

# about Plasmas

from the Coalition for Plasma Science

## Plasma - The First State of Matter

*In the beginning there was plasma.  
The other stuff came later.*

When students are told of the states of matter, they are usually told only of three: solid, liquid, and gas. Those are the states we experience most directly and most often in everyday life. The students are most aware of those states, and they can relate to the idea of adding heat to break bonds between molecules to move from one state to the next.

Rarely is the fourth state in the sequence mentioned -- the state resulting from adding energy to a gas to break the internal bonds of its individual atoms, ionizing those atoms and freeing electrons. When this happens to a significant number of atoms, the resulting collection of electrically charged particles forms an ionized gas -- or a "plasma" -- with unique properties.

As for the importance of material states in our larger world and in our lives, the usual ordering belies the truth of the matter. Not only should plasma be added to the list, but the order should be reversed to put plasma in first place. The Big Bang beginning of our universe was dominated by high-temperature plasma, and plasma continues today to comprise more than 99 percent of our visible universe. It's where we all came from, and it continues to play a major role in our universe and -- albeit not so apparent to the casual observer -- in our more immediate surroundings.

While solids represent familiar material in our immediate earthly surroundings and generally represent the coolest state (in the sense of temperature, not teenage sociology), starting the list with that material misses an important point. In general, material in various states in our universe was not formed by heat added to a more strongly bonded state; rather, it was formed by heat removed from a hotter, more weakly bonded state. That is, stuff is usually formed by cooling. As matter cools, it reaches temperatures at which the atoms and molecules bind together, condensing to form the next state of matter in the cooling sequence. The high temperatures that existed early in the universe clearly correspond to the presence of plasma, not the lower-temperature gases, liquids, and solids that would develop later.

The predominance of plasma in the early universe continues today. While the material in our immediate surroundings is mostly of the cooler varieties, plasma remains the most prevalent form of matter overall. It is the stuff of our sun and of other stars and of the vast interstellar space. Thus plasma not only precedes the other states in time and is their progenitor, it also dominates by occupying most of our universe.



When NASA's Hubble telescope looks far out into space and far back in time, it sees light from plasma.

Plasma is also in our more immediate surroundings. It is the stuff of lightning, of computer chip manufacturing, of flat panel televisions, and of lamps that are the light of our lives. In the future it will likely be the stuff of propulsion for interplanetary travel and of electric power generated from fusion.

Thus plasma deserves respect both as an ancestor and as a major player in our world. Clearly the usual sequence of states of matter should be reversed, with plasma not merely added to that list, but put first to lead that list.



**Most people seem to think that the words at the top of this license plate refer to the state of Delaware. Now you know the real story.**

**Suggested Reading:**

S. Eliezer and Y. Eliezer, "The Fourth State of Matter: An Introduction to Plasma Science," Second Edition, Institute of Physics Publishing, Bristol and Philadelphia, 2001.

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This essay is part of the *About Plasmas* series of two-page write-ups on plasmas. Each piece briefly examines – in a less lighthearted manner than this one – either a naturally-occurring plasma phenomenon or one of the many important application areas of plasma science. In addition to being available on the Coalition website, the write-ups can be obtained as paper copies by emailing a request to the Coalition (see Coalition information below).