Plasma

In physics and chemistry, a plasma is typically an ionized gas. Plasma is considered to be a distinct state of matter, in contrast to gases because of its unique properties. "Ionized" refers to presence of one or more free electrons which is not bound to an atom or molecule. The free electric charges make the plasma electrically conductive so that it responds strongly to electromagnetic fields.

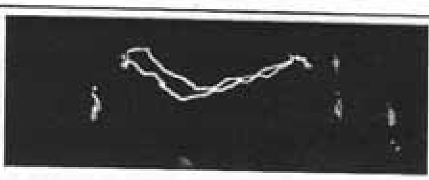
A plasma lamp, illustrating some of the more complex phenomena of a plasma, including *filamentation*. The colours are a result of the relaxation of electrons in excited states to lower energy states after they have recombined with ions. These processes emit light in a spectrum characteristic of the gas being excited.

Plasma typically takes the form of neutral gas-like clouds (e.g. stars) or charged ion beams, but may also include dust and grains (called dusty plasmas). They are typically formed by heating and ionizing a gas, stripping electrons away from atoms, thereby enabling the positive and negative charges to move more freely.

History

This state of matter was first identified in a Crookes tube, and so described by Sir William Crookes in 1879 (he called it "radiant matter"). The nature of the Crookes tube "cathode ray" matter was subsequently identified by British physicist Sir J.J. Thomson in 1897, and dubbed "plasma" by Irving Langmuir in 1928, perhaps because it reminded him of a blood plasma. Langmuir wrote:

"Except near the electrodes, where there are *sheaths* containing very few electrons, the ionized gas contains ions and electrons in about equal numbers so that the resultant space charge is very small. We shall use the name *plasma* to describe this region containing balanced charges of ions and electrons."



Plasma arcs between the probes on a Wimshurst Machine. This device, invented in the early 1880's, has long been a popular laboratory demonstration of plasma.

Common plasmas

Plasmas are the most common phase of matter. Some estimates suggest that up to 99% of matter in the entire visible universe is plasma. Since the space between the stars is filled with a plasma, albeit a very sparse one (see interstellar medium and intergalactic space), essentially the entire volume of the universe is plasma (see astrophysical plasmas). In the solar system, the planet Jupiter accounts for most of the *non*-plasma, only about 0.1% of the mass and 10^{-15}% of the volume within the orbit of Pluto. Notable plasma physicist Hannes Alfvén also noted that due to their electric charge, very small grains also behave as ions and form part of plasma (see dusty plasmas).

Common forms of plasma include		
Artificially produced plasma	**Terrestrial plasmas**	**Space and astrophysical plasmas**
Those found in plasma displays, including TVs Inside fluorescent lamps (low energy lighting), neon signs Rocket exhaust The area in front of a spacecraft's heat	Lightning Flames Ball lightning St. Elmo's fire Sprites, elves, jets	The Sun and other stars (which are plasmas heated by nuclear fusion) The solar wind The interplanetary medium (the space between the planets)

shield during reentry into the atmosphere Fusion energy research The electric arc in an arc lamp, an arc welder or plasma torch Plasma ball (sometimes called a plasma sphere or plasma globe) Plasma used to etch dielectric layers in the production of integrated circuits	The ionosphere The polar aurorae	The interstellar medium (the space between star systems) The Intergalactic medium (the space between galaxies) The Io-Jupiter flux-tube Accretion discs Interstellar nebulae

Degree of ionization

For plasma to exist, ionization is necessary. The word "plasma density" by itself usually refers to the **electron density**, that is, the number of free electrons per unit volume. The degree of ionization of a plasma is the proportion of atoms which have lost (or gained) electrons, and is controlled mostly by the temperature. Even a partially ionized gas in which as little as 1% of the particles are ionized can have the characteristics of a plasma (i.e. respond to magnetic fields and be highly electrically conductive). The degree of ionization, α is defined as $\alpha = n_i/(n_i + n_a)$ where n_i is the number density of ions and n_a is the number density of neutral atoms. The **electron density** is related to this by the average charge state $\langle Z \rangle$ of the ions through $n_e = \langle Z \rangle\, n_i$ where n_e is the number density of electrons.

Temperatures

A candle flame. Fire is frequently referred as being a *low temperature* partial plasma, because only a small proportion of the gas is ionized.

Plasma temperature is commonly measured in kelvins or electronvolts, and is (roughly speaking) a measure of the thermal kinetic energy per particle. In most cases the electrons are close enough to thermal equilibrium that their temperature is relatively well-defined, even when there is a significant deviation from a Maxwellian energy distribution function, for example due to UV radiation, energetic particles, or strong electric fields. Because of the large difference in mass, the electrons come to thermodynamic equilibrium among themselves much faster than they come into equilibrium with the ions or neutral atoms. For this reason the **ion temperature** may be very different from (usually lower than) the **electron temperature**. This is especially common in weakly ionized technological plasmas, where the ions are often near the ambient temperature. Based on the relative temperatures of the electrons, ions and neutrals, plasmas are classified as **thermal** or **non-thermal**. Thermal plasmas have electrons and the heavy particles at the same temperature i.e. they are in thermal equilibrium with each other. Non thermal plasmas on the other hand have the ions and neutrals at a much lower temperature (normally room temperature) whereas electrons are much "hotter". Temperature controls the degree of plasma ionization. In particular, plasma ionization is determined by the **electron temperature** relative to the ionization energy (and more weakly by the density) in accordance with the Saha equation. A plasma is sometimes referred to as being **hot** if it is nearly fully ionized, or **cold** if only a small fraction (for example 1%) of the gas molecules are ionized (but other definitions of the terms **hot plasma** and **cold plasma** are common). Even in a "cold" plasma the electron temperature is still typically several thousand degrees Celsius. Plasmas utilized in **plasma technology** ("technological plasmas") are usually cold in this sense.