THE CHEMISTRY OF PROPELLANTS IN THE CLASSROOM

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ABSTRACT

This paper presents a possible use of rocket chemistry (propellants) as a generating theme for teaching chemistry. The well-known "rocket candy" (sucrose-potassium nitrate propellant), KNSu is prepared and it is suggested as his combustion can be employed as a generating theme for teaching chemistry. *[African Journal of Chemical Education—AJCE 11(1), January 2021]*

INTRODUCTION

As is well known, the presence of playfulness (ludic) in the teaching-learning process can greatly facilitate the assimilation of content by the student. In addition, activities that favors multidisciplinary (content integration) are certainly also very beneficial.

As was pointed out by Bulunuz [1]: *The best predictors of developing a positive attitude toward science learning and teaching were playful activities in the methods course made learning easier and playful activities relieved boredom*. McDonald and co-workers [2] Reinforces this statement: *Teachers' attitudes toward science and teaching science are crucial factors influencing effective science education in the primary school years. The impact of negative teacher attitudes has been shown to hinder student learning, and ultimately diminish students' attitudes toward science due to dependence on transmissive pedagogies resulting from a lack of confidence in teaching science, and providing fewer opportunities for students to learn by devoting less time to teaching science in the curriculum*.

Using the words of Professor Thomas A. Logothetis [3]: *Study without desire spoils the memory, and it retains nothing that it takes in." remarks Leonardo da Vinci and Albert Einstein adds that "Learning is experience; everything else is just information." First and foremost, chemistry is a practical science and it is my pleasure offering such an experience for our students ensuring they achieve education rather than receiving it – and so kindling this desire.*

Of course, motivation of students is a key factor in any learning situation/process. In this connection, to create more meaningful and engaging learning environments is a purpose to be constantly pursued by teachers, especially in elementary and secondary education, in which the student does not yet have (as, it is thought, will have at the University) the exact notion of the relevance of what is being taught.

In this article we bring the use of rocket chemistry (propellants) as a generating theme for teaching chemistry.

METHODOLOGY

The prepared propellant was the well-known "rocket candy" (sucrose-potassium nitrate propellant), KNSu. Both reagents can be found very easily in supermarkets (sucrose) and stores that sell gardening and agriculture items (KNO_3).

The "ideal" proportion (m/m) is 65 g of KNO_3 to each 35 g of sucrose ($C_{12}H_{22}O_{11}$). Both reagents must be mixed mechanically and then heated until the melting of sucrose, forming a light brown (a darker one if the sucrose starts to decompose) viscous mass that can be shaped. On youtube, there are many videos showing how to prepare this propellant [4].

This viscous mass (the propellant) can then be used to fill a small cardboard tube, which will be the "engine" of our rocket. In our case, the "engine" was glued to the top of a cart (a small hammer), creating our "Hammer rocket" (Figure 1). A "wick" can be placed on the back of the rocket to start the ignition.

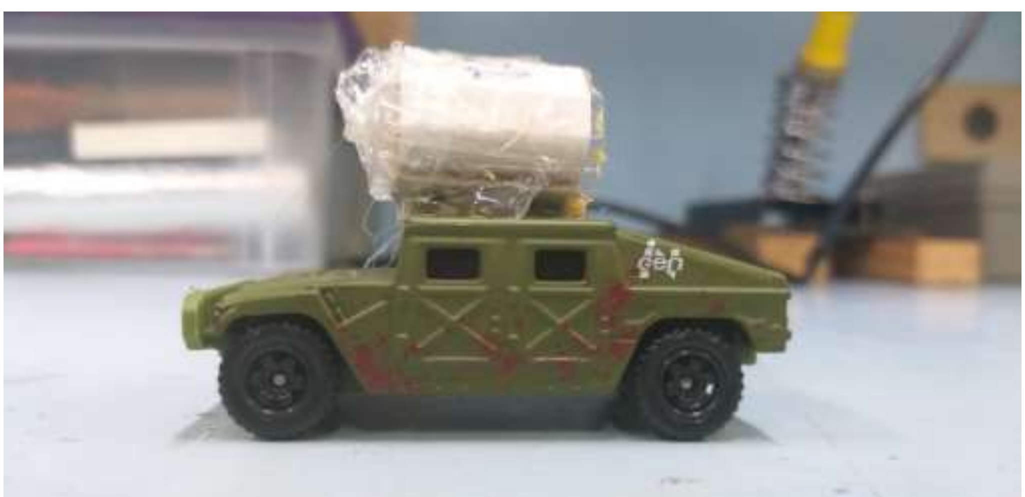

Fig. 1. The "Hammer rocket"

Using a small rocket, as shown in Figure 1, the amount of smoke released is relatively small. Taking the necessary precautions, the experiment can be carried out even in the classroom or outdoors (without the need to have a laboratory available; Figure 2).

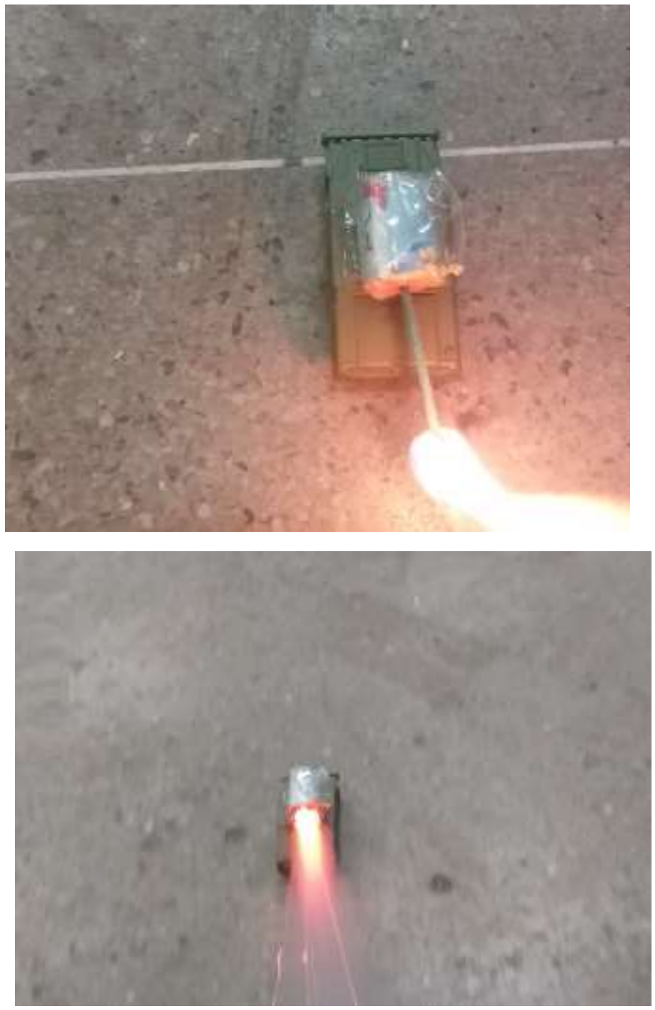

Fig. 2. The “Hammer rocket” been “launched”.

Since the discovery of fire, that humanity has an atavic attraction by fire, explosions and so one. The chemistry teaching based on the chemistry of propellants explores such attraction, of course.

RESULTS AND DISCUSSION

For KNSu, the stoichiometric balanced equation is:

$C_{12}H_{22}O_{11} + 6.3\ KNO_3 \rightarrow 3.8\ CO_2 + 5.2\ CO + 7.8\ H_2O + 3.1\ H_2 + 3.1\ N_2 + 3.1\ K_2CO_3 + 0.3\ KOH$

Hence, the first challenge for students is to show that the 65g: 35g ratio is in line with the balanced equation.

After combustion, in addition to black residues, the presence of white residues (K_2CO_3 and KOH) can be noticed. A portion of the residues can be removed, dissolved and tested with a phenolphthalein solution, checking the basicity of the residues formed.

Why is the role of sucrose? (combustible) and potassium nitrate? (oxidant). Why should a rocket load its own oxidizer? Answer: because in space there is no air (and, consequently, there is no oxygen) so that it is not enough to load the fuel (as we do in a car or plane, for example), it is also necessary to take the oxidizer.

The relation with physics is obvious: Newton´s third law explain the impulse provided by the rocket to the hammer and the law of motions could be, of course, applied to describe the "Hammer rocket" dislocation.

Of course, as the student can see, such reaction releases a lot of energy (an exothermic reaction). Taking into account the balanced chemical equation, can we calculate the enthalpy of such reaction? Answer: of course, by using the respective (reactants and products) formation enthalpy values:

$$\Delta H_{reaction} = \Sigma\Delta H_f\ (\text{products}) - \Sigma\Delta H_f\ (\text{reactants}) \quad (1)$$

In this case, we have: $\Sigma\Delta H_f$ (CO_2, CO, 7.8 H_2O, H_2, N_2, K_2CO_3, and KOH) - $\Sigma\Delta H_f$ ($C_{12}H_{22}O_{11}$ and KNO_3), each value, of course, multiplied by the respective stoichiometric coefficient:

[(3.8 x -393.51) + (5.2 x -110.53) + (7.8 x - 241.82) + (3.1 x 0) + (3.1 x 0) + (3.0 x -1150.1) + (0.3 x - 424.72) - [-2221.2 + (6.3 x -494.5] = -2197.5 $kJmol^{-1}$.

Potassium carbonate melts at 900º C [5], and at high temperatures, it decomposes, according to the reaction:

$$K_2CO_3 \leftrightarrow„\ K_2O + CO_2$$

Thus, an analysis of the rocket residues after combustion will help us to estimate the temperature reached: if K_2CO_3 is still present, the temperature reached was probably below 900ºC. Since the carbonates react with HCl (forming the respective chloride and releasing CO_2: bubbles formation) promoting the reaction of the residues with a diluted aqueous solution of HCl possibly (depending on the amount of residue used in the analysis) will allow us to know if the carbonate is present.

Since K_2CO_3 and KOH are solids (remains in the rocket after the reaction) it is easy to show that are only the gases formed (CO_2, CO, H_2, N_2 and H_2O) that are responsible by the impulse/movement of the "Hammer rocket". Hence, a good opportunity to introduce or remember the properties of gases specially the relations volume/pressure/temperature.

Since the temperature inside the rocket is much higher than the ambient temperature, the gases inside the rocket experiences very high pressures and then "escape" to an environment with lower pressure, suffering expansion, and such expansion promotes the "Hammer rocket" impulse/movement.

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