed Mark is incapable of functioning as an indicator of source.

135. Applicant's Claimed Mark comprises matter that fails to function as a mark and is therefore barred from registration under Sections 1, 2 and 45 of the Lanham Act.

Count III: Applicant's Claimed Mark Is Not Distinctive and Has Not Acquired Distinctiveness

136. Opposers restate and incorporate by reference the allegations in Paragraphs 1-135.

137. Upon information and belief, Applicant's Claimed Mark is functional and incapable of acquiring distinctiveness.

138. Applicant's Claimed Mark comprises matter that is not inherently distinctive.

139. Upon information and belief, consumers do not recognize Applicant's Claimed Mark as a source identifier.

140. Upon information and belief, the color white is not applied to Applicant's Goods.

141. Upon information and belief, the color white is a natural result of Applicant's manufacturing process for Applicant's Goods sold under Applicant's Claimed Mark.

142. Upon information and belief, Applicant has never used Applicant's Claimed Mark because Applicant's Claimed Mark is limited to the color white applied to gunpowder.

143. Upon information and belief, Applicant's Claimed Mark has not acquired distinctiveness in the minds of consumers.

144. Upon information and belief, multiple third-parties other than Applicant have developed gunpowder that is white in color.

145. Upon information and belief, multiple third-parties other than Applicant have sold gunpowder that is white in color.

146. Upon information and belief, any use of Applicant's Claimed Mark in connection with Applicant's Goods has not been substantially exclusive.

147. Applicant's Claimed Mark is not registrable under Section 2(f) of the Lanham Act.

148. Applicant's Claimed Mark is barred from registration under Sections 1, 2, and 45 of the Lanham Act.

149. Because Applicant's Claimed Mark is functional, fails to function as a mark, is non-distinctive, is incapable of acquired distinctiveness, and has not acquired distinctiveness, registration of Applicant's Claimed Mark would harm Opposers and other competitors of Applicant, making registration of Applicant's Claimed Mark in the Application improper, warranting registration refusal under Sections 1, 2, and 45 of the Lanham Act.

Count IV: Application is Void Ab Initio Based on Non-Use

150. Opposers restate and incorporate by reference the allegations in Paragraphs 1-149.

151. The Application defines Applicant's Claimed Mark as "the color white applied to gunpowder."

152. Upon information and belief, Applicant's gunpowder is naturally white based upon the natural color of the constituent elements of the goods.

153. Upon information and belief, Applicant does not apply the color white to Applicant's Goods.

154. Upon information and belief, Applicant had not applied the color white to Applicant's Goods on or before the day Applicant filed the Application with the U.S. Patent and Trademark Office.

155. Upon information and belief, Applicant has never applied the color white to Applicant's Goods.

156. Upon information and belief, the Application is void ab initio because Applicant had not used Applicant's Claimed Mark in commerce on or before the date Applicant filed the Application.

WHEREFORE, Opposers request that the Trademark Trial and Appeal Board:

- 1) Sustain this Opposition;
- 2) Refuse registration of the mark identified in Application Serial No. 85/947,962 for the goods identified in International Class 13; and
- 3) Grant Opposers any further relief the Board deems equitable.

Dated: May 10, 2017

WINTHROP & WEINSTINE, P.A.

A handwritten signature in black ink, reading "Tim Sitzmann", written over a horizontal line.

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Attorneys for Vista Outdoor Operations
LLC and Federal Cartridge Company

Exhibit A

Dextrin

From Wikipedia, the free encyclopedia

Dextrins are a group of low-molecular-weight carbohydrates produced by the hydrolysis of starch^[1] or glycogen.^[2] Dextrins are mixtures of polymers of D-glucose units linked by α -(1→4) or α -(1→6) glycosidic bonds.

Dextrins can be produced from starch using enzymes like amylases, as during digestion in the human body and during malting and mashing,^[3] or by applying dry heat under acidic conditions (pyrolysis or roasting). The latter process is used industrially, and also occurs on the surface of bread during the baking process, contributing to flavor, color, and crispness. Dextrins produced by heat are also known as **pyrodextrins**. During roasting under acid condition the starch hydrolyses and short chained starch parts partially rebranch with α -(1,6) bonds to the degraded starch molecule.^[4] See also Maillard Reaction.

Dextrins are white, yellow, or brown powders that are partially or fully water-soluble, yielding optically active solutions of low viscosity. Most of them can be detected with iodine solution, giving a red coloration; one distinguishes erythro-dextrin (dextrin that colours red) and achro-dextrin (giving no colour).

White and yellow dextrins from starch roasted with little or no acid are called **British gum**.

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Uses

Yellow dextrins are used as water-soluble glues^[5] in remoistable envelope adhesives and paper tubes, in the mining industry as additives in froth flotation, in the foundry industry as green strength additives in sand casting, as printing thickener for batik resist dyeing, and as binders in gouache paint and also in the leather industry.

White dextrins are used as:

- a crispness enhancer for food processing, in food batters, coatings, and glazes, (INS number 1400).
- a textile finishing and coating agent to increase weight and stiffness of textile fabrics.
- a thickening and binding agent in pharmaceuticals and paper coatings.
- As pyrotechnic binder and fuel, they are added to fireworks and sparklers, allowing them to solidify as pellets or "stars."
- As a stabilizing agent for certain explosive metal azides, particularly Lead(II) azide.

Due to the rebranching, dextrins are less digestible; indigestible dextrin are developed as soluble stand alone fiber supplements and for adding to processed food products.^[6]

Other types

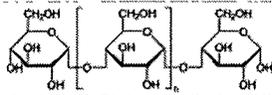
- Maltodextrin

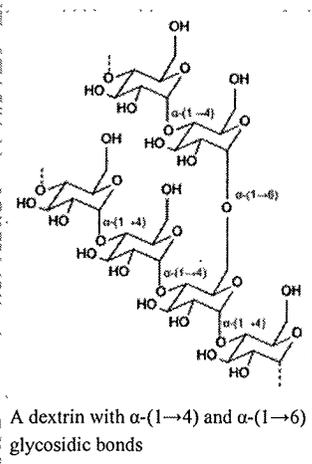
Maltodextrin is a short-chain starch sugar used as a food additive. It is produced also by enzymatic hydrolysis from gelled starch and is usually found as a creamy-white hygroscopic spray dried powder. Maltodextrin is easily digestible, being absorbed as rapidly as glucose, and might either be moderately sweet or have hardly any flavor at all.

- Cyclodextrin

The cyclical dextrins are known as cyclodextrins. They are formed by enzymatic degradation of starch by certain bacteria, for example, *Paenibacillus macerans* (*Bacillus macerans*). Cyclodextrins have toroidal structures formed by 6-8 glucose residues.

- Amylodextrin is a linear dextrin or short chained amylose (DP 20-30) that can be produced by enzymatic hydrolysis of the alpha-1,6 glycosidic bonds or debranching amylopectin. Amylodextrin colors blue with iodine.

Dextrin	
	
Identifiers	
CAS Number	9004-53-9 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=9004-53-9) ✓
ChemSpider	none
ECHA InfoCard	100.029.693 (https://echa.europa.eu/substance-information/-/substanceinfo/100.029.693)
E number	E1400 (additional chemicals)
KEGG	C00721 (http://www.kegg.jp/entry/C00721) ✓
PubChem CID	62698 (https://pubchem.ncbi.nlm.nih.gov/compound/62698)
UNII	2NX48Z0A9G (https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=2NX48Z0A9G) ✓
Properties	
Chemical formula	(C ₆ H ₁₀ O ₅) _n
Molar mass	variable
Appearance	white or yellow powder
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).	
✗ verify (what is ✗ ?)	
Infobox references	



- (Beta) Limit dextrin is the remaining polymer produced by enzymatic hydrolysis of amylopectin with beta amylase, which cannot hydrolyse the alpha-1,6 bonds at branch points.
- (Alpha) Limit dextrin is a short chained branched amylopectin remnant, produced by hydrolysis of amylopectin with alpha amylase.
- Highly branched cyclic dextrin is a dextrin produced from enzymatic breaking of the amylopectin in clusters and using branching enzyme to form large cyclic chains.^[7]

See also

- Brewing
- Cellodextrin, breakdown of cellulose
- Dextrose equivalent
- Icodextrin
- Modified starch
- Starch gelatinization

References

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2. Salway, JG. Medical Biochemistry at a Glance. Second Edition. Malden, MA (Blackwell Publishing), 2006; page 66
3. Michael Lewis, Tom W. Young (2002), "Brewing", Kluwer Academic, ISBN 0-306-47274-0.
4. Alistair M. Stephen, Glyn O. Phillips, Peter A. Williams (2006), "Food polysaccharides and their applications 2nd edition", p 92-99, CRC Press, Taylor & Francis Group, ISBN 0-8247-5922-2
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6. "Types of Fiber and Their Health Benefits".
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External links

- Dextrins (https://www.nlm.nih.gov/cgi/mesh/2011/MB_cgi?mode=&term=Dextrins) at the US National Library of Medicine Medical Subject Headings (MeSH)
- EAFUS (<https://web.archive.org/web/20070701050826/http://www.cfsan.fda.gov:80/~dms/eafus.html>)

 Look up *dextrin* in Wiktionary, the free dictionary.

Retrieved from "<https://en.wikipedia.org/w/index.php?title=Dextrin&oldid=778154782>"

Categories: Edible thickening agents | Food additives | Polysaccharides | Pyrotechnic chemicals | Starch

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Exhibit B

Potassium nitrate

From Wikipedia, the free encyclopedia

Potassium nitrate is a chemical compound with the chemical formula KNO_3 . It is an ionic salt of potassium ions K^+ and nitrate ions NO_3^- , and is therefore an alkali metal nitrate.

It occurs as a mineral niter and is a natural solid source of nitrogen. Potassium nitrate is one of several nitrogen-containing compounds collectively referred to as **saltpeper** or **saltpetre**.

Major uses of potassium nitrate are in fertilizers, tree stump removal, rocket propellants and fireworks. It is one of the major constituents of gunpowder (blackpowder) and has been used since the Middle Ages as a food preservative.

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Etymology

Potassium nitrate, because of its early and global use and production, has many names.

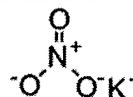
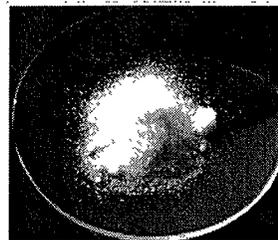
The Greeks used the term *nitron*, which was Latinised to *nitrum* or *nitrium*, while earlier Hebrews and Egyptians used words with the consonants n-t-r, which leads some to speculate that the Latin term is closer to the original than the Greek term. Middle English styled it *nitre*. Old French had *niter*. By the 15th century, Europeans referred to it as *saltpeper*^[6] and later as *nitrate of potash*, as the chemistry of the compound was more fully understood.

The Arabs called it "Chinese snow" (Arabic: *ثلج الصين* *thalj al-ṣīn*). It was called "Chinese salt" by the Iranians/Persians^{[7][8][9][10][11]} or "salt from Chinese salt marshes" (Persian: نمک شورہ چینی *namak shūra chīnī*).^{[12][13]}

Properties

Potassium nitrate has an orthorhombic crystal structure at room temperature, which transforms to a trigonal system at 129 °C (264 °F).

Potassium nitrate^[1]



Names

IUPAC name
Potassium nitrate

Other names
Saltpeper
Saltpetre
Nitrate of potash^[2]

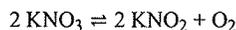
Identifiers

CAS Number	7757-79-1 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=7757-79-1) [✓]
3D model (Jmol)	Interactive image (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5B%5D%2B%5D.%5B%5D%2B%5D%28%5B%5D%29%3D%5B%5D)
ChemSpider	22843 (http://www.chemspider.com/Chemical-Structure.22843.html) [✓]
ECHA InfoCard	100.028.926 (https://echa.europa.eu/substance-information/-/substanceinfo/100.028.926)
EC Number	231-818-8
E number	E252 (preservatives)
KEGG	D02051 (http://www.kegg.jp/entry/D02051) [✓]
PubChem CID	24434 (https://pubchem.ncbi.nlm.nih.gov/compound/24434)
RTECS number	TT3700000
UNII	RU45X2JN0Z (https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=RU45X2JN0Z) [✓]
UN number	1486
InChI	
SMILES	
Properties	
Chemical formula	KNO_3
Molar mass	101.1032 g/mol
Appearance	white solid
Odor	odorless

Potassium nitrate is moderately soluble in water, but its solubility increases with temperature (see infobox). The aqueous solution is almost neutral, exhibiting pH 6.2 at 14 °C (57 °F) for a 10% solution of commercial powder. It is not very hygroscopic, absorbing about 0.03% water in 80% relative humidity over 50 days. It is insoluble in alcohol and is not poisonous; it can react explosively with reducing agents, but it is not explosive on its own.^[3]

Thermal decomposition

Between 550–790 °C (1,022–1,454 °F), potassium nitrate reaches a temperature dependent equilibrium with potassium nitrite:^[14]



History of production

From mineral sources

The earliest known complete purification process for potassium nitrate was outlined in 1270 by the chemist and engineer Hasan al-Rammah of Syria in his book *al-Furusiyya wa al-Manasib al-Harbiyya (The Book of Military Horsemanship and Ingenious War Devices)*. In this book, al-Rammah describes first the purification of *barud* (crude saltpeter mineral) by boiling it with minimal water and using only the hot solution, then the use of potassium carbonate (in the form of wood ashes) to remove calcium and magnesium by precipitation of their carbonates from this solution, leaving a solution of purified potassium nitrate, which could then be dried.^[15] This was used for the manufacture of gunpowder and explosive devices. The terminology used by al-Rammah indicated a Chinese origin for the gunpowder weapons about which he wrote.^[16]

At least as far back as 1845, Chilean saltpeter deposits were exploited in Chile and California, USA.

From caves

A major natural source of potassium nitrate was the deposits crystallizing from cave walls and the accumulations of bat guano in caves.^[17] Extraction is accomplished by immersing the guano in water for a day, filtering, and harvesting the crystals in the filtered water. Traditionally, guano was the source used in Laos for the manufacture of gunpowder for *Bang Fai* rockets.

LeConte

Perhaps the most exhaustive discussion of the production of this material is the 1862 LeConte text.^[18] He was writing with the express purpose of increasing production in the Confederate States to support their needs during the American Civil War. Since he was calling for the assistance of rural farming communities, the descriptions and instructions are both simple and explicit. He details the "French Method", along with several variations, as well as a "Swiss method". N.B. Many references have been made to a method using only straw and urine, but there is no such method in this work.

French method

Niter-beds are prepared by mixing manure with either mortar or wood ashes, common earth and organic materials such as straw to give porosity to a compost pile typically 4 feet (1.2 m) high, 6 feet (1.8 m) wide, and 15 feet (4.6 m) long.^[18] The heap was usually under a cover from the rain, kept moist with urine, turned often to accelerate the decomposition, then finally leached with water after approximately one year, to remove the soluble calcium nitrate which was then converted to potassium nitrate by filtering through the potash.

Swiss method

LeConte describes a process using only urine and not dung, referring to it as the *Swiss method*. Urine is collected directly, in a sandpit under a stable. The sand itself is dug out and leached for nitrates which were then converted to potassium nitrate via potash, as above.

Density	2.109 g/cm ³ (16 °C)
Melting point	334 °C (633 °F; 607 K)
Boiling point	decomposes at 400 °C
Solubility in water	133 g/L (0 °C) 316 g/L (20 °C) 2460 g/L (100 °C) ^[3]
Solubility	slightly soluble in ethanol soluble in glycerol, ammonia
Basicity (p <i>K</i> _b)	15.3 ^[4]
Magnetic susceptibility (<i>χ</i>)	−33.7·10 ^{−6} cm ³ /mol
Refractive index (<i>n</i> _D)	1.335, 1.5056, 1.5604
Structure	
Crystal structure	Orthorhombic, Aragonite
Thermochemistry	
Specific heat capacity (<i>C</i>)	95.06 J/mol K
Std enthalpy of formation (<i>Δ</i> <i>f</i> [∘] ₂₉₈)	−494.00 kJ/mol
Hazards	
Main hazards	Oxidant, Harmful if swallowed, Inhaled, or absorbed on skin. Causes Irritation to Skin and Eye area.
Safety data sheet	See: <i>data page</i> ICSC 0184 (http://www.inchem.org/documents/icsc/icsc/eics0184.htm)
EU classification (DSD)	Oxidant (O)
R-phrases	R8 R22 R36 R37 R38
S-phrases	S7 S16 S17 S26 S36 S41
NFPA 704	
Flash point	Non-flammable
Lethal dose or concentration (<i>LD</i> , <i>LC</i>):	
<i>LD</i> ₅₀ (median dose)	1901 mg/kg (oral, rabbit) 3750 mg/kg (oral, rat) ^[5]
Related compounds	
Other anions	Potassium nitrite
Other cations	Lithium nitrate Sodium nitrate Rubidium nitrate Caesium nitrate
Related compounds	Potassium sulfate Potassium chloride
Supplementary data page	
Structure and properties	Refractive index (<i>n</i>), Dielectric constant (<i>ε</i> _r), etc.
Thermodynamic data	Phase behaviour solid–liquid–gas
Spectral data	UV, IR, NMR, MS
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).	
✖ verify (what is <i>*X</i> ?)	
Infobox references	

From nitric acid

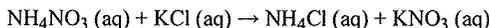
From 1903 until the World War I era, potassium nitrate for black powder and fertilizer was produced on an industrial scale from nitric acid produced via the Birkeland–Eyde process, which used an electric arc to oxidize nitrogen from the air. During World War I the newly industrialized Haber process (1913) was combined with the Ostwald process after 1915, allowing Germany to produce nitric acid for the war after being cut off from its supplies of mineral sodium nitrates from Chile (see nitratite).

Production

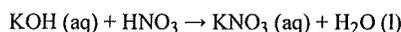
Potassium nitrate can be made by combining ammonium nitrate and potassium hydroxide.



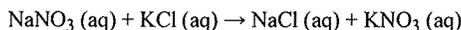
An alternative way of producing potassium nitrate without a by-product of ammonia is to combine ammonium nitrate and potassium chloride, easily obtained as a sodium-free salt substitute.



Potassium nitrate can also be produced by neutralizing nitric acid with potassium hydroxide. This reaction is highly exothermic.



On industrial scale it is prepared by the double displacement reaction between sodium nitrate and potassium chloride.



Uses

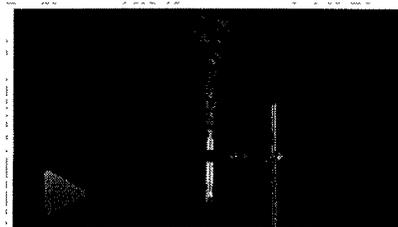
Potassium nitrate has a wide variety of uses, largely as a source of nitrate.

Nitric acid production

Historically, nitric acid was produced by combining sulfuric acid with nitrates such as saltpeter. In modern times this is reversed: nitrates are produced from nitric acid produced via the Ostwald process.

Oxidizer

The most famous use of potassium nitrate is probably as the oxidizer in blackpowder. From the most ancient times through the late 1880s, blackpowder provided the explosive power for all the world's firearms. After that time, small arms and large artillery increasingly began to depend on cordite, a smokeless powder. Blackpowder remains in use today in black powder rocket motors, but also in combination with other fuels like sugars in "rocket candy". It is also used in fireworks such as smoke bombs.^[19] It is also added to cigarettes to maintain an even burn of the tobacco^[20] and is used to ensure complete combustion of paper cartridges for cap and ball revolvers.^[21] It can also be heated to several hundred degrees to be used for niter bluing, which is less durable than other forms of protective oxidation, but allows for specific and often beautiful coloration of steel parts, such as screws, pins, and other small parts of firearms.



A demonstration of the oxidation of a piece of charcoal in molten potassium nitrate.

Food preservation

In the process of food preservation, potassium nitrate has been a common ingredient of salted meat since the Middle Ages,^[22] but its use has been mostly discontinued because of inconsistent results compared to more modern nitrate and nitrite compounds. Even so, saltpeter is still used in some food applications, such as *charcuterie* and the brine used to make corned beef.^[23] When used as a food additive in the European Union,^[24] the compound is referred to as E252; it is also approved for use as a food additive in the USA^[25] and Australia and New Zealand^[26] (where it is listed under its INS number 252).^[3] Although nitrate salts have been suspected of producing the carcinogen nitrosamine, both sodium and potassium nitrates and nitrites have been added to meats in the US since 1925, and nitrates and nitrites have not been removed from preserved meat products because nitrite and nitrate inhibits the germination of *C. botulinum* endospores, and thus prevents botulism from bacterial toxin that may otherwise be produced in certain preserved meat products.^{[27][28]}

Food preparation

In West African cuisine, potassium nitrate (saltpetre) is widely used as a thickening agent in soups and stews such as okra soup^[29] and isi ewu. It is also used to soften food and reduce cooking time when boiling beans and tough meat. Saltpetre is also an essential ingredient in making special porridges, such as *kunun kanwa*^[30] literally translated from the Hausa language as 'saltpetre porridge'. In the Shetland Islands (UK) it is used in the curing of mutton to make "reestit" mutton, a local delicacy.

Fertilizer

Potassium nitrate is used in fertilizers as a source of nitrogen and potassium – two of the macronutrients for plants. When used by itself, it has an NPK rating of 13-0-44.^{[31][32]}

Pharmacology

- Used in some toothpastes for sensitive teeth.^[33] Recently, the use of potassium nitrate in toothpastes for treating sensitive teeth has increased and it may be an effective treatment.^{[34][35]}
- Used historically to treat asthma.^[36] Used in some toothpastes to relieve asthma symptoms.^[37]
- Used in Thailand as main ingredient in kidney tablets to relieve the symptoms of cystitis, pyelitis and urethritis.^[38]
- Combats high blood pressure and was once used as a hypotensive.^[39]

Other uses

- Electrolyte in a salt bridge
- Active ingredient of condensed aerosol fire suppression systems. When burned with the free radicals of a fire's flame, it produces potassium carbonate.^[40]
- Works as an aluminium cleaner.
- Component (usually about 98%) of some tree stump removal products. It accelerates the natural decomposition of the stump by supplying nitrogen for the fungi attacking the wood of the stump.^[41]
- In heat treatment of metals as a medium temperature molten salt bath, usually in combination with sodium nitrite. A similar bath is used to produce a durable blue/black finish typically seen on firearms. Its oxidizing quality, water solubility, and low cost make it an ideal short-term rust inhibitor.^[42]
- To induce flowering of mango trees in the Philippines.^{[43][44]}
- Thermal storage medium in power generation systems. Sodium and potassium nitrate salts are stored in a molten state with the solar energy collected by the heliostats at the Gemasolar Thermosolar Plant. Ternary salts, with the addition of calcium nitrate or lithium nitrate, have been found to improve the heat storage capacity in the molten salts.^[45]

In folklore and popular culture

Potassium nitrate was once thought to induce impotence, and is still falsely rumored to be in institutional food (such as military fare) as an aphrodisiac; however, there is no scientific evidence for such properties.^{[46][47]}

See also

- Nitrocellulose
- Potassium perchlorate

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External links

- International Chemical Safety Card 018402216 (<http://www.inchem.org/documents/icsc/icsc/icsc0184.htm>)



Wikiquote has quotations related to: *Potassium nitrate*

Salts and covalent derivatives of the Nitrate ion

HNO ₃														
LiNO ₃	Be(NO ₃) ₂												B(NO ₃) ₄ ⁻	C
NaNO ₃	Mg(NO ₃) ₂												Al(NO ₃) ₃	Si
KNO ₃	Ca(NO ₃) ₂	Sc(NO ₃) ₃	Ti(NO ₃) ₄	VO(NO ₃) ₃	Cr(NO ₃) ₃	Mn(NO ₃) ₂	Fe(NO ₃) ₃ , Fe(NO ₃) ₂	Co(NO ₃) ₂ , Co(NO ₃) ₃	Ni(NO ₃) ₂	Cu(NO ₃) ₂	Zn(NO ₃) ₂		Ga(NO ₃) ₃	Ge
RbNO ₃	Sr(NO ₃) ₂	Y	Zr(NO ₃) ₄	Nb	Mo	Tc	Ru	Rh	Pd(NO ₃) ₂	AgNO ₃	Cd(NO ₃) ₂	In	Sn	
CsNO ₃	Ba(NO ₃) ₂		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg ₂ (NO ₃) ₂ , Hg(NO ₃) ₂	Tl(NO ₃) ₃ , TlNO ₃	Pb(NO ₃) ₂	
FrNO ₃	Ra(NO ₃) ₂		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	
		↓												
	La(NO ₃) ₃	Ce(NO ₃) ₃ , Ce(NO ₃) ₄	Pr		Nd	Pm	Sm	Eu	Gd(NO ₃) ₃	Tb	Dy	Ho	Er	
	Ac(NO ₃) ₃	Th(NO ₃) ₄	Pa		U(NO ₃) ₂	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	

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Categories: Nitrates | Potassium compounds | Salts | Pyrotechnic oxidizers | Preservatives | Inorganic fertilizers | Oxidizing agents

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Exhibit C

Potassium perchlorate

From Wikipedia, the free encyclopedia

Potassium perchlorate is the inorganic salt with the chemical formula KClO_4 . Like other perchlorates, this salt is a strong oxidizer although it usually reacts very slowly with organic substances. This usually obtained as a colorless, crystalline solid is a common oxidizer used in fireworks, ammunition percussion caps, explosive primers, and is used variously in propellants, flash compositions, stars, and sparklers. It has been used as a solid rocket propellant, although in that application it has mostly been replaced by the higher performance ammonium perchlorate. KClO_4 has the lowest solubility of the alkali metal perchlorates (1.5 g in 100 mL of water at 25 °C).^[1]

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- 3 Medicine use
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Production



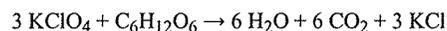
Potassium perchlorate in crystal form

KClO_4 is prepared industrially by treating an aqueous solution of sodium perchlorate with KCl . This single precipitation reaction exploits the low solubility of KClO_4 , which is about 100 times less than the solubility of NaClO_4 (209.6 g/100 mL at 25 °C).^[8] It can also be produced by the reaction of perchloric acid with potassium hydroxide; however, this is not used widely due to the dangers of perchloric acid. In laboratory or by hobbists it can be prepared by bubbling chlorine gas through a solution of KClO_3 and KOH . Another way to make it is the electrolysis

of potassium chlorate solution, KClO_4 form a precipitate at the anode.

Oxidizing properties

KClO_4 is an oxidizer in the sense that it exothermically transfers oxygen to combustible materials, greatly increasing their rate of combustion relative to that in air. Thus, with glucose it gives carbon dioxide:



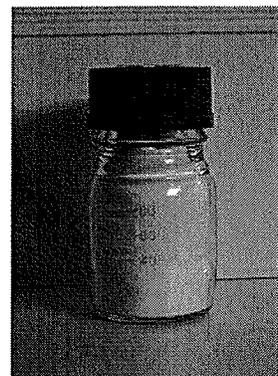
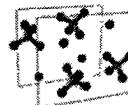
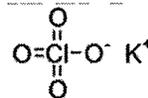
The conversion of solid glucose into hot gaseous CO_2 is the basis of the explosive force of this and other such mixtures. With sugar, KClO_4 yields a low explosive, provided the necessary confinement. Otherwise such mixtures simply deflagrate with an intense purple flame characteristic of potassium. Flash compositions used in firecrackers usually consist of a mixture of aluminium powder and potassium perchlorate. This mixture, sometimes called flash powder, is also used in ground and air fireworks.

As an oxidizer, potassium perchlorate can be used safely in the presence of sulfur, whereas potassium chlorate cannot. The greater reactivity of chlorate is typical – perchlorates are kinetically poorer oxidants. Chlorate produces chloric acid, which is highly unstable and can lead to premature ignition of the composition. Correspondingly, perchloric acid is quite stable.^[9]

Medicine use

Potassium perchlorate can be used as an antithyroid agent used to treat hyperthyroidism, usually in combination with one other medication. This application exploits the similar ionic radius and hydrophilicity of perchlorate and iodide.

Potassium perchlorate



Names

Other names

Potassium chlorate(VII); Perchloric acid, potassium salt; peroidin

Identifiers

CAS Number	7778-74-7 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=7778-74-7) ✓
3D model (Jmol)	Interactive image (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BK%2B%5D.%5BO-%5DCl%28%3DO%29%28%3DO%29%3DO)
ChemSpider	22913 (http://www.chemspider.com/Chemical-Structure.22913.html) ✓
ECHA InfoCard	100.029.011 (https://echa.europa.eu/substance-information/-/substanceinfo/100.029.011)
EC Number	231-912-9
PubChem CID	516900 (https://pubchem.ncbi.nlm.nih.gov/compound/516900)
RTECS number	SC9700000
UNII	42255P5X4D (https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=42255P5X4D) ✓
UN number	1489
InChI	
SMILES	
Properties	
Chemical formula	KClO_4

The administration of known goitrogen substances can also be used as a prevention in reducing the bio-uptake of iodine, (whether it be the nutritional non-radioactive iodine-127 or radioactive iodine, radioiodine - most commonly iodine-131, as the body cannot discern between different iodine isotopes). perchlorate ions, a common water contaminant in the USA due to the aerospace industry, has been shown to reduce iodine uptake and thus is classified as a goitrogen. Perchlorate ions are a competitive inhibitor of the process by which iodide, is actively deposited into thyroid follicular cells. Studies involving healthy adult volunteers determined that at levels above 0.007 milligrams per kilogram per day (mg/(kg·d)), perchlorate begins to temporarily inhibit the thyroid gland's ability to absorb iodine from the bloodstream ("iodide uptake inhibition", thus perchlorate is a known goitrogen).^[10] The reduction of the iodide pool by perchlorate has dual effects – reduction of excess hormone synthesis and hyperthyroidism, on the one hand, and reduction of thyroid inhibitor synthesis and hypothyroidism on the other. Perchlorate remains very useful as a single dose application in tests measuring the discharge of radioiodide accumulated in the thyroid as a result of many different disruptions in the further metabolism of iodide in the thyroid gland.^[11]

Treatment of thyrotoxicosis (including Graves' disease) with 600-2,000 mg potassium perchlorate (430-1,400 mg perchlorate) daily for periods of several months or longer was once common practice, particularly in Europe,^{[10][12]} and perchlorate use at lower doses to treat thyroid problems continues to this day.^[13] Although 400 mg of potassium perchlorate divided into four or five daily doses was used initially and found effective, higher doses were introduced when 400 mg/day was discovered not to control thyrotoxicosis in all subjects.^{[10][11]}

Current regimens for treatment of thyrotoxicosis (including Graves' disease), when a patient is exposed to additional sources of Iodine, commonly include 500 mg potassium perchlorate twice per day for 18–40 days.^{[10][14]}

Prophylaxis with perchlorate containing water at concentrations of 17 ppm, which corresponds to 0.5 mg/kg-day personal intake, if one is 70 kg and consumes 2 litres of water per day, was found to reduce baseline radioiodine uptake by 67%.^[10] This is equivalent to ingesting a total of just 35 mg of Perchlorate ions per day. In another related study were subjects drank just 1 litre of perchlorate containing water per day at a concentration of 10 ppm, i.e. daily 10 mg of Perchlorate ions were ingested, an average 38% reduction in the uptake of Iodine was observed.^[15]

However, when the average perchlorate absorption in perchlorate plant workers subjected to the highest exposure has been estimated as approximately 0.5 mg/kg-day, as in the above paragraph, a 67% reduction of iodine uptake would be expected. Studies of chronically exposed workers though have thus far failed to detect any abnormalities of thyroid function, including the uptake of iodine.^[16] this may well be attributable to sufficient daily exposure or intake of healthy Iodine-127 among the workers and the short 8 hr Biological half life of Perchlorate in the body.^[10]

To completely block the uptake of Iodine-131 by the purposeful addition of perchlorate ions to a populace's water supply, aiming at dosages of 0.5 mg/kg-day, or a water concentration of 17 ppm, would therefore be grossly inadequate at truly reducing radioiodine uptake. Perchlorate ion concentrations in a regions water supply, would need to be much higher, at least 7.15 mg/kg of body weight per day or a water concentration of 250 ppm, assuming people drink 2 liters of water per day, to be truly beneficial to the population at preventing bioaccumulation when exposed to a radioiodine environment,^{[10][14]} independent of the availability of Iodate or Iodide drugs.

The continual distribution of perchlorate tablets or the addition of perchlorate to the water supply would need to continue for no less than 80–90 days, beginning immediately after the initial release of radioiodine was detected, after 80–90 days had passed released radioactive iodine-131 would have decayed to less than 0.1% of its initial quantity at which time the danger from biouptake of iodine-131 is essentially over.^[17]

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Molar mass	138.55 g/mol
Appearance	colourless/ white crystalline powder
Density	2.5239 g/cm ³
Melting point	610 °C (1,130 °F; 883 K) decomposes from 400 °C ^{[4][5]}
Solubility in water	0.76 g/100 mL (0 °C) 1.5 g/100 mL (25 °C) ^[1] 4.76 g/100 mL (40 °C) 21.08 g/100 mL (100 °C) ^[2]
Solubility product (<i>K</i> _{sp})	1.05·10 ^{−2} ^[3]
Solubility	negligible in alcohol insoluble in ether
Solubility in ethanol	47 mg/kg (0 °C) 120 mg/kg (25 °C) ^[2]
Solubility in acetone	1.6 g/kg ^[2]
Solubility in ethyl acetate	15 mg/kg ^[2]
Refractive index (<i>n</i> _D)	1.4724
Structure	
Crystal structure	Rhombohedral
Thermochemistry	
Specific heat capacity (<i>C</i>)	111.35 J/mol·K ^[6]
Std molar entropy (<i>S</i> ^o ₂₉₈)	150.86 J/mol·K ^[6]
Std enthalpy of formation (<i>Δ</i> _f <i>H</i> ^o ₂₉₈)	−433 kJ/mol ^[7]
Gibbs free energy (<i>Δ</i> _f <i>G</i> ^o)	−300.4 kJ/mol ^[2]
Hazards	
Safety data sheet	MSDS (http://physchem.ox.ac.uk/MSDS/PO/potassium_perchlorate.html)
GHS pictograms	 ^[5]
GHS signal word	Danger
GHS hazard statements	H271, H302 ^[5]
GHS precautionary statements	P220 ^[5]
EU classification (DSD)	 Xn
R-phrases	R9, R22
S-phrases	(S2), S13, S22, S27
NFPA 704	
Related compounds	
Other anions	Potassium chloride Potassium chlorate Potassium periodate
Other cations	Ammonium perchlorate Sodium perchlorate

- Potassium perchlorate (<http://webbook.nist.gov/cgi/cbook.cgi?ID=C7778747&Mask=FFFF&Units=SI>) in Linstrom, P.J.; Mallard, W.G. (eds.) *NIST Chemistry WebBook, NIST Standard Reference Database Number 69*. National Institute of Standards and Technology, Gaithersburg MD. <http://webbook.nist.gov> (retrieved 2014-05-27)
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- "Nuclear Chemistry: Half-Lives and Radioactive Dating - For Dummies". Dummies.com. 2010-01-06. Retrieved 2013-01-21.

Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).

verify (what is ✗ ?)

Infobox references

External links

- WebBook page for KClO₄ (<http://webbook.nist.gov/cgi/cbook.cgi?ID=C7778747>)



Wikimedia Commons has media related to *Potassium perchlorate*.

Salts and the ester of the perchlorate ion

HClO₄

LiClO₄ Be(ClO₄)₂

B(ClO₄)₄[−] R₄
B(ClO₄)₃

NaClO₄ Mg(ClO₄)₂

Al(ClO₄)₃ Si

KClO ₄	Ca(ClO ₄) ₂	Sc(ClO ₄) ₃	Ti(ClO ₄) ₄	VO(ClO ₄) ₃	Cr(ClO ₄) ₃	Mn(ClO ₄) ₂	Fe(ClO ₄) ₃	Co(ClO ₄) ₂	Ni(ClO ₄) ₂	Cu(ClO ₄) ₂	Zn(ClO ₄) ₂	Ga(ClO ₄) ₃	Ge
RbClO ₄	Sr(ClO ₄) ₂	Y(ClO ₄) ₃	Zr(ClO ₄) ₄	Nb(ClO ₅) ₄	Mo	Tc	Ru	Rh	Pd(ClO ₄) ₂	AgClO ₄	Cd(ClO ₄) ₂	In(ClO ₄) ₃	Sr
CsClO ₄	Ba(ClO ₄) ₂	Hf	Ta(ClO ₅) ₅	W	Re	Os	Ir	Pt	Au	Hg ₂ (ClO ₄) ₂	Tl(ClO ₄) ₃	Pt	
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl
		↓											
		La	Ce(ClO ₄) _x	Pr	Nd	Pm	Sm(ClO ₄) ₃	Eu(ClO ₄) ₃	Gd(ClO ₄) ₃	Tb(ClO ₄) ₃	Dy(ClO ₄) ₃	Ho(ClO ₄) ₃	Er
		Ac	Th(ClO ₄) ₄	Pa	UO ₂ (ClO ₄) ₂	Np	Pu	Am	Cm	Bk	Cf	Es	Fr

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Categories: Potassium compounds | Perchlorates | Pyrotechnic oxidizers | Oxidizing agents

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Exhibit D

Tricalcium phosphate

From Wikipedia, the free encyclopedia

Tricalcium phosphate (sometimes abbreviated **TCP**) is a calcium salt of phosphoric acid with the chemical formula $\text{Ca}_3(\text{PO}_4)_2$. It is also known as **tribasic calcium phosphate** and **bone phosphate of lime** (BPL). It is a white solid of low solubility. Most commercial samples of "tricalcium phosphate" are in fact hydroxyapatite.^[2]

It exists as three crystalline polymorphs α , α' , and β . The α and α' states are stable at high temperatures. As mineral, it is found in Whitlockite.^[2]

Contents

- 1 Nomenclature
- 2 Preparation
- 3 Structure of β -, α - and α' - $\text{Ca}_3(\text{PO}_4)_2$ polymorphs
- 4 Occurrence
- 5 Biphasic tricalcium phosphate, BCP
- 6 Uses
 - 6.1 Biomedical
- 7 References

Nomenclature

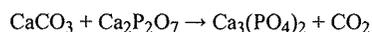
Calcium phosphate refers to numerous materials consisting of calcium ions (Ca^{2+}) together with orthophosphates (PO_4^{3-}), metaphosphates or pyrophosphates ($\text{P}_2\text{O}_7^{4-}$) and occasionally oxide and hydroxide ions. Especially, the common mineral apatite has formula $\text{Ca}_5(\text{PO}_4)_3\text{X}$, where X is F, Cl, OH, or a mixture; it is hydroxyapatite if the extra ion is mainly hydroxide. Much of the "tricalcium phosphate" on the market is actually powdered hydroxyapatite.

Preparation

Tricalcium phosphate is produced commercially by treating hydroxyapatite with phosphoric acid and slaked lime.^[2]

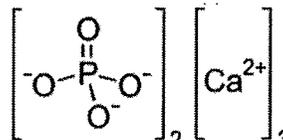
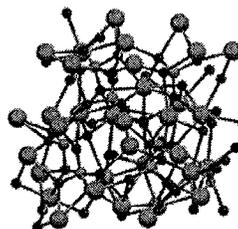
It cannot be precipitated directly from aqueous solution. Typically double decomposition reactions are employed, involving a soluble phosphate and calcium salts, e.g. $(\text{NH}_4)_2\text{HPO}_4 + \text{Ca}(\text{NO}_3)_2$.^[3] is performed under carefully controlled pH conditions. The precipitate will either be "amorphous tricalcium phosphate", ATCP, or calcium deficient hydroxyapatite, CDHA, $\text{Ca}_9(\text{HPO}_4)(\text{PO}_4)_5(\text{OH})$, (note CDHA is sometimes termed apatitic calcium triphosphate).^{[3][4][5]} Crystalline tricalcium phosphate can be obtained by calcining the precipitate. β - $\text{Ca}_3(\text{PO}_4)_2$ is generally formed, higher temperatures are required to produce α - $\text{Ca}_3(\text{PO}_4)_2$.

An alternative to the wet procedure entails heating a mixture of a calcium pyrophosphate and calcium carbonate:^[4]



Structure of β -, α - and α' - $\text{Ca}_3(\text{PO}_4)_2$

Tricalcium phosphate



Names

IUPAC name	Tricalcium bis(phosphate)
Other names	Tribasic calcium phosphate
Identifiers	
CAS Number	7758-87-4 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=7758-87-4) ✓
3D model (Jmol)	Interactive image (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BO-%5DP%28%3DO%29%28%5BO-%5D%29%5BO-%5D.%5BO-%5DP%28%3DO%29%28%5BO-%5D%29%5BO-%5D.%5BO-%5DP%28%3DO%29%28%5BO-%5D%29%5BO-%5D.%5BCa%2B2%5D.%5BCa%2B2%5D.%5BCa%2B2%5D)
CHEBI	CHEBI:9679 (https://www.ebi.ac.uk/chebi/searchId.do?chebiId=9679) ✓
ChemSpider	22864 (http://www.chemspider.com/Chemical-Structure.22864.html) ✓
ECHA InfoCard	100.028.946 (https://echa.europa.eu/substance-information/-/substanceinfo/100.028.946)
PubChem CID	516943 (https://pubchem.ncbi.nlm.nih.gov/compound/516943)
UNII	K4C08XP666 (https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=K4C08XP666) ✓
InChI	
SMILES	
Properties	
Chemical formula	$\text{Ca}_3(\text{PO}_4)_2$
Appearance	White amorphous powder
Density	3.14 g/cm ³
Melting point	Liquifies under high pressure at 1670 K (1391 °C)
Solubility in water	0.002 g/100 g
Thermochemistry	
Std enthalpy of formation ($\Delta_f H^\ominus_{298}$)	-4126 kcal/mol (α -form) ^[1]
Pharmacology	
ATC code	A12AA01 (WHO (https://www.whocc.no/atc_ddd_index/?code=A12AA01))
Hazards	
NFPA 704	

polymorphs

Tricalcium phosphate has three recognised polymorphs, the rhombohedral β - form (shown above), and two high temperature forms, monoclinic α - and hexagonal α' -. β -tricalcium phosphate has a crystallographic density of 3.066 g cm^{-3} while the high temperature forms are less dense, α -tricalcium phosphate has a density of 2.866 g cm^{-3} and α' -tricalcium phosphate has a density of 2.702 g cm^{-3} . All forms have complex structures consisting of tetrahedral phosphate centers linked through oxygen to the calcium ions.^[6] The high temperature forms each have two types of columns, one containing only calcium ions and the other both calcium and phosphate.^[7]

There are differences in chemical and biological properties between the beta and alpha forms, the alpha form is more soluble and biodegradable. Both forms are available commercially and are present in formulations used in medical and dental applications.^[7]

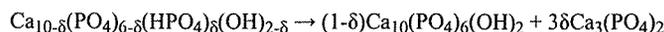
Occurrence

Calcium phosphate is one of the main combustion products of bone (see bone ash). Calcium phosphate is also commonly derived from inorganic sources such as mineral rock.^[8] Tricalcium phosphate occurs naturally in several forms, including:

- as a rock in Morocco, Israel, Philippines, Egypt, and Kola (Russia) and in smaller quantities in some other countries. The natural form is not completely pure, and there are some other components like sand and lime which can change the composition. In terms of P_2O_5 , most calcium phosphate rocks have a content of 30% to 40% P_2O_5 in weight.
- in the skeletons and teeth of vertebrate animals
- in milk.

Biphasic tricalcium phosphate, BCP

Biphasic tricalcium phosphate, BCP, was originally reported as tricalcium phosphate, but X-Ray diffraction techniques showed that the material was an intimate mixture of two phases, hydroxyapatite, HA, and β -tricalcium phosphate.^[9] It is a ceramic.^[10] Preparation involves the sintering causing the irreversible decomposition of calcium deficient apatites^[4] alternatively termed non-stoichiometric apatites or basic calcium phosphate,^[11] an example is:^[12]



β -TCP can contain impurities, for example calcium pyrophosphate, CaP_2O_7 and apatite. β -TCP is bioresorbable. The biodegradation of BCP involves faster dissolution of the β -TCP phase followed by elimination of HA crystals. β -TCP does not dissolve in body fluids at physiological pH levels, dissolution requires cell activity producing acidic pH.^[4]

Uses

Tricalcium phosphate is used in powdered spices as an anticaking agent, e.g. to prevent table salt from caking. It is also found in baby powder and toothpaste.^[2]

Biomedical

It is also used as a nutritional supplement^[13] and occurs naturally in cow milk, although the most common and economical forms for supplementation are calcium carbonate (which should be taken with food) and calcium citrate (which can be taken without food).^[14] There is some debate about the different bioavailabilities of the different calcium salts.

It can be used as a tissue replacement for repairing bony defects when autogenous bone graft is not feasible or possible.^{[15][16][17]} It may be used alone or in combination with a biodegradable, resorbable polymer such as polyglycolic acid.^[18] It may also be combined with autologous materials for a bone graft.^{[19][20]}

Porous beta-Tricalcium phosphate scaffolds are employed as drug carrier systems for local drug delivery in bone.^[21]

References

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Flash point	Non-flammable
Related compounds	
Other anions	Calcium pyrophosphate
Other cations	Trimagnesium phosphate Trisodium phosphate Tripotassium phosphate
Related compounds	Monocalcium phosphate Dicalcium phosphate
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).	
<div> ✓ verify (what is <i>*K</i> ?)</div>	
Infobox references	

2. Klaus Schrödter; Gerhard Bettermann; Thomas Staffel; Friedrich Wahl; Thomas Klein; Thomas Hofmann (2008). *Phosphoric Acid and Phosphates*. Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH. doi:10.1002/14356007.a19_465.pub3.
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Categories: Biomaterials | Calcium compounds | Phosphates

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Exhibit E

Sodium benzoate

From Wikipedia, the free encyclopedia

Sodium benzoate is a substance which has the chemical formula $\text{NaC}_7\text{H}_5\text{O}_2$. It is a widely used food preservative, with an E number of **E211**. It is the sodium salt of benzoic acid and exists in this form when dissolved in water. It can be produced by reacting sodium hydroxide with benzoic acid.

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Uses

Preservative

Sodium benzoate is a preservative. As a food additive, sodium benzoate has the E number E211. It is bacteriostatic and fungistatic under acidic conditions. It is most widely used in acidic foods such as salad dressings (vinegar), carbonated drinks (carbonic acid), jams and fruit juices (citric acid), pickles (vinegar), and condiments. It is also used as a preservative in medicines and cosmetics.^{[3][4]} Concentration as a food preservative is limited by the FDA in the U.S. to 0.1% by weight.^[5] Sodium benzoate is also allowed as an animal food additive at up to 0.1%, according to AFCO's official publication.^[6]

Pharmaceutical applications

Sodium benzoate is used as a treatment for urea cycle disorders due to its ability to bind amino acids.^{[7][8]} This leads to excretion of these amino acids and a decrease in ammonia levels. Recent research shows that sodium benzoate may be beneficial as an add-on therapy (1 gram/day) in schizophrenia.^{[9][10][11]} Total Positive and Negative Syndrome Scale scores dropped by 21% compared to placebo.

Sodium benzoate is used to treat hyperammonemia.^[12]

Sodium benzoate has been shown to halt the progression of Parkinson's in mice.^[12]

Other uses

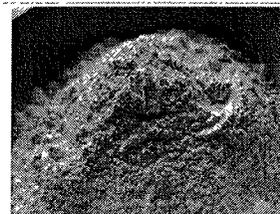
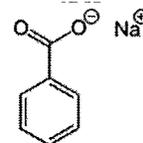
Sodium benzoate is also used in fireworks as a fuel in whistle mix, a powder that emits a whistling noise when compressed into a tube and ignited.

Mechanism of food preservation

The mechanism starts with the absorption of benzoic acid into the cell. If the intracellular pH falls to 5 or lower, the anaerobic fermentation of glucose through phosphofructokinase decreases sharply,^[13] which inhibits the growth and survival of microorganisms that cause food spoilage.

Production

Sodium benzoate



Names

IUPAC name	sodium benzoate
Other names	E211, benzoate of soda
Identifiers	
CAS Number	532-32-1 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=532-32-1) ✓
3D model (Jmol)	Interactive image (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BNa%2B%5D.%5BO-%5DC%28%3DO%29c1cccc1)
CHEBI	CHEBI:113455 (https://www.ebi.ac.uk/chebi/searchId.do?chebiId=113455) ✗
ChemSpider	10305 (http://www.chemspider.com/Chemical-Structure.10305.html) ✓
ECHA InfoCard	100.007.760 (https://echa.europa.eu/substance-information/-/substanceinfo/100.007.760)
E number	E211 (preservatives)
PubChem CID	517055 (https://pubchem.ncbi.nlm.nih.gov/compound/517055)
RTECS number	DH6650000
UNII	OJ245FE5EU (https://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=OJ245FE5EU) ✓
InChI	
SMILES	
Properties	
Chemical formula	$\text{C}_7\text{H}_5\text{NaO}_2$
Molar mass	144.10 g·mol ^{−1}
Appearance	white or colorless crystalline powder
Odor	odorless
Density	1.497 g/cm ³
Melting point	410 °C (770 °F; 683 K)

Sodium benzoate is produced by the neutralization of benzoic acid with sodium hydroxide.^[14] Sodium benzoate can also be prepared by adding benzoic acid to a hot concentrated solution of sodium carbonate until effervescence ceases. The solution is then evaporated, cooled and allowed to crystallize or evaporate to dryness, and then granulated.

Health and safety

In the United States, sodium benzoate is designated as generally recognized as safe (GRAS) by the Food and Drug Administration.^[15] The International Programme on Chemical Safety found no adverse effects in humans at doses of 647–825 mg/kg of body weight per day.^{[16][17]}

Cats have a significantly lower tolerance against benzoic acid and its salts than rats and mice.^[18]

A paper published in the March 2015 Journal of the Science of Food and Agriculture found that sodium benzoate has been replaced by potassium sorbate in the majority of soft drinks in the United Kingdom to avoid the use of anything the consumer might consider an additive, particularly in connection with colours and preservatives.^[19]

Association with benzene in soft drinks

In combination with ascorbic acid (vitamin C, E300), sodium benzoate and potassium benzoate may form benzene, a known carcinogen. When tested by the FDA, most beverages that contained both ascorbic acid and benzoate had benzene levels that were below those considered dangerous for consumption by the World Health Organization (5 ppb).^[20] Most of the beverages that tested higher have been reformulated and subsequently tested below the safety limit.^[20] Heat, light and shelf life can increase the rate at which benzene is formed.

Hyperactivity

Research published in 2007 for the UK's Food Standards Agency (FSA) suggests that certain artificial colors, when paired with sodium benzoate, may be linked to hyperactive behavior. The results were inconsistent regarding sodium benzoate, so the FSA recommended further study.^{[21][22][23]} The Food Standards Agency concluded that the observed increases in hyperactive behavior, if real, were more likely to be linked to the artificial colors than to sodium benzoate.^[23] The report's author, Jim Stevenson from Southampton University, said: "The results suggest that consumption of certain mixtures of artificial food colours and sodium benzoate preservative are associated with increases in hyperactive behaviour in children. . . . Many other influences are at work but this at least is one a child can avoid."^[23]

Sodium benzoate may trigger or exacerbate symptoms or episodes of attention-deficit/hyperactivity disorder, or ADHD, according to the Mayo Clinic. The condition is most common in children but it can be present in adults as well, and affected individuals may be forgetful, have difficulty concentrating and following directions or display impulsiveness.^[24]

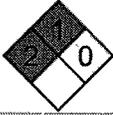
In response to consumer insistence on a more natural product, the Coca Cola Company is in the process of phasing sodium benzoate out of Diet Coke. The company has stated it plans to remove sodium benzoate from its other products — including Sprite, Fanta, and Oasis — as soon as a satisfactory alternative is discovered.^[25]

Compendial status

- British Pharmacopoeia^{[26][27][28]}
- European Pharmacopoeia^[26]
- Food Chemicals Codex^[26]
- Japanese Pharmacopoeia ^[29]
- United States Pharmacopoeia 29^[30]

See also

- Acceptable daily intake

Solubility in water	62.69 g/100 mL (0 °C) 62.78 g/100 mL (15 °C) 62.87 g/100 mL (30 °C) 71.11 g/100 mL (100 °C) ^[1]
Solubility	soluble in liquid ammonia, pyridine ^[1]
Solubility in methanol	8.22 g/100 g (15 °C) 7.55 g/100 g (66.2 °C) ^[1]
Solubility in ethanol	2.3 g/100 g (25 °C) 8.3 g/100 g (78 °C) ^[1]
Solubility in 1,4-Dioxane	0.818 mg/kg (25 °C) ^[1]
Pharmacology	
ATC code	A16AX11 (WHO (https://www.whocc.no/atc_ddd_index/?code=A16AX11))
Hazards	
GHS pictograms	 ^[2]
GHS signal word	Warning
GHS hazard statements	H319 ^[2]
GHS precautionary statements	P305+351+338 ^[2]
EU classification (DSD)	 Xi
R-phrases	R36
S-phrases	S26
NFPA 704	
Flash point	100 °C (212 °F; 373 K)
Autoignition temperature	500 °C (932 °F; 773 K)
Lethal dose or concentration (<i>LD</i> , <i>LC</i>):	
<i>LD</i> ₅₀ (median dose)	4100 mg/kg (oral, rat)
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).	
X verify (what is ✓ ?)	
Infobox references	

- Potassium benzoate
- Potassium sorbate^[19]

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- ChemSub Online: Sodium benzoate (http://chemsub.online.fr/name/sodium_benzoate.html)



Wikimedia Commons has media related to ***Benzoates***.



Wikimedia Commons has media related to ***Benzoate salts***.

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Categories: Antiseptics | Benzoates | Preservatives | Sodium compounds

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Exhibit F



US007914633B1

(12) **United States Patent**
Barrett et al.

(10) **Patent No.:** **US 7,914,633 B1**
(45) **Date of Patent:** **Mar. 29, 2011**

(54) **WHITE PROPELLANT COMPOSITIONS**
(75) Inventors: **G Dean Barrett**, Kansas City, MO (US);
Terry M Dielh, Alta Vista, KS (US);
Thomas W Bowen, Shawnee, KS (US)

(73) Assignee: **Hodgdon Powder Company, Inc.**,
Shawnee Mission, KS (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 623 days.

(21) Appl. No.: **11/870,383**

(22) Filed: **Oct. 10, 2007**

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/352,542,
filed on Jan. 28, 2003, now Pat. No. 7,344,610.

(51) **Int. Cl.**
C06B 31/00 (2006.01)
C06B 31/02 (2006.01)
C06B 31/08 (2006.01)
C06B 29/00 (2006.01)
C06B 29/02 (2006.01)
D03D 23/00 (2006.01)
D03D 43/00 (2006.01)

(52) **U.S. Cl.** **149/45**; 149/61; 149/70; 149/75;
149/77; 149/109.4

(58) **Field of Classification Search** 149/83,
149/45, 61, 70, 75, 77, 109.4
See application file for complete search history.

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Primary Examiner — James E McDonough

(74) *Attorney, Agent, or Firm* — Joseph B Bowman

(57) **ABSTRACT**

Sulfur-free and carbon-free, white propellant compositions for use as a blackpowder substitute in firearms, munitions, and pyrotechnics to form combustion byproducts that are water soluble and are free of corrosive sulfur compounds and black carbon residues. Formulations include a fuel agent selected from the group consisting of sodium benzoate, lactose, sodium salicylate, sodium m-nitrobenzoate, and mixtures thereof. The fuel agent is combined with dextrin, potassium nitrate, potassium perchlorate, and tricalcium phosphate. Dicyanodiamide may be incorporated in the formulation as a burn rate modifier.

14 Claims, No Drawings

WHITE PROPELLANT COMPOSITIONS**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation-in-part of co-pending application Ser. No. 10/352,542, filed Jan. 28, 2003, entitled "Sulfur-Free Propellant Compositions".

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

None

BACKGROUND OF THE INVENTION

This invention relates to propellants in firearms, munitions, pyrotechnics, and the like. More specifically, this invention relates to a blackpowder substitute which is white in color that forms combustion byproducts that are easily cleaned with water and that are free of corrosive sulfur compounds and of black residues.

Blackpowder was one of the first materials that could be used as a propellant, an explosive, and in pyrotechnic devices. The Chinese are credited with its development many centuries ago. As blackpowder characteristics became known, its uses expanded. It was first used in cannons and hand cannons in Europe in the 14th century. It began to be used in civil engineering projects in the 16th century and in coal mining operations during the 17th century. The forerunner of today's muzzleloading guns, the matchlock musket, was also invented in the 16th century. Following that matchlock, further developments in firearms made the use of blackpowder more effective and convenient. In rapid succession, better ignition systems were developed with both the wheellock and the flintlock during the 16th century. The percussion cap firearm, similar to that used today, was not developed until the 19th century.

Thus, for hundreds of years, blackpowder remained unchallenged as the only material of its type. Inventors directed their efforts to making better use of blackpowder. With the advent of nitro-cellulose smokeless powder in the latter part of the 19th century, blackpowder lost its preeminence as the only gun propellant. Smokeless powder burned cleaner and produced more energy than did blackpowder, and it was safer to use and handle. However, because of blackpowder's lower gun barrel pressures, ignition characteristics, and low cost of manufacture, blackpowder retained its place in the market as the only propellant for antique firearms such as muzzleloaders and the preferred material for use in fuse manufacture, ignition devices, cannon round igniters, fireworks, and the like.

In 1978, U.S. Pat. No. 4,128,443 was issued to Pawlak and Levenson for Deflagrating Propellant Compositions. Blackpowder was soon no longer the muzzleloading propellant of choice for many sportsmen. The principal product marketed as a result of the Pawlak et. al. patent is known as Pyrodex powder. This product does not detonate and is less prone to accidental ignition than is blackpowder. In addition to being used as a propellant in muzzleloading and cartridge guns, Pyrodex powder has been formulated as a delay powder, a fuse powder, a fireworks powder, and in some military applications. However, Pyrodex is not without its own drawbacks. It does not ignite satisfactorily in flintlock guns and, like blackpowder, it contains sulfur which results in combustion residues that are hard to remove and can cause corrosion if left in the gun barrel.

U.S. Pat. No. 4,497,676 issued in 1985 to Kurtz. It was the first in a number of patents on sulfur-free compositions utilizing potassium nitrate and ascorbic or erythorbic acid. Some of these patents used slurries in the manufacture thus requiring the subsequent removal of large quantities of water. Others required cooking or heating with the attendant high production cost and hazard. Many of these products had low energy content and were very hygroscopic with the result that the product coagulated in the container, becoming a single, unusable lump.

Cioffe further expanded on the use of ascorbic or erythorbic acid in U.S. Pat. No. 5,449,423 by adding potassium perchlorate. This product had reduced hygroscopicity and higher energy, however, it requires high energy inputs during manufacture for compaction and subsequent granulation. The resulting product has been known to detonate. Other similar products are known that have the same bad characteristics.

Several factors have combined to increase the market for a clean burning, high performance propellant composition. Deer population in many states has grown substantially due to good conservation management, and these states now have separate seasons for muzzleloading guns during a so-called primitive weapons season, as well as a regular season for conventional, high powered firearms. The same is true in many western states having elk herds. Due to the growing popularity of muzzleloaders, gun manufacturers have developed the "in-line" rifle which gives better ignition than the side-hammer percussion rifle, and these weapons are made to withstand higher gun barrel pressures. When Pyrodex powder was first introduced, the most popular projectile was the patched round ball. Today, modern projectiles using plastic sabots with a metal jacketed bullet are gaining acceptance and higher velocities are desirable.

The demand is growing for propellant compositions that will keep pace with expanding market of shooters and sportsmen having an interest in muzzleloading type weaponry. At the same time, the need remains for propellant compositions which solve the many disadvantages and drawbacks of corrosiveness and cleaning difficulty associated with blackpowder and conventional blackpowder substitutes such as Pyrodex powder. The primary objective of this invention is to meet these needs.

SUMMARY OF THE INVENTION

More specifically, an object of the invention is to provide a propellant composition as a sulfur free deflagrating gas generating formulation to eliminate the presence of corrosive, sulfur-containing byproducts of combustion.

A corollary object of the invention is to provide a propellant composition as a sulfur free substitute for conventional blackpowder and which may be loaded in firearms on a volumetric basis similar to the way that blackpowder is loaded, rather than on a weight basis.

Another object of the invention is to provide a propellant composition of the character described which is white in color and free of elemental carbon to eliminate the presence of black residues associated with conventional blackpowder and blackpowder substitutes.

Another object of the invention is to provide a propellant composition for which the combustion byproducts may be readily removed with water to provide easy cleanup of weaponry in which such propellant composition is utilized.

Another object of the invention is to provide a propellant composition of the character described which forms water soluble combustion products free of sulfur-containing compounds and of black carbonaceous residues.

An additional object of the invention is to provide a propellant composition of the character described with significant water formation in the combustion products as compared to blackpowder in order to facilitate cleaning of the firearm.

A further object of the invention is to provide a propellant composition of the character described having reliable and consistent performance characteristics of good ignition, no detonation, good burn rate, low hygroscopic properties, reasonable time to peak pressure, adequate fouler pressure, moderate peak pressure, and reproducible velocity performance and ballistics.

Yet another object of the invention is to provide a propellant composition of the character described which can be manufactured from readily available chemicals, can be safely handled and stored, has an adequate shelf life, and can be manufactured in a modern gunpowder plant within industry standards for safety, handling, manufacture and storage.

In summary, an object of the invention is to provide sulfur-free and carbon-free, white propellant compositions for use as a blackpowder substitute in firearms, munitions, and pyrotechnics to form combustion byproducts that are water soluble and are free of corrosive sulfur compounds and black carbon residues. Formulations include a fuel agent selected from the group consisting of sodium benzoate, lactose, sodium salicylate, sodium m-nitrobenzoate, and mixtures thereof. The fuel agent is combined with dextrin, potassium nitrate, potassium perchlorate, and tricalcium phosphate. Dicyanodiamide may be incorporated in the formulation as a burn rate modifier.

Other and further objects of the invention, together with the features of novelty appurtenant thereto, will appear in the following detailed description of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The important benefits of sulfur in various pyrotechnic mixtures such as blackpowder and modern blackpowder substitutes, such as Pyrodex powder as taught in U.S. Pat. No. 4,128,443 incorporated herein by reference, have long been known. However, the significant drawbacks and disadvantages of sulfur in pyrotechnic mixtures for firearms have also long been understood. The presence of sulfur in these prior art mixtures results in sulfur compounds being present in the combustion residue. In the case of blackpowder, such compounds include hydrogen sulfide, potassium sulfate, potassium thiosulfate, and potassium sulfide. In the case of Pyrodex powder, the sulfur-containing byproducts include principally potassium sulfate and potassium thiosulfate. Such sulfur compounds are difficult to remove from gun barrels where repeated use of the firearms without intermediate cleaning is frequently practiced. Without cleaning, such sulfur compounds combine with moisture and are highly corrosive to the metal parts of the firearm.

In both blackpowder and Pyrodex, sulfur is a necessary component. The low melting point of sulfur (i.e., 244° F.) contributes to a lower autoignition temperature and promotes a faster burning rate in propellant mixtures. In the traditional formulation of blackpowder, charcoal represents 15% by weight, potassium nitrate represents 75% by weight and sulfur represents 10% by weight. The autoignition temperature of blackpowder is approximately 580° F. and the burn rate is about 2.3 seconds per inch at atmospheric pressure.

If sulfur is simply removed from blackpowder, in an effort to control production of the corrosive sulfur byproducts, the product is changed dramatically. The autoignition temperature rises from 580 to 750 or higher, the burn rate slows down from 2.3 seconds/inch to more than 4.1 seconds/inch, and the

ignition properties become very poor. In other words, the modified blackpowder becomes ineffective for use as a propellant composition.

Although the numbers themselves change, the same relationship holds true for Pyrodex powder. When sulfur is removed from Pyrodex powder, the autoignition temperature rises, the burn rate slows down, and the ignition is poor. Therefore, it has heretofore not been possible to simply eliminate sulfur from Pyrodex powder and still maintain a propellant composition useful in muzzleloading weapons.

We have discovered that sulfur can be eliminated and still maintain a propellant by using a gluconic acid salt or an alkali metal nitrobenzoate salt as an ignition aid to various mixtures of oxidizing and reducing agents known to those skilled in the art. It is also possible to combine these novel formulations with various propellant additives known to those skilled in the gunpowder arts, such as binders, burning rate modifiers, flow agents, colorants, coating agents, moisture retardants and mixtures thereof.

The gluconic acid salts tested in formulations coming within the scope of this invention include sodium gluconate and potassium gluconate. Sodium gluconate has a chemical formula of $C_6H_{11}NaO_7$, a molecular weight of 218.13 and the recognized properties as indicated as reference #8372 of The Merck Index (9th Edition), incorporated herein by reference. The form most commonly used and readily available is sodium D-gluconate. Potassium gluconate has a chemical formula of $C_6H_{11}KO_7$, a molecular weight of 234.24 and the recognized properties as indicated as reference #7413 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as an ignition aid, the gluconic acid salt may be present in the amount of 0 to 45% by weight, is preferably present in the amount of 1 to 25% by weight, and is present in the amount of 2 to 15% by weight in the most likely commercial product applications.

The alkali metal nitrobenzoate salt tested in formulations within the scope of this invention include sodium meta-nitrobenzoate, or sodium 3-nitrobenzoate.

The compound has a chemical formula of $C_7H_5NO_3Na$, a molecular weight of 189.11 and the recognized properties as indicated as reference #6411 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as an ignition aid, the sodium meta-nitrobenzoate may be present in the amount of 0 to 40% by weight, is preferably present in the amount of 1 to 15% by weight, and is present in the amount of 2 to 12% by weight in the most likely commercial product applications.

The oxidizing and reducing or fuel agents useful in the formulations of this invention include carbon, sugars, nitrate salts, perchlorate salts, benzoate salts, and mixtures thereof. Oxidizing and reducing agents specifically tested include carbon, lactose, potassium nitrate, potassium perchlorate, sodium benzoate, and mixtures thereof.

The element carbon has a chemical formula of C, a molecular weight of 12.01 and the recognized properties as indicated as reference #1814 of The Merck Index (9th Edition). The form most commonly used and readily available for use in this invention is charcoal. More specifically, the charcoal was air float charcoal derived from wood.

Within the broad working range of concentrations tested for use as a fuel in the propellant formulations, carbon may be present in the amount of 0 to 15% by weight, is preferably present in the amount of 1 to 12% by weight, and is present in the amount of 3 to 7% by weight in the most likely commercial product applications.

Numerous sugars have served as fuels for prior art compositions of propellants. Lactose has specifically been tested and found useful as a fuel in the formulations of this invention. However, other known sugars, such as dextrose, sucrose and fuels derived therefrom, are expected to be useful when combined with ignition agents of gluconate or sodium nitrobenzoate salts, or mixtures thereof. Lactose has a chemical formula of $C_{12}H_{22}O_{11}$, a molecular weight of 360.31 and the recognized properties as indicated as reference #5192 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as a fuel in the propellant formulations, lactose may be optionally present in the amount of 0 to 15% by weight, is preferably present in the amount of 0 to 12% by weight, and may be optionally present in the amount of 0 to 10% by weight in the most likely commercial product applications.

Nitrate salts have served as oxidizing agents in prior art propellants. Potassium nitrate, known commonly as saltpeter, has been extensively tested and found useful as an oxidizing agent in the formulations of this invention. Potassium nitrate has a chemical formula of KNO_3 , a molecular weight of 101.10 and the recognized properties as indicated as reference #7432 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as an oxidizing agent in the propellant formulations, potassium nitrate may be present in the amount of 0 to 60% by weight, is preferably present in the amount of 20 to 50% by weight, and may be present in the amount of 30 to 45% by weight in the most likely commercial product applications.

Since the development of Pyrodex powder as a blackpowder substitute, perchlorate salts have also served as oxidizing agents in prior art propellants. Potassium perchlorate has been extensively tested and found useful as an oxidizing agent in the formulations of this invention. Potassium perchlorate has a chemical formula of $KClO_4$, a molecular weight of 138.55 and the recognized properties as indicated as reference #7439 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as an oxidizing agent in the propellant formulations, potassium perchlorate may be present in the amount of 0 to 70% by weight, is preferably present in the amount of 15 to 50% by weight, and may be present in the amount of 20 to 40% by weight in the most likely commercial product applications.

The benzoate salts sodium benzoate and potassium benzoate have been tested and found useful in the formulations of this invention. Sodium benzoate has a chemical formula of $C_7H_5NaO_2$, a molecular weight of 144.11 and the (9th recognized properties as indicated as reference #8326 of The Merck Index Edition). Potassium benzoate has a chemical formula of $C_7H_5KO_2$, a molecular weight of 160.22 and the recognized properties as indicated as reference #1100 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use in the propellant formulations, benzoate salt may be present in the amount of 0 to 30% by weight, is preferably present in the amount of 2 to 20% by weight, and may be present in the amount of 3 to 10% by weight in the most likely commercial product applications.

A broad range of various formulations of oxidizing and reducing agents with the ignitions agents of gluconic acid salts, or an alkali metal nitrobenzoate salt such as sodium nitrobenzoate or potassium nitrobenzoate, or mixtures thereof have been combined, without product degradation, with a variety of known propellant additives. Such additives

include binders, burning rate modifiers, flow agents, colorants, coating agents, moisture retardants and mixtures thereof.

Propellant binders may comprise simply water, but dextrin is an agent known to serve as an effective binder in gunpowders. Dextrin has a chemical formula of $C_6H_{10}O_5$, a molecular weight of 162.14 and the recognized properties as indicated as reference #2909 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as a binder in the propellant formulations, dextrin may be present in the amount of 0 to 10% by weight, is preferably present in the amount of 1 to 9% by weight, and may be present in the amount of 2 to 8% by weight in the most likely commercial product applications.

Likewise, water may also serve as a burning rate modifier. Dicyanodiamide is another agent known to modify burn rate in gunpowders. Dicyanodiamide has a chemical formula of $C_2H_4N_4$, a molecular weight of 84.08 and the recognized properties as indicated as reference #3068 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as burn rate modifier in the propellant formulations, dicyanodiamide may be present in the amount of 0 to 10% by weight, is preferably present in the amount of 1 to 8% by weight, and may be present in the amount of 2 to 7% by weight in the most likely commercial product applications.

Tricalcium phosphate may serve as a flow agent in the propellant formulations. Tricalcium phosphate has a chemical formula of $Ca_3(PO_4)_2$, a molecular weight of 310.20 and the recognized properties as indicated as reference #1695 of The Merck Index (9th Edition).

Within the broad working range of concentrations tested for use as a flow agent in the propellant formulations, tricalcium phosphate may be present in the amount of 0 to 1% by weight, is preferably present in the amount of 0.1 to 0.9% by weight, and may be present in the amount of 0.2 to 0.8% by weight in the most likely commercial product applications.

A small amount of carbon black may serve as a colorant in the propellant formulations. Blackpowder traditionalists and muzzleloading enthusiasts expect substitute powders to have a pleasing black color. Accordingly, an appropriate color shade may be achieved by adding up 0.5% by weight carbon black to the propellant formulations of this invention.

Likewise, coating agents such as graphite may be added to the propellant formulations of this invention. This may be done to improve the pouring and consistency of the product to better match the esthetics of traditional blackpowder characteristics.

Although the propellant formulations of this invention have not been found to be excessively hygroscopic, moisture retardants may be included in the product. Acceptable moisture retardants include silicon compounds known in the art for their moisture trapping and retaining properties.

Since the gluconic acid salts and alkali metal nitrobenzoate salt disclosed for use in this invention have not been previously known to have any use in pyrotechnic compositions, extensive tests have been conducted to attempt to understand the nature and scope of these compounds in various propellant formulations. A large number of the tested formulations are included in this application in Tables 1 through 3.

In the reported formulations of Tables 1 through 3, the raw materials of each formulation are given as a weight percentage. The combustion products are theoretically calculated and are likewise given as weight percentage.

In order to characterize the research compositions, the byproducts of the combustion reaction were calculated by a mass balance and a uniform method of determining the reac-

tion byproducts. It is of course recognized that the uniform method does not necessarily yield correct absolute values due to the changes in byproducts that can occur from the reaction environment of high temperature and pressure to atmospheric conditions. Nonetheless, such method does give a good basis for relative comparison of one formulation with another.

The uniform method selected to calculate the reaction byproducts involves certain assumptions as follows. Materials that have very high melting points and are basically inert are considered to pass through the reaction unchanged. The inert portion of trace materials such as in charcoal are assumed to pass through the reaction unchanged. All hydrogen in the raw materials is assumed to be converted to water. All nitrogen in the raw materials is produced as nitrogen gas. All sodium in the raw materials is first produced as sodium chloride and secondly as sodium carbonate. All chlorine in the raw materials is first produced as sodium chloride and secondly as potassium chloride. Any remaining potassium after the above conversions is produced as potassium carbonate. Any remaining carbon is converted to carbon monoxide. Any remaining oxygen is used to convert carbon monoxide to carbon dioxide.

The composition of combustion products given in Tables 1 through 3, therefore, were determined in accordance with the foregoing method with the exception of the combustion products for blackpowder which are well known to those skilled in the gunpowder art to have the accepted values as listed.

As reported under performance characteristics in each of Tables 1 through 3, various test procedures or observations were made for each propellant formulation. A brief description of the test procedure or observation of the reported results are given as follows.

Autoignition Temperature is given in degrees Fahrenheit. Grains of the composition were placed on a hot plate at various locations until a location was found that caused combustion. The temperature of that location on the plate was then measured and recorded.

In the Open Tube Burn test, a small quantity of the composition was placed in a 1/2" diameter plastic tube which was taped at one end. A fuse was placed in the open end and ignited. The nature of combustion of the composition was observed and the results recorded.

Burn Rate is given in seconds per inch. A quantity of the composition was compressed in a 1/2" diameter tube at consistent pressure by increments until a pressing of about 1 1/2" in length was obtained. The pressed composition was then ignited and the time of burning was measured. The walls of

the tube restricted the burning to just the cross-sectional area of the tube so that the composition burned in a cigarette type manner.

The Bulk Density is given in grams per cubic centimeter (gms/cc). A known volume of the composition was weighed, and the bulk density was calculated and recorded.

Moisture content is given as a weight percentage. Moisture content was measured using an Ohaus-type scale.

Ballistic characteristics were taken for 80 grains volumetric samples which means that the same volume was used that was equal to the volume of 80 grains by weight of blackpowder. The ballistic data was recorded.

The projectile velocities of multiple tests were measured and recorded as feet per second. For each shot, the test gun was charged with a known quantity of composition and the projectile was fired through velocity screens separated by a known distance. The time for the projectile to pass through one screen to the next was measured and the velocity was then calculated and recorded. Lo velocity represents the lowest velocity in the range of tests for the particular powder formulation being studied, Hi velocity represents the highest in the range of tests, ES velocity represents the spread between Lo and Hi velocities, Av velocity represents the average velocity, and SD velocity is the standard deviation for the range of tests.

The TTP test is given in milliseconds and represents the time to peak pressure. An electronic device was used to measure the elapsed time from the onset of pressure rise until the maximum pressure occurs in the gun barrel breech.

The Pressure test is given in pounds per square inch. A piezometer was used to determine the pressure in the breech of the gun at each firing of the composition and the maximum of such readings was recorded.

The Fouler pressure test is given in pounds per square inch. The Fouler pressure is measured with the piezometer as above, but this reading represents the first shot in a group of firings and was normally done with a clean barrel.

The ability to clean any combustion residue with water alone was also observed as part of the tests. With the exception of the tests on blackpowder recorded for comparative purposes, all of the formulations of this invention formed combustion byproducts which were easily removed with gun cleaning patches dipped in plain water.

In the following Table 1 representative examples are shown of propellant formulations in which a gluconic acid salt alone serves as the ignition aid for the oxidizing and reducing agents as indicated.

TABLE 1

Gluconate Formulations						
	Chemical Formula	Mole Weight	Black Powder	Ref #657	Ref #171	Ref #75
RAW MATERIALS, wt. %						
Carbon Black	C	12.01		0.45	0.5	0.5
Charcoal	C	12.01	15.00	3.15	3	
Dextrin	C ₆ H ₁₀ O ₅	162.14		6.00	6	6
Dicyanodiamide	C ₂ H ₄ N ₄	84.08				
Graphite	C	12.01				
Lactose	C ₁₂ H ₂₂ O ₁₁	360.31			6.1	
Sodium m-Nitrobenzoate	C ₇ H ₄ NO ₄ Na	189.11				
Potassium Nitrate	KNO ₃	101.10	75.00	16.63	38	53.1
Potassium Perchlorate	KClO ₄	138.55		48.83	32.5	21.2
Sodium Benzoate	C ₇ H ₅ NaO ₂	144.11		21.00	9.8	14.8
Potassium Benzoate	C ₇ H ₅ KO ₂	160.22				
Sodium Gluconate	C ₆ H ₁₁ NaO ₇	218.13		3.55	3.7	4
Potassium Gluconate	C ₆ H ₁₁ KO ₇	234.24				

TABLE 3-continued

Gluconate with Sodium m-Nitrobenzoate Formulations					
	0.9	0.8	0.9	0.8	
Moisture, wt. %	0.9	0.8	0.9	0.8	
Ballistics 80 gr. vol.					
Lo velocity, fps	1848	1899	1610	1483	
Hi velocity, fps	1888	1990	1676	1517	
ES velocity, fps	40	91	66	34	
Av velocity, fps	1874	1945	1650	1502	
SD velocity, fps	16	39	27	12	
TTP, ms.	0.7	0.65	0.9	0.9	
Pressure, psi max.	9500	12600	5900	5000	
Fouler pressure, psi	6100	9400	3200	3100	
RAW MATERIALS, wt. %	Chemical Formula	Ref #727	Ref #811	Ref #813	Ref #814
Carbon Black	C				
Charcoal	C	4	5.6	5.6	6.6
Dextrin	C ₆ H ₁₀ O ₅	3	5.8	5.8	4.8
Dicyanodiamide	C ₂ H ₄ N ₄		4.9	4.9	5.9
Graphite	C				
Lactose	C ₁₂ H ₂₂ O ₁₁				
Sodium m-Nitrobenzoate	C ₇ H ₄ NO ₄ Na	8	7.3	7.3	6.3
Potassium Nitrate	KNO ₃	39.4	38.7	38.7	38.7
Potassium Perchlorate	KClO ₄	30.7	29	29	29
Sodium Benzoate	C ₇ H ₅ NaO ₂			6.1	
Potassium Benzoate	C ₇ H ₅ KO ₂		6.1		5.1
Sodium Gluconate	C ₆ H ₁₁ NaO ₇	14.5			
Potassium Gluconate	C ₆ H ₁₁ KO ₇		2.2	2.2	3.2
Sulfur	S				
Tricalcium Phosphate	Ca ₃ (PO ₄) ₂	0.4	0.4	0.4	0.4
TOTAL COMBUSTION PRODUCTS, wt. %		100	100	100	100
RAW MATERIALS, wt. %	Chemical Formula	Ref #727	Ref #811	Ref #813	Ref #814
Ammonium Carbonate	(NH ₄) ₂ CO ₃				
Carbon Dioxide	CO ₂	31.3	9.6	8.2	8
Carbon Monoxide	CO	2	22.3	23.9	23.6
Hydrogen Sulfide	H ₂ S				
Methane	CH ₄				
Nitrogen	N ₂	6.1	9.2	9.2	9.8
Potassium Carbonate	K ₂ CO ₃	34.5	32.5	32.7	32.4
Potassium Thiocyanate	KCNS				
Potassium Sulfate	K ₂ SO ₄				
Potassium Thiosulfate	K ₂ S ₂ O ₃				
Potassium Sulfide	K ₂ S				
Potassium Chloride	KCl	8.4	12.6	9.5	10.3
Sodium Carbonate	Na ₂ CO ₃				
Sodium Chloride	NaCl	6.4	2.3	4.8	4.1
Tricalcium Phosphate	Ca ₃ (PO ₄) ₂	0.4	0.4	0.4	0.4
Water	H ₂ O	9.7	9.4	9.6	9.4
Ash or Unburned Carbon	C	1.2	1.7	1.7	2
TOTAL PERFORMANCE FACTORS		100	100	100	100
Autoignition Temp, ° F.		760	790	780	820
Open tube burn					
Burn rate, secs/in.		6.4	6.8	7.3	6.9
Bulk Density		0.85	0.85	0.79	0.83
Moisture, wt. %		0.7	0.9	0.8	0.8
Ballistics 80 gr. vol.					
Lo velocity, fps		1426	1947	1762	1904
Hi velocity, fps		1466	2030	1815	1945
ES velocity, fps		40	83	83	41
Av velocity, fps		1449	1995	1786	1924
SD velocity, fps		14	33	20	16
TTP, ms.		0.9	0.6	0.7	0.6
Pressure, psi max.		3500	12600	9300	10400
Fouler pressure, psi		1900	8500	6700	7600

In addition to the elimination of sulfur as previously disclosed in the teachings of our parent application, we have now discovered that it is possible to eliminate elemental carbon also in order to formulate a fully functional white propellant. Thus, two of the three traditional constituents of blackpowder can be omitted utilizing our new formulations. Sulfur and

carbon have accounted for many of the problems associated with blackpowder since the products of combustion form corrosive sulfur compounds and black carbonaceous residues.

White propellants free of both sulfur and carbon can be formulated with a fuel agent selected from the group consist-

TABLE 4-continued

White Powder Formulations					
Sodium Benzoate	NaC7H5O2	18.9	13.9	20.9	
Potassium Nitrate	KNO3	41.7	41.7	46.7	
Potassium Perchlorate	KClO4	28	28	26	
Tricalcium Phosphate	Ca3(PO4)2	0.4	0.4		
Lactose	C12H22O11				
Sodium Salicylate	NaC7H5O3				
Sodium m-Nitrobenzoate	C7H4NO4Na	5	10		
Dicyandiamide	C2H4N4				
TOTAL		100	100	100	
Oxidizer %		69.7	69.7	72.7	
COMBUST PRODUCTS, wt. %					
Ammonium Carbonate	(NH4)2CO3				
Carbon Dioxide	CO2	5.8	12.4		
Carbon Monoxide	CO	25.5	19.7		
Hydrogen Sulfide	H2S				
Methane	CH4				
Nitrogen	N2	6.1	6.5		
Potassium Carbonate	K2CO3	39.2	38.7		
Potassium Thiocyanate	KCNS				
Potassium Sulfate	K2SO4				
Potassium Thiosulfate	K2S2O3				
Potassium Sulfide	K2S, K2S2				
Potassium Chloride	KCl	3.4	4		
Sodium Carbonate	Na2CO3				
Sodium Chloride	NaCl	9.2	8.7		
Tricalcium Phosphate	Ca3(PO4)2	0.4	0.4		
Water	H2O	10.4	9.6		
Ash or Unburned Carbon					
TOTAL		100	100		
GASES, wt. %		47.8	48.2		
SOLIDS, wt. %		52.2	51.8		
PERFORMANCE FACTORS					
Autoignition Temp, ° F.					
Burn rate, secs/in.		5.5	5.2		
Bulk Density		0.80	0.77	0.86	
Moisture, wt. %		0.75	0.8	1	
Ballistics for 100 gr. Sabot					
Av velocity, fps		1918	1964	1831	
SD velocity, fps		16	41	29	
Ignition		ok	ok	ok	
Pressure, psi max.		28200	37000	18800	
Pressure, avg		23000	31500	16600	

From the foregoing it will be seen that this invention is one well adapted to attain all the ends and objects hereinabove set forth, together with the other advantages which are obvious and which are inherent to the invention.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

Since many possible embodiments may be made of the invention without departing from the scope thereof, it is understood that all matter herein set forth is to be interpreted as illustrative and not in a limiting sense.

Having thus described our invention, we claim:

1. A white propellant composition free of elemental sulfur and elemental carbon, said composition consisting of a fuel agent select from the group consisting sodium benzoate and sodium m-nitrobenzoate and mixtures thereof, dextrin, present in the range of 4 to 8 percent by weight, potassium nitrate, potassium perchlorate and tricalcium phosphate present in the range of 0.1 to 0.7 percent by weight.

2. The propellant composition as in claim 1, said fuel agent present in the range of 17 to 25 percent by weight.

3. The propellant composition as in claim 2, said fuel agent present in the range of 19 to 23 percent by weight.

4. The propellant composition as in claim 2 with potassium nitrate present in the range of 42 to 52 percent by weight and potassium perchlorate present in the range of 21 to 31 percent by weight.

5. The propellant composition as in claim 4, said fuel agent present in the range of 19 to 23 percent by weight; dextrin present in the range of 5.5 to 6.5 percent by weight; potassium nitrate present in the range of 45 to 49 percent by weight; potassium perchlorate present in the range of 24 to 28 percent by weight; and tricalcium phosphate present in the range of 0.3 to 0.5 percent by weight.

6. The propellant composition as in claim 1, said fuel agent consisting of sodium benzoate present in the range of 17 to 25 percent by weight; dextrin present in the range of 4 to 8 percent by weight; potassium nitrate present in the range of 42 to 52 percent by weight; potassium perchlorate present in the range of 21 to 31 percent by weight; and tricalcium phosphate present in the range of 0.1 to 0.7 percent by weight.

7. The propellant composition as in claim 6 with sodium benzoate present in the range of 19 to 23 percent by weight; dextrin present in the range of 5.5 to 6.5 percent by weight; potassium nitrate present in the range of 45 to 49 percent by weight; potassium perchlorate present in the range of 24 to 28 percent by weight; and tricalcium phosphate present in the range of 0.3 to 0.5.

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8. A white propellant composition free of elemental sulfur and elemental carbon, said composition consisting of a fuel agent select from the group consisting sodium benzoate and sodium m-nitrobenzoate and mixtures thereof, dextrin, potassium nitrate, potassium perchlorate, tricalcium phosphate, and dicyanodiamide.

9. The propellant composition as in claim 8, said fuel agent present in the range of 17 to 25 percent by weight.

10. The propellant composition as in claim 9, said fuel agent present in the range of 19 to 23 percent by weight.

11. The propellant composition as in claim 9 with potassium nitrate present in the range of 42 to 52 percent by weight; potassium perchlorate present in the range of 21 to 31 percent by weight; and dicyanodiamide present in the range of 0 to 5 percent by weight.

12. The propellant composition as in claim 11, said fuel agent present in the range of 19 to 23 percent by weight; dextrin present in the range of 5.5 to 6.5 percent by weight; potassium nitrate present in the range of 45 to 49 percent by weight; potassium perchlorate present in the range of 24 to 28 percent by weight; tricalcium phosphate present in the range

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of 0.3 to 0.5 percent by weight; and dicyanodiamide present in the range of 0 to 5 percent by weight.

13. The propellant composition as in claim 8, said fuel agent consisting of sodium benzoate present in the range of 17 to 25 percent by weight; dextrin present in the range of 4 to 8 percent by weight; potassium nitrate present in the range of 42 to 52 percent by weight; potassium perchlorate present in the range of 21 to 31 percent by weight; tricalcium phosphate present in the range of 0.1 to 0.7 percent by weight; and dicyanodiamide present in the range of 0 to 5 percent by weight.

14. The propellant composition as in claim 13 with sodium benzoate present in the range of 19 to 23 percent by weight; dextrin present in the range of 5.5 to 6.5 percent by weight; potassium nitrate present in the range of 45 to 49 percent by weight; potassium perchlorate present in the range of 24 to 28 percent by weight; tricalcium phosphate present in the range of 0.3 to 0.5; and dicyanodiamide present in the range of 0 to 5 percent by weight.

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