Preparation of KNSB Composite Sugar Propellant: An Investigation and Commentary

on

Wednesday, 5th March, 2025

1 Introduction

This report aims at investigating and commenting on an optimal procedure for lab-scale production of Potassium Nitrate-Sorbitol Composite Sugar Propellant (KNSB). This investigation is essential as it will form a basis for future synthesis and will mitigate potential failures during testing of the Solid Rocket Motor (SRM).

The KNSB produced through this procedure will be sufficient for two to four grains, depending on the target size of grain and class of SRM of the enthusiast.

2 Apparatus and Reagents

- Fine Potassium Nitrate ($KNO_{3(s)}$)
- Liquid Sorbitol ($C_6H_{14}O_{6(l)}$)
- Casting mold
- Casting foil
- Core rods
- Stopwatch
- Skillet
- Induction Oven
- Electronic Balance

- Silicon Spatula
- Gloves
- Face Mask
- Goggles
- Pestle & Mortar
- Grease
- Zip-lock bags
- Silica Gel beads

3 Method

The skillet was weighed on the electric balance before 1453.16 g of $C_6H_{14}O_{6(l)}$ were added to it. The skillet, now with $C_6H_{14}O_{6(l)}$, was transferred to the induction oven that was set at 240°C. As the $C_6H_{14}O_{6(l)}$ was boiled, 1889.68 g of $KNO_{3(s)}$ were weighed on the electric balance as the casting molds were being assembled and lined with casting foil. After 30 minutes had elapsed on the stopwatch, the temperature was reduced to 180°C and the stirring of the $C_6H_{14}O_{6(l)}$ began, while checking its color. After 5 minutes, the temperature was further reduced to 90°C after a color change from colorless to light caramel was noticed. Small amounts of $KNO_{3(s)}$ were added while stirring the contents in the skillet and the temperature was increased to 120°C. After 20 minutes, after the $KNO_{3(s)}$ was added, temperature was reduced to 60°C while stirring. After 10 minutes, the mixture turned white in color and the temperature was raised to 90°C in preparation for casting. The prepared KNSB was then transferred to two casting molds and two greased core rods were inserted in the middle of the cast. After 3 hours had elapsed, the core rods were removed from the casting molds. The casting molds, still with the KNSB, was transferred in to two zip-lock bags, quarter-filled with silica beads. After 2 days, the KNSB grain was demolded and then sealed in the beaded zip-lock bag.[1]

4 Discussion

4.1 Determining the Optimal KNSB Ratio

The steps below outline how we came up with the weights of reagents used in the preparation of KNSB. This is for two Grains. Further optimization of these calculations is encouraged. [2]

Soln: Using Grain with core diameter of $33\,mm$ and taking the simulated mass of one Grain to be $1,264\,g$, also allowing 15% for wastage, the expected mass of Grain will be:

$$M_{KNSB}:\ 1.15 \times 1,264 = 1,454\,g$$

Taking optimum $KNO_{3(s)}$ to $C_6H_{14}O_{6(l)}$ ratio to be $65:35$, the mass of $KNO_{3(s)}$ to be weighed will be:

$$M_{KNO_{3(s)}}:\ 0.65 \times 1,454 = 945\,g$$

Expected mass of $C_6H_{14}O_{6(l)}$ to be weighed will be:

$$M_{C_6H_{14}O_{6(l)}}:\ 0.35 \times 1,454 = 509\,g$$

Since there is 70% of $C_6H_{14}O_{6(l)}$ in solution, the adjusted mass of $C_6H_{14}O_{6(l)}$ will be:

$$\left(\frac{100 \times 509}{70}\right) g = 727g$$

Adjusting for 2 grains:

$$M_{KNO_{3(s)}} = 2 \times 945 = 1,890\,g$$
$$M_{C_6H_{14}O_{6(l)}} = 2 \times 727 = 1,454\,g$$

4.2 Error Analysis

The basis of the error in masses of the reagents will be mostly due to the accuracy and precision of the electronic balance and therefore systematic in nature. We'll now provide the absolute and relative error encountered in this experiment.
Soln: The absolute error is given by:

$$\Delta x = |x_0 - x|$$

...where x_0 is the **measured value** and x is the **actual or ideal value**

$$\therefore\ \Delta x_{KNO_3} = |(1889.68 - 1890.00)|\,g = 0.32\,g$$

$$\Delta\, x_{C_6H_{14}O_6} = |(1453.16 - 1454.00)|\,g = 0.84\,g$$

The total error will be:

$$\begin{aligned}\Delta x_{KNSB} &= \Delta x_{\mathrm{KNO_3}} + \Delta x_{\mathrm{C_6H_{14}O_6}} \\ &= 0.32 + 0.84 \\ &= 1.16\, g\end{aligned}$$

The relative error is given by:

$$\begin{aligned}\delta x_{KNSB} &= \frac{\Delta x_{KNSB}}{x} \\ &= \frac{1.16}{3344.00} \\ &= 0.00034688995 \\ &= 3.4689 \times 10^{-4}\end{aligned}$$

...and the percentage error will be:

$$\begin{aligned}\%\, \delta x_{KNSB} &= \delta x \times 100\% \\ &= 3.4689 \times 10^{-4} \times 100\% \\ &= 3.4689 \times 10^{-2}\% \\ &= 0.035\%\end{aligned}$$

5 Conclusion

Through this brief report, we have described an example procedure for the synthesis of KNSB. Modification of, at most, one parameter i.e. either **temperature**, **pressure**, **mass of reagents** or **wait time**; is encouraged for far from ideal results.

References

[1] R. Nakka, *Knsb propellant*, Jul. 2023. [Online]. Available: `https://www.nakka-rocketry.net/sorb.html`.

[2] J. Kimanthi Kioko, M. Kinyua, N. Ndung'u, *et al.*, *N-3.5 rocket launch (2024): Solid propulsion: Technical report.* 2024. [Online]. Available: `https://nakujaproject.com/resource/N3.5_Solid_Propulsion_Technical_Report.pdf`.

[3] A. I. Vogel, *Vogels Textbook Of Quantitative Chemical Analysis*. Pearson Education, 2006, ISBN: 9788177581805. [Online]. Available: `https://books.google.co.ke/books?id=b5WbqDuL0foC`.

Appendices

A Comment on the % H_{20} in Sorbitol

We carried out an investigation on the moisture content of Sorbitol and we found some interesting results. This leads to the modification of the calculation of the optimal KNSB ratio (*See 4.1*).

W_0	W_1	W_2	$\%H_2O_{experimental}$	$\%H_2O_{theoretical}$	Elapsed Time
5.58 g	22.87 g	18.40 g	19.50	25.85	53 min 42 s
5.58 g	18.99 g	14.00 g	26.30	37.21	67 min 12 s
5.58 g	19.01 g	13.90 g	26.85	38.05	56 min 34 s

Table 1: *Testing H_2O of Sorbitol using KERB DAB Moisture Analyzer*

In Table 1 above:

- W_0 refers to the mass of the measuring lid of the analyzer
- W_1 refers to the initial mass of the sorbitol and the lid
- W_2 refers to the final mass of the sorbitol and the lid

These are results from heating the 70% solution at 105°C, with the respective elapsed times provided.

The theoretical value for the $\%H_2O$ calculation was obtained using the formula [3]:

$$\%H_2O_{theoretical} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

We found that using the mean $\%H_2O_{experimental}$ to be favorable in the synthesis. $\therefore$ Adjusting the KNSB ratio calculations, the mean $\%H_2O$ found to be:

$$\left(\frac{19.50 + 26.30 + 26.85}{3}\right)\% = 24.22\%$$

Corrected mass of $C_6H_{14}O_{6(l)}$ to be weighed will be:

$$\left(\frac{100 \times 509}{75.78}\right)\ g = 672\ g$$

...and for 2 grains:

$$M_{C_6H_{14}O_{6(l)}} = 2 \times 672 = 1,343\ g$$