



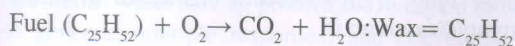
A Flame Full of Science

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"There is no more open door by which you can enter into the study of natural philosophy than by considering the physical phenomena of a candle" – Michael Faraday

Picture credit: National Science Gallery

CANDLE flames always fascinated me as a kid. I wondered what substance it was. But I knew one thing that it was different from other common substances, and we controlled it when we wanted it, with a match or lighter. Little did I know that it's not a substance at all. It's a chemical reaction, an event, not a noun. It's precisely defined by RM Fristom in his textbook as *"An exothermic chain reaction that can propagate subsonically through space."* Here, the exothermic chain reaction is mostly a combustion reaction. It can be described by the overall reaction formula:



The use of the word "subsonic" is interesting. It means that flames, in general, have a speed (relative to unburnt fuel) being less than the speed of sound. But can there be a possibility that it's more? Otherwise, why was this particular word used in the definition in the first place? It turns out there is. Examples are explosions that can spread comparably to the speed of sound.

Chains in Chemistry

The term "chain reaction" is of immense significance as it gives combustion its distinguishing feature — self-sustenance. All chemical reactions have an energy barrier, which can be little but not zero. One can metaphorically think of it as resistance of molecules to change — breaking and formation of new bonds, which essentially happens in a reaction. For combustion, the activation energy to continue the reaction with the incoming fuel is provided by the heat generated in the reaction itself, just some time before. This self-sustenance is the distinguishing feature of combustion from most other chemical reactions (non-chain reactions).

It's linked with another term — ignition temperature. Wikipedia defines it as the lowest temperature at which a substance spontaneously ignites in a normal atmosphere, without a source of external ignition such as a flame or spark. In a candle flame, an initial spark is needed, which is given from a match or lighter, but later on, the produced heat itself increases the temperature of the incoming fuel above ignition temperature, so it continues burning. Technically, it's called a positive feedback loop.

Fight for Electrons

Combustion is a redox reaction; it typically involves two reactants, one of which gets oxidised, and the other gets reduced. Oxygen typically gets reduced, and the fuel gets oxidised. Almost all combustion reactions produce a flame, but the reverse is not true. A common example is the burning of coal. Coal (pure carbon) gets oxidised, and oxygen gets reduced to CO_2 . But on burning, it just gets red-hot; there's no flame. Being exothermic is the property shared in all combustion reactions that makes it so useful for humans and has made humanity evolve.