Eutectic Sugar Propellant Research, Part I

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Introduction

A eutectic system is a mixture of chemical compounds or elements that has a single chemical composition that solidifies at a lower temperature than any other composition. This composition is known as the eutectic composition and the temperature is known as the eutectic temperature. On a phase diagram the intersection of the eutectic temperature and the eutectic composition gives the eutectic point.
One of many eutectic salt mixtures is 54.5 parts by weight KNO_3 and 45.5 parts by weight $NaNO_3$. The melting point of the eutectic system is approx. 220°C (428°F). Fig. 1 shows the phase diagram [1].

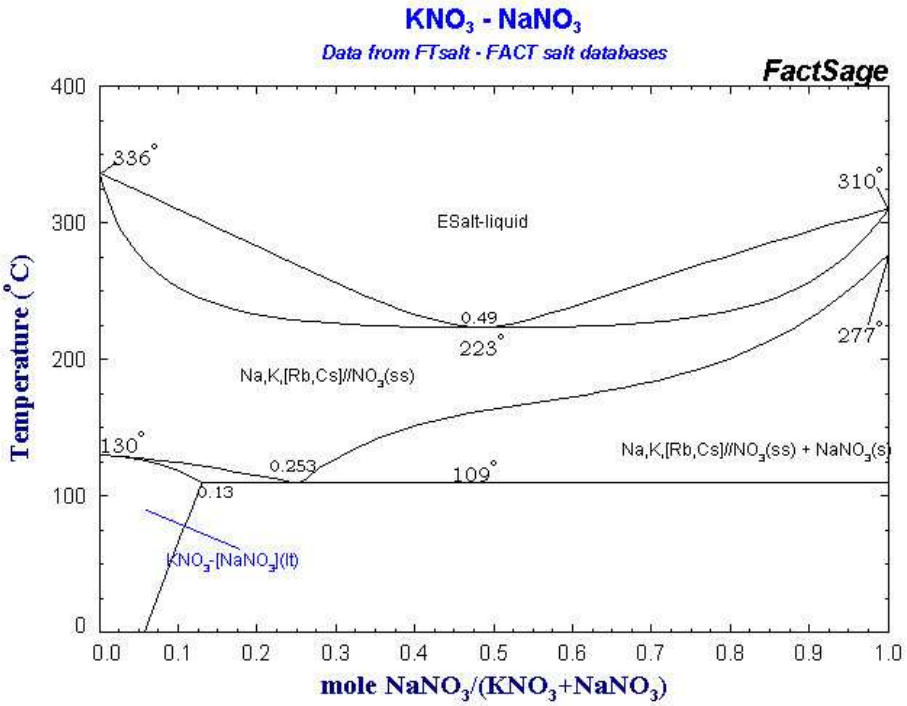

Fig. 1

Normal sugars like sucrose can not be used as fuels as it decomposes as it melts at 186 °C (367 °F) to form caramel. Fortunately sugar alcohols like sorbitol or mannitol have a different thermal behavior. They can be heated up to the boiling point without decomposition. Sorbiol has for example a melting point of 110-112°C and a boiling point of 295°C, mannitol a melting point of 166-168°C and a boiling point of 290-295°C. This non-pyrolysis behavior of sugar alcohols makes them a useful fuel for eutectic oxidizer mixtures like $KNO_3/NaNO_3$.

Experiment

Chemicals required:

- KNO_3 
- $NaNO_3$ 
- Sorbitol ($C_6H_{14}O_6$)

Equipment required:

- Laboratory scale (resolution 0.01g)
- Laboratory heating plate with temperature sensor and thermostat
- Beaker 100ml (Borosilicate glass!)
- Glass rod
- Coated baking paper
- Butane torch
- Fire proof surface (tile)

Procedure:

- Weigh 5.45g KNO_3 and 4.55g $NaNO_3$
- Put the KNO_3 and $NaNO_3$ into a beaker (Borosilicate glass!)
- Mix the two substances
- Put the beaker with mixture on laboratory heating plate with temperature sensor and thermostat, insert temperature sensor into salt mixture
- Pre-set the temperature to 220ºC
- Heat till 220ºC are reached and salt mixture is liquefied (the theoretical melting point of the eutectic mixture is approx 220ºC but my mixture was already completely liquefied at 180ºC, maybe due to some impurities)
- Add slowly 5.4g sorbitol, stir with glass rod till the sorbitol is molten and 'dissolved' completely in the salt bath. The solution will turn slightly brown, but will turn white again after cured
- Pour the solution slowly on a coated baking paper. Be careful, it has a viscosity nearly like water!
- Let it cool down for 10 minutes
- Ignite the cured puddle on a fire proof surface like a tile with a butane torch. The mixture is very difficult to ignite due to its high heat of fusion (nearly like thermite), but then burn violently

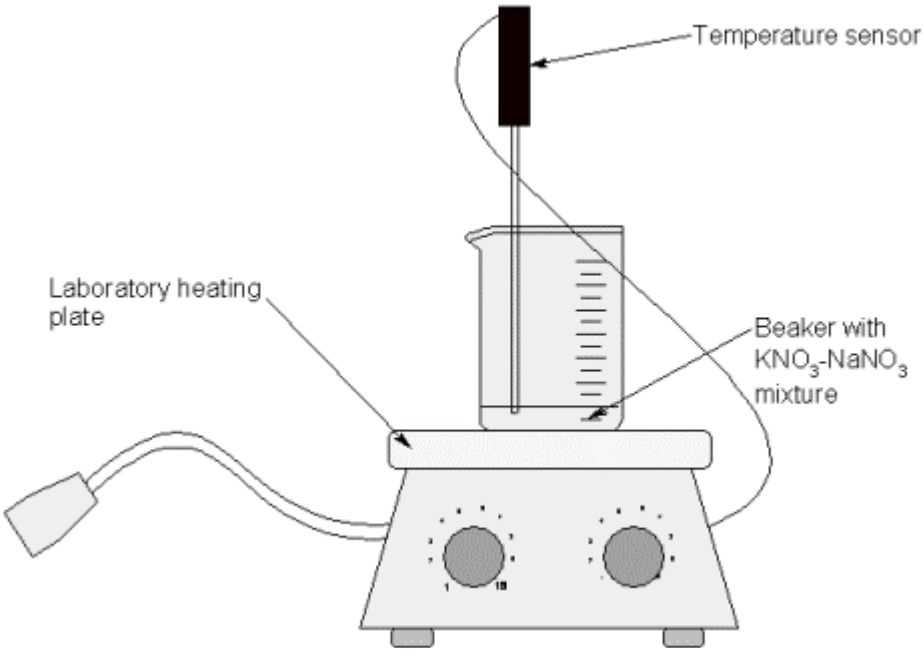

Fig. 2

Combustion test video: http://www.youtube.com/watch?v=4QjOm_zOI9s

Discussion

Pros:

- The burn rate is very fast due to its solution homogeneity and density. No other method can archive a higher density and homogeneity
- The eutectic propellant contains no water
- The eutectic propellant is less prone to hygroscopy due to its crystalline structure and reduced surface area
- It is difficult to ignite (safety)
- Impurities of the oxidizer salts can be skimmed from the surface after liquefaction

Cons:

- Difficult to manufacture, special apparatus needed to cast bigger propellant grains
- Danger of self ignition by over heating the oxidizer/fuel solution
- Difficult to ignite, similar igniters like for thermite

References

[1] http://www.sgte.org/fact/phase_diagram.php?file=KNO3-NaNO3.jpg&dir=FTsalt