Letters

Demonstrations with Nitrocellulose: Possible Further Pedagogic Value

As a chemist with a background in fuels and combustion, I was deeply interested in the article by E. G. Senkbeil and T. P. Gonnella, "Combustion Demonstration Using Updated Flame Tornado" in the November 2000 issue of this *Journal*. One point they made is particularly striking, namely, the statement (p 1450), with reference to the behavior of nitrocellulose in their apparatus, that "having both fuel and oxidizer in the same structure significantly increases the rate of combustion."

I believe that in tertiary teaching of combustion science this point, made on the basis of the simple experimental observations, is very helpful. TNT and dynamite, like nitrocellulose, rely on intramolecular oxygen for reaction, and in my own lecturing to fourth-year students in Fire and Explosions I present them with the statement (*1*) "There is more energy in a candle than in a stick of dynamite [of the same weight]", or sometimes I substitute "TNT" for "dynamite".

This statement is of course true. Hydrocarbon wax has a heat of combustion of around 40 MJ kg^{-1}; TNT, a heat of combustion of 15 MJ kg^{-1}. Moving from hydrocarbon wax to propane gas, heat of combustion 50 MJ kg^{-1}, we can adapt the expression quoted to "kilo for kilo, there is more energy in propane than in TNT"—in fact, by a factor of 50/15 or 3.3. Yet materials such as TNT and dynamite, while having smaller heats of combustion than hydrocarbons, obviously have greater blast potential ("brisance"). This is because about 28% of the combustion energy of TNT becomes blast energy, or about 4.2 MJ of blast energy per kilogram of TNT reacted. By contrast (*1*), when propane ignites only something of the order of 5% of the heat of combustion becomes blast energy, or 2.5 MJ of blast energy per kilogram. This can be linked to the statement by Senkbeil and Gonella quoted above. High explosives have "fuel and oxidizer in the same structure" as already noted, and the consequent enhancement of reaction rate and its effects on the post-combustion gases are the origin of the powerfully explosive behavior of such substances.

Literature Cited

1. See for example, Marshall V. C. *Major Chemical Hazards*; Wiley, New York, 1987; p 255.

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The author replies:

The comments by Dr. Jones are very appropriate and further extend the discussion–comparison of rates of reactions. The comments help to explain the differences in rates of reactions for explosions versus combustion reactions. The comparison of the energy in a candle with that of an equivalent mass of dynamite is an interesting one for students to consider. The comparison of energy available from equivalent masses of propane and TNT provides an excellent example for distinguishing the difference between total heat of combustion and blast energy potential (brisance).

The comparisons could be used in the context of a general chemistry stoichiometric mole problem. If students were given the structures and heats of combustion per mole for both TNT and propane, they could determine the energy available from one kilogram of each. After having found out that propane has more energy available, an explanation of the significance of blast energy potential (brisance) could be used to explain the explosive properties of TNT. The discussion should also include the comment that explosives commonly have both the oxidizer and the fuel in the same structure and this significantly increases the rate of reaction to the point of creating an explosive process.

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