STUDY AND APPLICATION OF PLASMA PHYSICS

By

Fatimah jumaah moean

WHAT'S THE PLASMA ?

- The word ‘plasma’ means jelly in Greek.
- The term plasma was first used by Langmuir in 1928 to describe the inner region of a glowing ionized gas found in an arc discharge.
- Any ionized gas cannot be called a plasma, of course; there is always some small degree of ionization in any gas

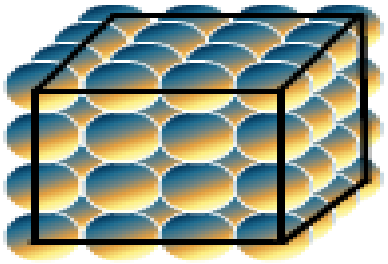
In physics “plasma” is used to describe a partially or completely ionized gas containing electrons, ions, and neutrals atoms . A plasma is a *quasineutral* gas of charged and neutral particles which exhibits *collective behavior*

Properties	Plasma	Gas	Liquid	Solid
Mass, volume, density and shape	Stable mass, no definite shape volume, density	Stable mass, no definite volume, density and shape	Stable mass and volume, no definite density and shape	Stable mass, volume, density and shape
Relative position of particles	Relatively far away from each other	Relatively far away from each other	Free lowing, loosely packed	Fairly stationary, tightly packed
Particle interaction	Collective behavior	Two-particle collision,	Slides over each other and few collisions	Vibrates in place
Independently acting species	Different particles behave differently	Particles behave in the same way in neutral gas	Atoms/molecules behave the same way	Atoms/molecules behave the same way
Velocity distribution	Often non-Maxwellian	Maxwellian vel. distribution	Eddy and laminar velocities	Vibrate about a fixed position
Energy	Extremely high	High	Medium	low
Electrical Conductivity	Usually very high (infinite)	Conductivity is very low	Conductivity is low	Very high in solid conductors

So What's the difference between a gas and plasma?

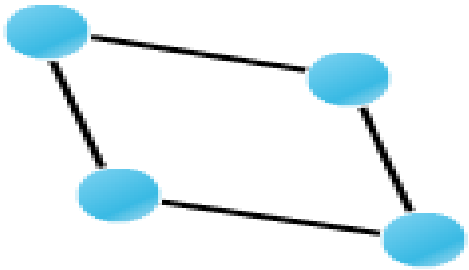
- Gas is electrically neutral throughout and is used as an electrical insulator
- Plasma is electrically charged and used as a conductor of electricity

Solid



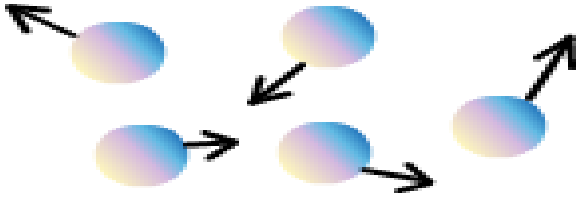
Strong bonds

Liquid



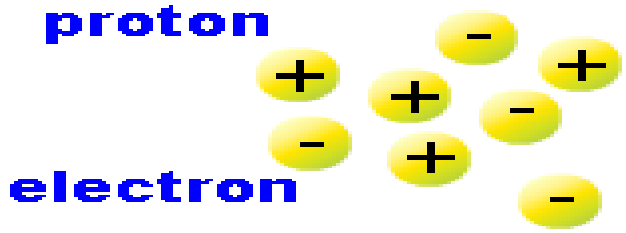
Weak bonds

Gas



no bonds

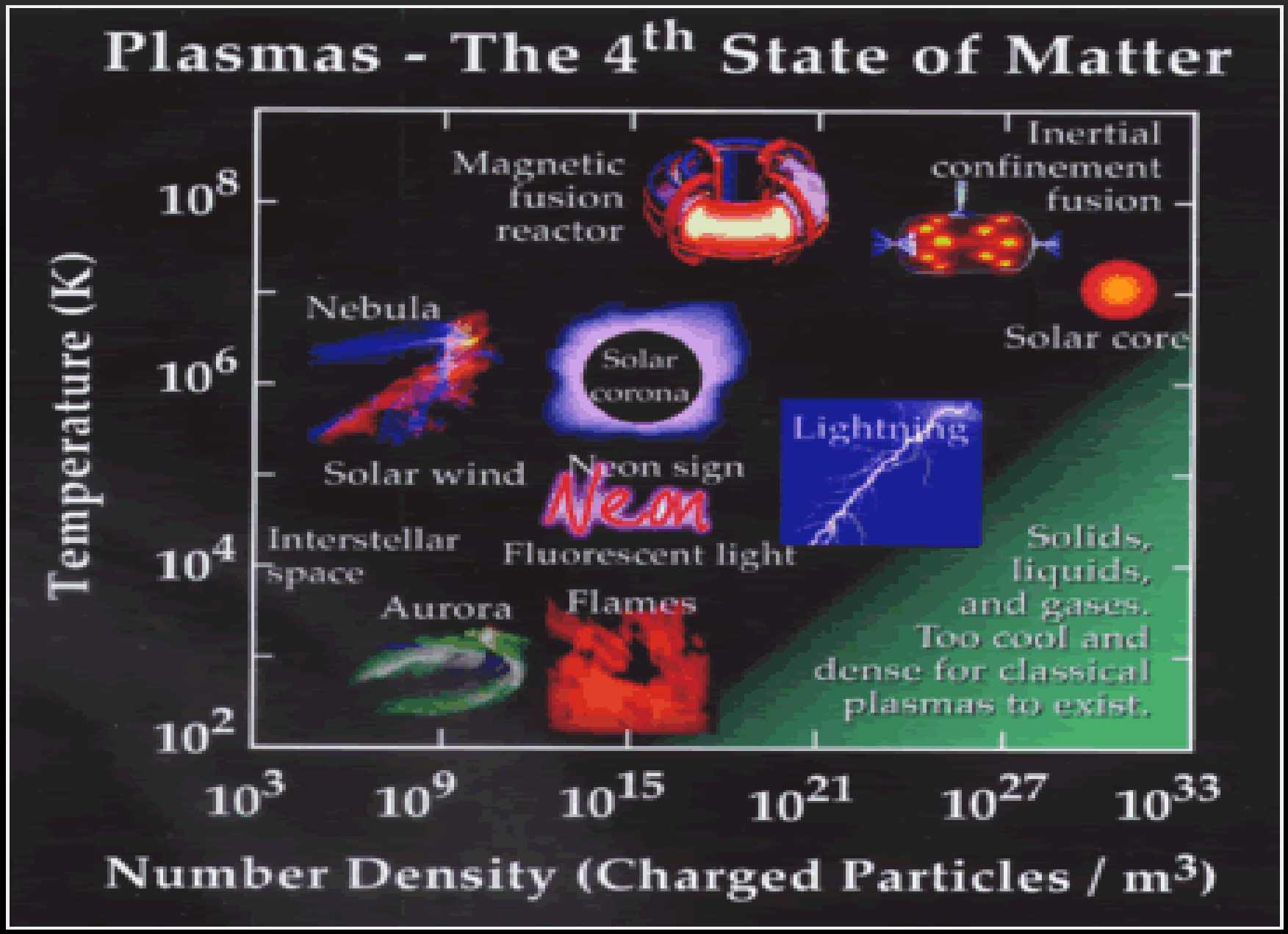
Plasma



ionization

TYPES OF PLASMA :

- Plasma can be categorized into:
- high temperature known as fusion plasma
- low temperature plasma.
- Low temperature plasmas can be further divided into:
- plasma that is in *thermal equilibrium* and those which are *not in thermal equilibrium* ,the term thermal equilibrium refers to when the temperature of all plasma species such as electrons, ions, neutral particles is the same.


Plasmas - The 4th State of Matter
Temperature (K)
10^8
10^6
10^4
10^2
Magnetic fusion reactor
Inertial confinement fusion
Solar core
Nebula
Solar corona
Solar wind
Neon sign
Neon
Lightning
Interstellar space
Fluorescent light
Aurora
Flames
Solids, liquids, and gases. Too cool and dense for classical plasmas to exist.
10^3
10^9
10^15
10^21
10^27
10^33
Number Density (Charged Particles / m^3)

CHARACTERISTICS OF PLASMAS

- *A plasma is a group of charged particles, which consists of free positive and negative charge carriers , have some characteristics such as :*
- **Debye shielding :** A fundamental characteristic of the behavior of plasma is its ability to shield out electric potentials that are applied to it .

$$\lambda_D = \left[\frac{\varepsilon_0 K_B T_e}{n_e e^2}\right]^{1/2} \cong 7.43 x 10^2 \left(\frac{T_e(eV)}{n_e}\right)^{\frac{1}{2}}$$

Debye number Since the shielding effect is the result of the collective behavior inside a Debye sphere of radius λ_D, it is necessary that this sphere contains enough particles due to the exponential decay of the potential .

$$N_D = \frac{4}{3}\pi\, n_e\, \lambda_D^3$$

Plasma frequency An important plasma property is the stability of its macroscopic space charge neutrality

$$\omega_{pe} = (n_e e^2 / m_e \varepsilon_0)^{1/2}$$

PLASMA CRITERIA

- N_D>>1. The number of charged particles within a Debye cube (or sphere) must be large so that collective interactions dominate at the mean interparticle separation distance.

- L >>λ_D .The spatial extent of a collection of charged particles must be large if it is compared to the collective interaction scale length for plasmas, and the Debye length λ_D.

- $\omega_\rho >> \upsilon_{ne}$. The collective inertial response frequency in a plasma, the electron plasma frequency ω_ρ, must be large if it is compared to the electron neutral collision frequency υ_{ne}.

PLASMA DIAGNOSTICS WITH EMISSION SPECTROSCOPY:

- ***Electrostatic ion probes (Langmuir probes)***
- ***Optical emission spectroscopy (OES)***
- ***Laser Induced Fluorescence (LIF) and Optical Absorption Spectroscopy (OAS)***

TYPICAL PLASMA APPLICATIONS

- plasma etching.
- Digital printing.
- 3D printing.
- Semiconductor technology.
- Shipbuilding and aircraft construction.
- Medicine and Cosmetics.
- plasma coating.
- Electronics

PLASMA CONFINEMENT:

- ***tokamak*** magnetic field coils confine plasma particles to allow the plasma to achieve the conditions necessary for fusion.
- ***magnetic mirror,*** known as a magnetic trap is a type of magnetic confinement fusion device used in fusion power to trap high temperature plasma using magnetic fields.

Thank you