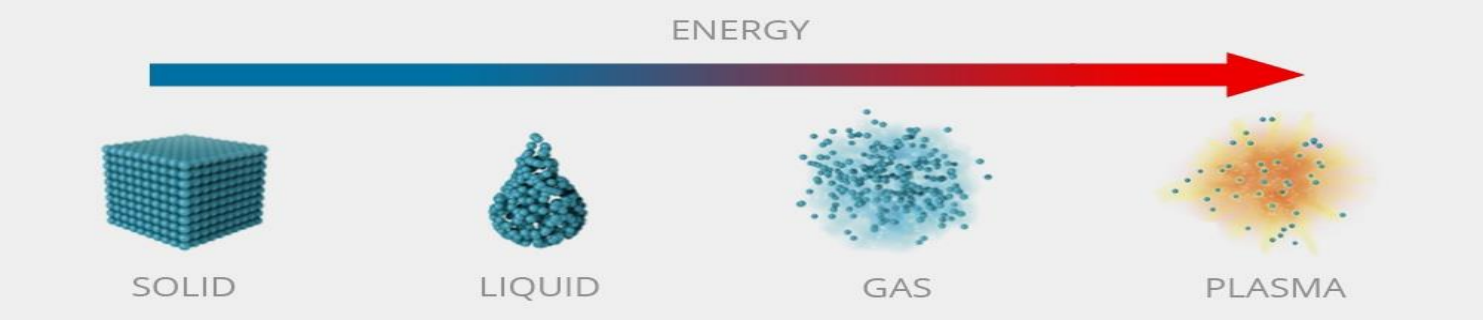
PLASMA

- It is called “the fourth state of matter” comes from the Greek word **plásma** and means “moldable substance” or “jelly”.
- Plasma was first identified by Sir William Crookes in a Crookes tube in 1879.
- He gave name as “radiant matter”
- Irving Langmuir in 1927, studied the ionized gas and gave this new state of matter the name “Plasma”.
- More than 99% of the mass of the universe is in the Plasma state.
- It is a hot ionized gas consists approximately equal numbers of positive ions and free.
- Electrons resulting in more or less no overall charge.

As the fourth state of matter

- As far as we know, matter generally exists in three states in nature.
  These are: (i) $Solid$ (ii) $Liquid$ and (iii) Gas.
- Now when a solid is heated sufficiently that the thermal motion of the atoms break the crystal lattice structure apart, usually a liquid is formed.
- When a liquid is heated enough that atoms vaporize off the surface faster than they recondense, a gas is formed.

Now what happens to a matter just after that gaseous state?



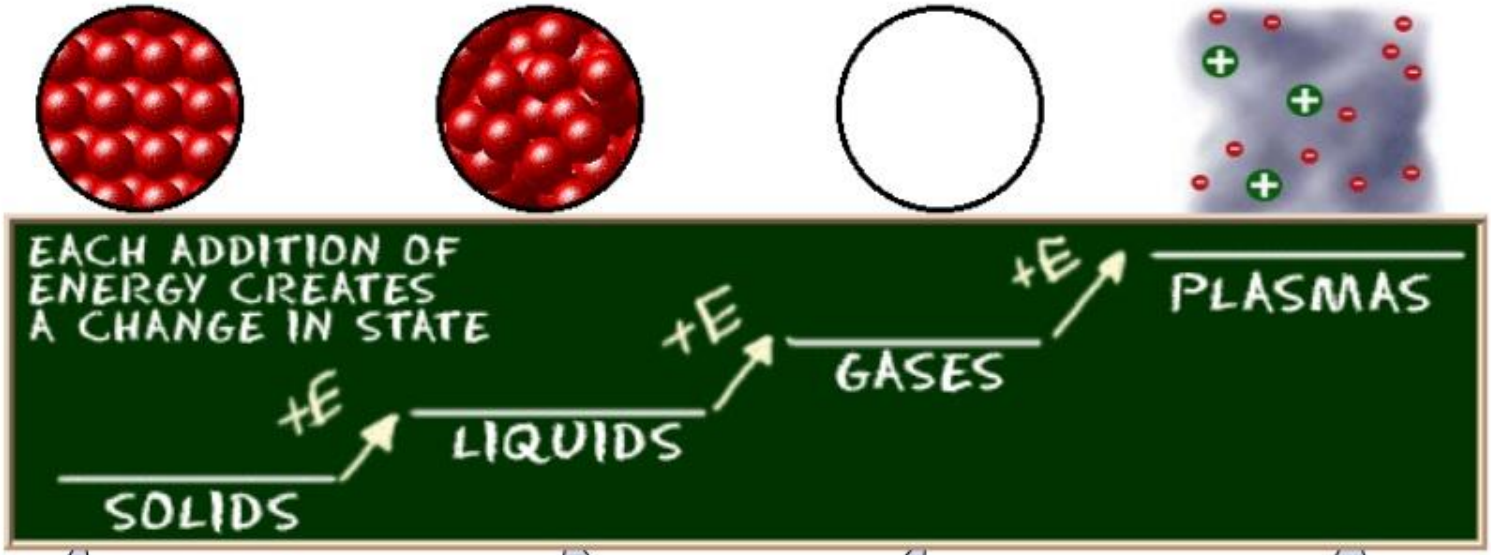
When a gas is heated enough (T > 100,000°C) that the atoms collide with each other and knock their electrons off and in this process a mixture of ions, electrons and neutral atoms is formed.

This is called Plasma: The so-called "fourth state of matter".

http://www.plasmasurgical.com

https://apsplasma.com/

STATES OF MATTER



SOLID

Tightly packed, in a regular pattern
Vibrate, but do not move from place to place

LIQUID

Close together with no regular arrangement.
Vibrate, move about, and slide past each other

GAS

Well separated with no regular arrangement.
Vibrate and move freely at high speeds

PLASMA

Has no definite volume or shape and is composed of electrical charged particles

Characterization of Plasma

Plasma is characterized by following parameter

1. Electron temperature

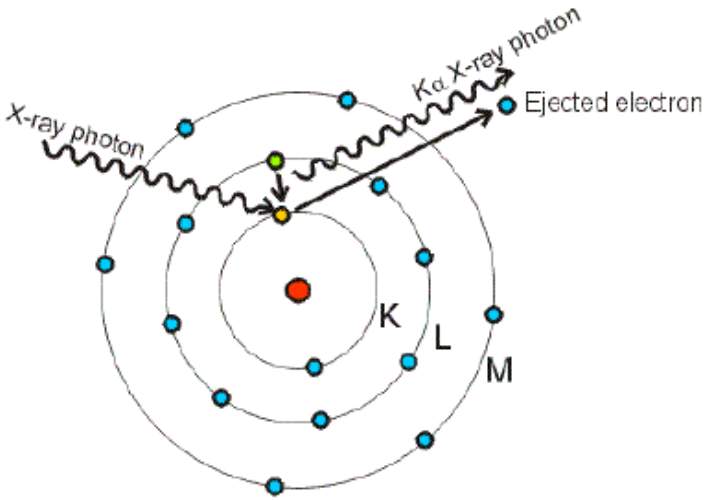
2. Charge particle number density

Details on attached page

HOW TO CREATE PLASMA??

There are many different methods of creating plasmas in the laboratory. The most commonly known processes are (i) *Photoionization* and (ii) *Electric discharge* in gases.

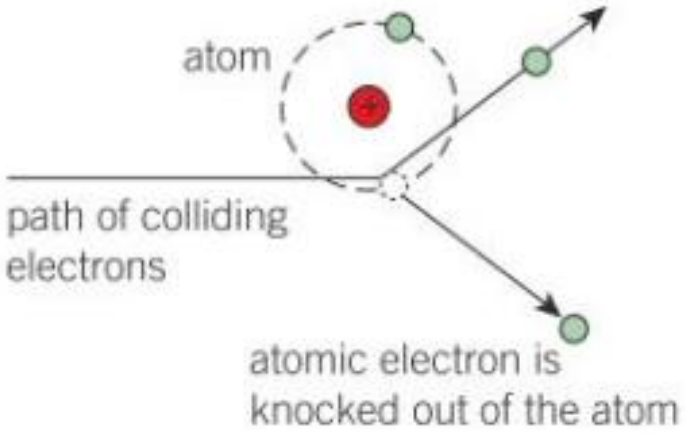
(i) <u>Photoionization</u> : In that process, ionization occurs by absorption of incident photons whose energy is equal to or greater than the ionization potential of the absorbing atom.



The excess energy of the photon is transformed into kinetic energy of the electron-ion pair formed. Ionization can also be produced by X-rays or gamma rays, which have much smaller wavelengths.

https://projects.exeter.ac.uk

(*ii*) <u>Electric discharge</u>: In a gas discharge, an electric field is applied across the ionized gas, which accelerates the free electrons to energies sufficiently high to ionize other atoms by collisions.



When a high-speed electron collides with an electron bound to a nucleus, it can give both electrons enough energy to escape. Thus, ionization is occurred.

https://quizlet.com

Waves in Plasmas

- Waves in plasmas are an interconnected set of particles and fields which propagate in a periodically repeating fashion.
- Due to its electrical conductivity, a plasma couples to electric and magnetic fields. This complex of particles and fields supports a wide variety of wave phenomena.
- The electromagnetic fields in a plasma are assumed to have two parts, one static/equilibrium part and one oscillating/perturbation part.
- Depending on the oscillation of magnetic field, plasma waves can be classified into electromagnetic or electrostatic.
- When Faraday's law of Electromagnetic Induction is applied then it is found that electrostatic waves are purely longitudinal whereas electromagnetic waves may be longitudinal and transverse both.

CLASSIFICATION OF PLASMAS

The degree of ionization of a plasma is the proportion of charged particles to the total number of particles including neutrals and ions.

The degree of ionization α is defined as, $\alpha = \frac{n_i}{n_i+n_n}$ where, n_i is the number density of ions and n_n is the number density of neutral atoms.

Depending on the degree of ionization of the plasma it is classified as (i) *Fully ionized plasma*, and (iii) *Partially ionized plasma*

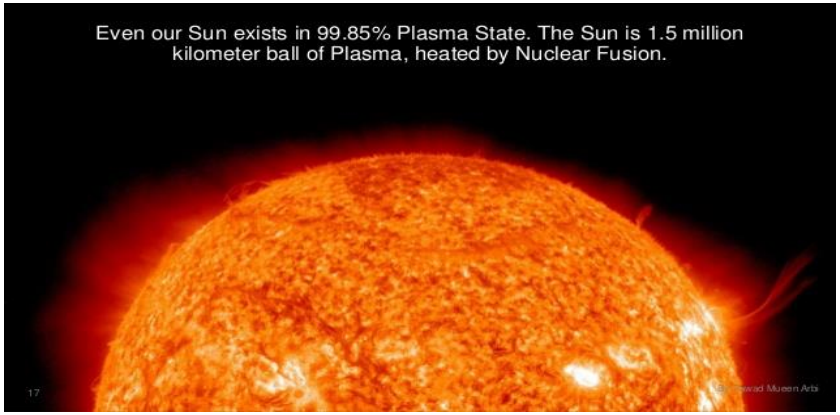
(i) Fully ionized plasma: A fully ionized plasma has a degree of ionization approaching 1 (i.e., 100%).
Examples: The Solar Wind (interplanetary medium), stellar interiors (the Sun's core), fusion plasmas.

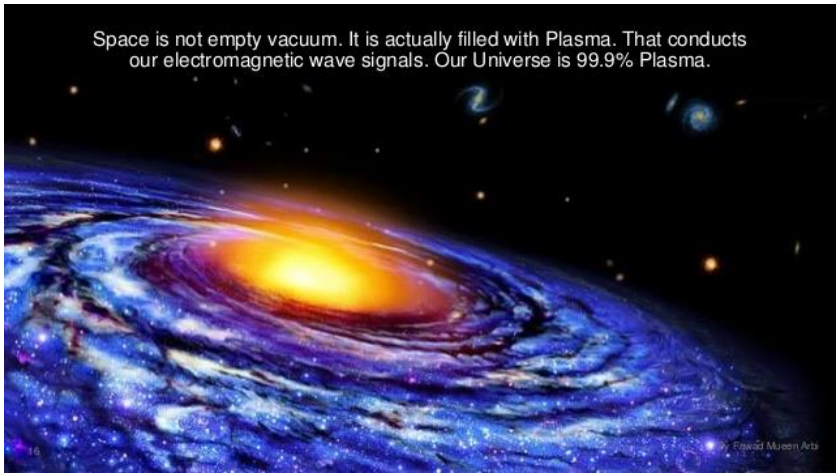
(iii) Partially ionized plasma : A partially ionized plasma has a degree of ionization that is less than 1.
Examples: The ionosphere, gas discharge tubes.

PLASMAS IN NATURE

❖ Plasma in Space

- Stars
- Coronas
- Solar wind
- Star nurseries
- Interstellar Nebulae
- The accretion disks and accretion disk jets of black holes
- Sun exists in 99.85% plasma state. The Sun is 1.5 million Km ball of plasma heated by Nuclear Fusion
- Space is not empty vacuum. It is actually filled with plasma that conducts our EM wave signals. Our Universe is 99.9% Plasma





https://www.plasmas.org/

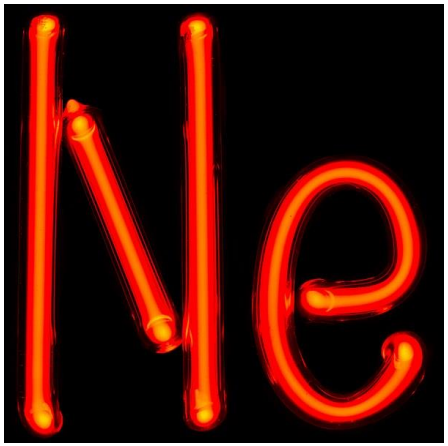
❖ Terrestrial Plasmas

- Fire (When hotter than 1500℃)
- Lightning
- The magnetosphere
- The ionosphere
- The plasmasphere
- The polar aurorae
- The polar wind
- Upper atmospheric lightning (e.g. Blue jets, Blue starters)
- Sprites

https://www.plasmas.org/

❖ Artificial Plasma

- Those found in plasma displays, including TV screen
- Inside fluorescent lamps, neon signs
- Rocket exhaust and ion thrusters
- The area in front of a spacecraft's heat shield during re-entry into the atmosphere
- Fusion energy research
- The electric area in an arc lamp, an arc welder or plasma torch
- Plasma ball (Plasma sphere or Plasma globe)
- Arcs produced by Tesla coils
- Plasmas are used in semiconductor device fabrication
- Laser produced plasma
- Static electric sparks
- In Fusion Test Reactor (FTR) to produce controlled thermonuclear fusion power



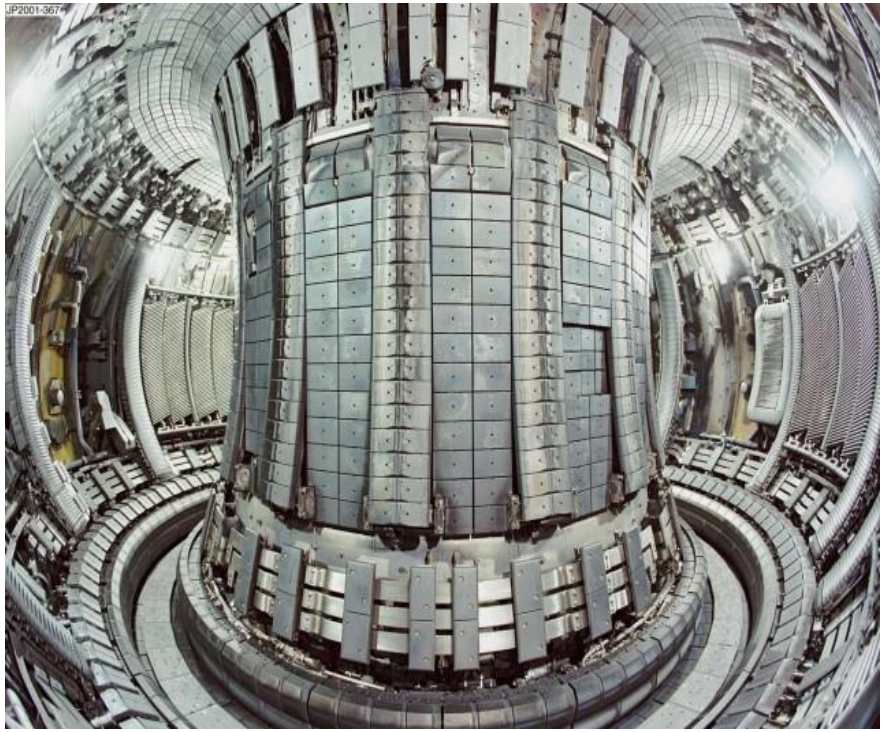
https://www.plasmas.org/


INP
Plasma
Wind turbine: protective wear coating
Plasma
Architectual glass: thermal insulation, self-cleaning, mirror coating
Plasma
Aircraft turbine: protective wear resistant coating
Plasma
Car: xenon headlights, wear protection, friction reduction
Plasma
Implants: biocompatibility, antimicrobial features
Plasma
Functional clothing: thermal insulation, breathability, flexible sensors, water-repellant
Plasma
Food packaging: barrier layers, antimicrobial features
Plasma
Notebook: LED backlight, reflective coating on CD
Plasma
Tools: polishing, hardening, decoating, hard layer coating
Plasma
Smartphone: adhesion, battery, semiconductor technology, display
Plasma
PET bottle: barrier layer for product preservation
Plasma
Mug: printability of polymers
Plasma
Lenses: anti-reflection coating, lotus effect, scratch protection
Plasma
Camera lens: optical coatings

HOW TO CONTAIN IT

Because of the extreme heat of most plasmas, conventional materials can not be used to contain plasma.

However, Plasma is an excellent conductor and hence magnetic fields are used to contain high-density, high-temperature plasmas because such fields exert pressures and tensile forces on the plasma.



https://phys.org

FUTURE OF PLASMA

- One of the great challenges of humankind is to create high temperatures in a controlled manner and to harness the energy of nuclear fusion.
- This is the great practical goal of Plasma Physics to produce nuclear fusion on the Earth. Modern Plasma theory has developed to meet the demands of fusion research.
- Researchers have used the properties of plasma as a charged gas to confine it with magnetic fields and to heat it to temperatures hotter than the core of the sun. Thus scientists have used Plasma in Fusion Test Reactor (FTR).
- Other researchers pursue plasmas for making computer chips, rocket propulsion, cleaning the environment, destroying biological hazards, healing wounds and other exciting applications.

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