Langat Singh College, Muzaffarpur
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# Plasma physics –lecture - 01

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# Plasma

- It is a study of a state of matter comprising charged particles.
- It is an electrically conducting medium in which there are roughly equal numbers of positively and negatively charged particles.
- Plasma are usually created by heating a gas until the electrons become detached from their parent atom or molecule.
- This so called ionization can also be achieved using high power laser light or microwaves.
- It is sometimes referred as the fourth state of matter distinct from solid, liquid and gaseous state.

# Occurrence of Plasmas

- Gas Discharges: Fluorescent Lights, Spark gaps, arcs, welding, lighting Controlled Fusion
- Ionosphere: Ionized belt surrounding earth
- Interplanetary Medium: Magnetospheres of planets and starts. Solar Wind. Stellar Astrophysics: Stars. Pulsars. Radiation processes.
- Ion Propulsion: Advanced space drives, etc. and Space Technology Interaction of Spacecraft with environment Gas Lasers: Plasma discharge pumped lasers: $CO_2$, He, Ne, HCN. Materials Processing: Surface treatment for hardening. Crystal Growing. Semiconductor Processing: Ion beam doping, plasma etching & sputtering. Solid State Plasmas: Behavior of semiconductors.

# Different Descriptions of Plasma

- 1. Single Particle Approach. (Incomplete in itself). Eq. of Motion
- 2. Kinetic Theory. Boltzmann Equation.

$$\left[\frac{\partial}{\partial t} + \mathbf{v}.\frac{\partial}{\partial \mathbf{x}} + \mathbf{a}.\frac{\partial}{\partial \mathbf{v}}\right] f = \left.\frac{\partial f}{\partial t}\right)_{\text{col.}}$$

- 3. Fluid Description. Moments, Velocity, Pressure, Currents, etc.

- Uses of these.
- Single Particle Solutions → Orbits
- → Kinetic Theory Solutions → Transport Coefficients.
- → Fluid Theory → Macroscopic Description
- All descriptions should be consistent. Sometimes they are different ways of looking at the same thing

- **Equations of Plasma Physics**

$$\nabla.\mathbf{E} = \frac{\rho}{\epsilon_0} \qquad \nabla.\mathbf{B} = 0$$

$$\nabla \wedge \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \wedge \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

$$F = q(\mathbf{E} + \mathbf{v} \wedge \mathbf{B})$$

A plasma is a gas in which an important fraction of the atoms is ionized, so that the electrons and ions are separately free.

When does this ionization occur? When the temperature is hot enough.

Balance between collisional ionization and recombination:

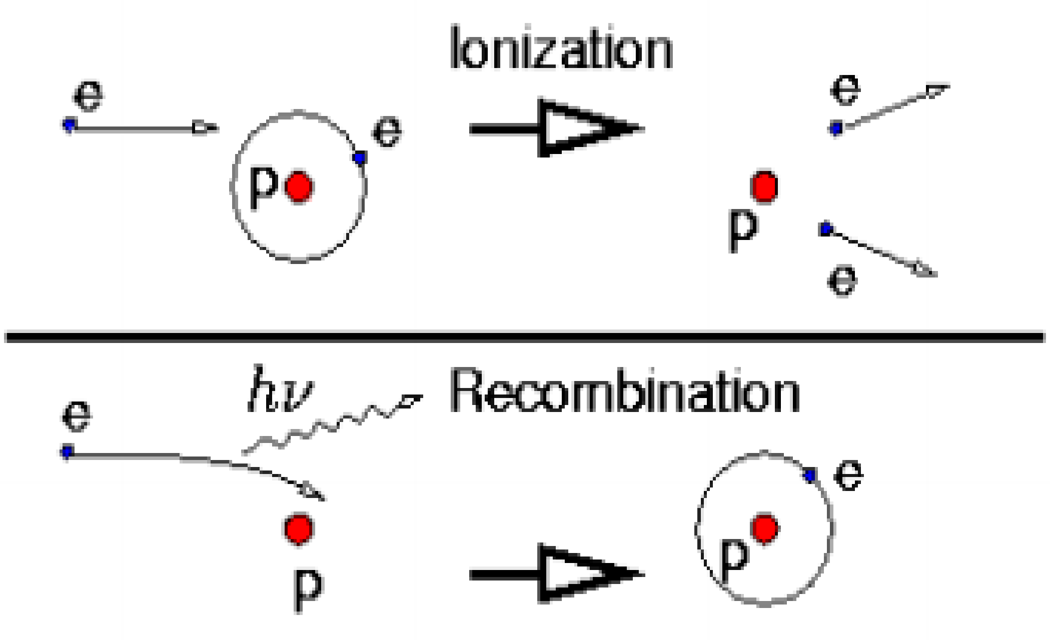


Figure 1: Ionization and Recombination

- Ionization has a threshold energy. Recombination has not but is much less probable. Threshold is ionization energy (13.6eV, H). $\chi_i$
- Integral over Maxwellian distribution gives rate coefficients (reaction rates). Because of the tail of the Maxwellian distribution, the ionization rate extends below T = $\chi_i$. And in equilibrium, when

$$\frac{n_{\text{ions}}}{n_{\text{neutrals}}} = \frac{< \sigma_i v >}{< \sigma_r v >} \qquad (1)$$

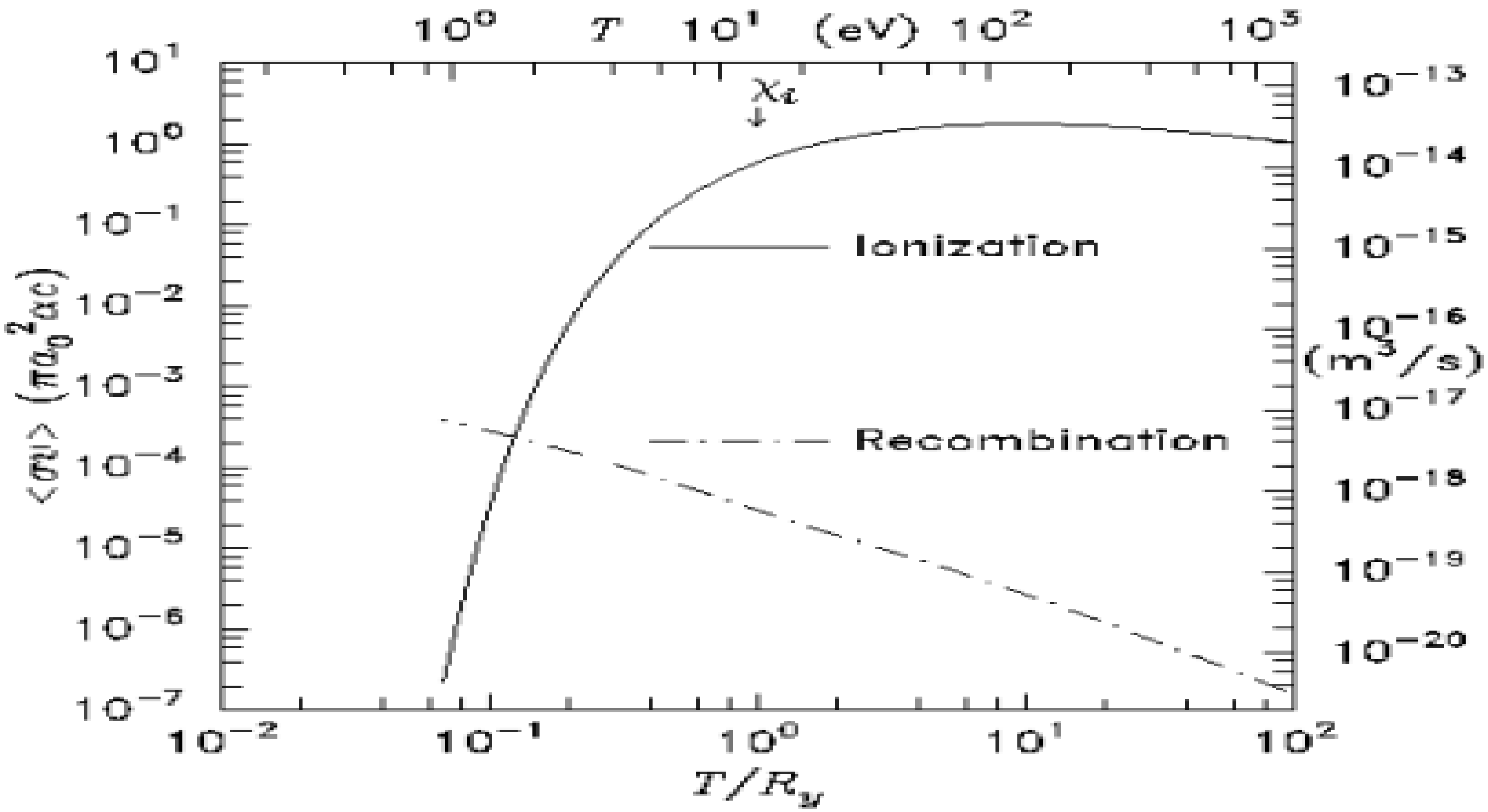


Figure 2: Ionization and radiative recombination rate coefficients for atomic hydrogenthe percentage of ions is large ($\sim$ 100%) if electron temperature: $T_e$ $\chi_i/10$. e.g. Hydrogen is ionized for $T_e \gtrsim$ $1_e$ v (11,600◦k). At room temp r ionization is negligible.

- For dissociation and ionization balance figure see e.g. Delcroix Plasma Physics Wiley (1965) figure 1A.5, page 25