Explainer: How and why fires burn

- Environment
- Chemistry

The secret of fire: Prometheus to pyrolysis

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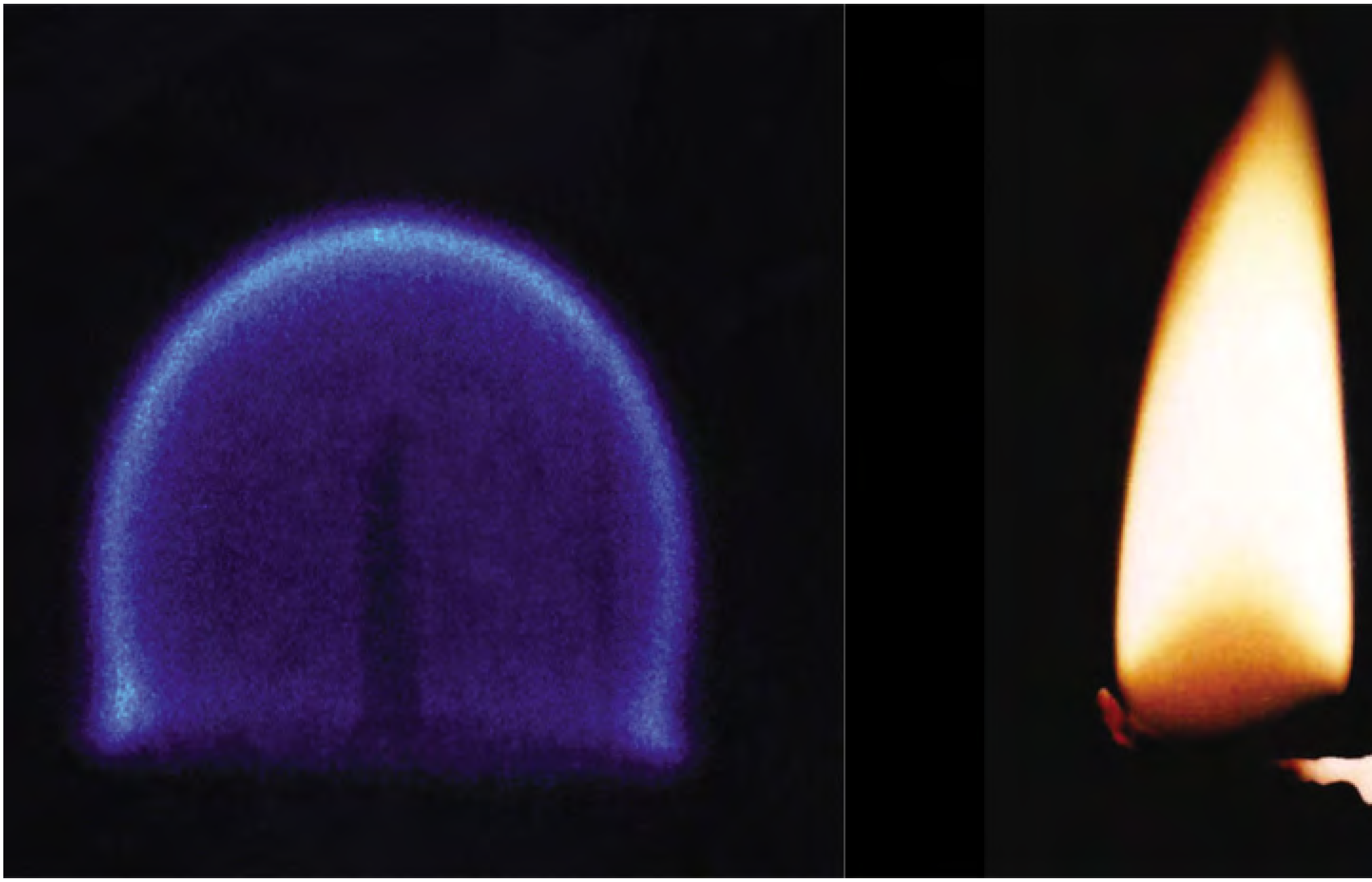

On Earth's surface, gravity gives flames their characteristic shape (right). But in the weak gravity of space, a flame appears as a sphere (left).

NASA

According to Greek mythology, the gods took fire away from people. Then a hero named Prometheus stole it back. As punishment, the gods chained the thief to a rock, where an eagle fed on his liver. Every night, his liver grew back. And each day, the eagle returned. Like other myths, the Prometheus story offered one explanation for the origins of fire. It doesn't, however, offer clues to why things burn. That's what science is for.

Some ancient Greeks believed that fire was a basic element of the universe — one that gave rise to other elements, like earth, water and air. (Aether, that stuff the ancients thought stars were made of, was later added to the list of elements by the philosopher Aristotle.)

Now scientists use the word “element” to describe the most basic types of matter. Fire does not qualify.

A fire’s colorful flame results from a chemical reaction known as combustion. During combustion, atoms rearrange themselves irreversibly. In other words, when something burns, there’s no un-burning it.

Fire also is a glowing reminder of the oxygen that pervades our world. Any flame requires three ingredients: oxygen, fuel and heat. Lacking even one, a fire won’t burn. As an ingredient of air, oxygen is usually the easiest to find. (On planets such as Venus and Mars, with atmospheres containing far less oxygen, fires would be hard to start.) Oxygen’s role is to combine with the fuel.

Any number of sources may supply heat. When lighting a match, friction between the match’s head and the surface against which it’s struck releases enough heat to ignite the coated head. In the Avalanche Fire, lightning delivered the heat.

Fuel is what burns. Almost anything can burn, but some fuels have a far higher flash point — the temperature at which they’ll ignite — than others.

People feel heat as warmth on the skin. Not atoms. The building blocks of all materials, atoms just get antsy as they warm. They initially vibrate. Then, as they warm even more, they start dancing, faster and faster. Apply enough heat, and atoms will break the bonds linking them together.

Wood, for example, contains molecules made from bound atoms of carbon, hydrogen and oxygen (and smaller amounts of other elements). When wood gets hot enough — such as when lightning hits or a log is tossed on an already burning fire — those bonds break. The process, called pyrolysis, releases atoms and energy.

Unbound atoms form a hot gas, mingling with oxygen atoms in the air. This glowing gas — and not the fuel itself — produces the spooky blue light that appears at the base of a flame.

But the atoms don’t stay single long: They quickly bond with oxygen in the air in a process called oxidation. When carbon bonds with oxygen, it produces carbon dioxide — a colorless gas. When hydrogen bonds with oxygen, it produces water vapor — even as the wood burns.

Fires burn only when all that atomic shuffling releases enough energy to keep the oxidation going in a sustained chain reaction. More atoms released from the fuel combine with nearby oxygen. That releases more energy, which releases more atoms. This heats the oxygen — and so on.

The orange and yellow colors in a flame appear when extra, free-floating carbon atoms get hot and begin to glow. (These carbon atoms also make up the thick black soot that forms on grilled burgers or the bottom of a pot heated over a fire.)