

7B35.75 Plasma Tubes

Abstract

An electrode placed at the center of a plasma globe is charged, and an electric field is generated between the electrode and the surrounding glass dome. This electric field frees electrons from the inert gases present in the plasma globe, leaving a mixture of electrons and charged gas. When these electrons are recaptured light is emitted. If a finger is touched to the globe, the strands of light focus at the point of contact since the human body is a better conductor than the air surrounding the globe, altering the path of the electrons.

Picture



Safety Concerns

Do not leave finger at one spot on the dome as the electric discharge from the plasma globe can cause the glass to become hot.

Equipment

- Plasma globe
- Plasma mug
- Power adapter
- Geissler or Fluorescent tube

Procedure

Connect the adapter to the plasma globe and turn the setting on the base of the plasma globe to "on". If the lights are dimmed, the plasma streams can be seen more easily. Touch the plasma globe with your finger and

trace around the globe, noting the movement of the electric discharge. If the setting on the base of the globe is turned to the middle slot (labelled "sound") the plasma globe responds to sound. A Geissler or fluorescent tube can be touched to the globe where it produces a colour characteristic of the gas in the tube.

Place the Geissler tube back into its container, and return all pieces to the demonstrations room.

Theory

The theory behind the plasma ball and the plasma mug are similar, therefore only the plasma ball will be discussed.

A plasma ball consists of a small electrode inside a low pressure glass dome containing a mixture of inert gases, such as argon and neon. A low pressure is necessary so that the gases can be ionized easier, and inert gases must be used so that there is no reaction between the gas and the metal electrode.

When the power adapter is connected to the plasma ball, a high voltage, high frequency power supply charges the electrode, which places the electrode at a much higher potential than the surrounding glass. There now exists a strong electric field within the glass dome. The electric field is strong enough to ionize some of the inert gas particles, leaving a neutral mixture of electrons and ions. This ionized gas is a state of matter called **plasma**. Figure 1 depicts a particular stream of plasma.

The electrons that were "pulled" from the gas are now accelerated by the electric field. They can be recaptured as they collide with ions in the globe, resulting in the gas atoms being in an **excited state**. It is also possible for these electrons to collide with neutral atoms, exciting the electrons already present in those atoms (in this case, the free electrons are not recaptured). The excited electrons in the gas atoms transition to a lower energy state through the **emission of a photon** with energy equal to the difference in energy between the electron's initial and final energy levels. The energy levels in an atom are characteristic of the atom. For instance, when excited, an electron in a xenon atom enters different energy states than an excited electron in a neon atom. Suppose two particular electron energy states have energy difference

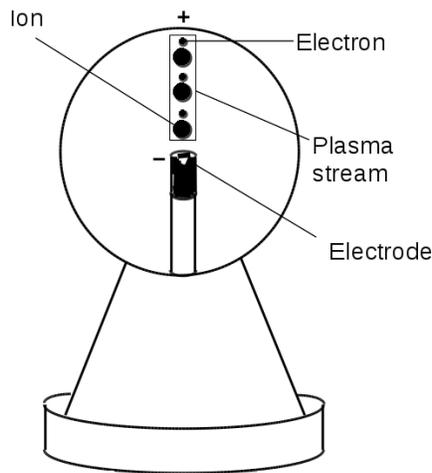


Figure 1: Diagram of a plasma stream within a plasma tube.

$$\Delta E = |E_f - E_i|, \quad (1)$$

where ΔE is the difference in energy states, E_f is the final energy state of the electron, and E_i is the initial energy state of the electron. The photon emitted from this electron transition has energy

$$E_\gamma = |E_f - E_i|, \quad (2)$$

where E_γ is the energy of the photon. The energy of a photon is related to its frequency and wavelength by

$$E_\gamma = hf = \frac{hc}{\gamma}, \quad (3)$$

where h is Planck's constant ($h = 6.63 \times 10^{-34} \text{ m}^2\text{kg/s}$), f is the frequency of the photon, c is the speed of light ($c = 3.00 \times 10^8 \text{ m/s}$), and γ is the wavelength of the photon. Substituting Equation 3 into Equation 2 yields

$$\frac{hc}{\gamma} = |E_f - E_i| \Rightarrow \gamma = \frac{hc}{|E_f - E_i|}, \quad (4)$$

which shows that the wavelength of the emitted photon is inversely proportional to the difference between the energy states of the electron. The emitted photons are responsible for the streams of colour in the plasma globe, and since the energy levels of an electron in an atom are quantized, the wavelength of the emitted photon is also quantized. As a result, only certain colours are seen in the plasma globe. Different plasma globes can produce different colours because the gas mixture present in each plasma globe can vary.

When a finger is touched to the glass dome, the plasma streams trace from the electrode to the finger because the human body is a better conductor than the surrounding air. There is no shock or danger to the person

touching the dome because the insulating glass stops actual current from flowing to the finger. However, the electromagnetic fields due to the current discharge do permeate through the glass where they induce a current in the finger. There is no risk to the demonstrator because the high frequency of the oscillating electromagnetic fields ensures that the small buildup of current is located at the surface of the finger (this is known as the "**skin effect**").

In place of a finger, a Geissler tube can be touched to the glass dome. In this case, the electromagnetic fields from the plasma globe ionize the atoms in the tube, and a colour characteristic of the gas in the tube is seen when electrons recombine with the ions.

The sequence of gas ionization, electron excitation, and photon emission is used in many applications, such as **neon lighting**. In neon lights, glass tubes molded into various letters or shapes for advertising are filled with inert gases. Two electrodes are placed at the ends of the tube, and they are charged to opposite potentials when a power supply is connected. The gases in the tube are excited, and the subsequent photon emission produces eye-catching colours.

Fluorescent lighting is similar to neon lighting, but with a couple of additional steps. In a fluorescent lamp, mercury vapour is also present in addition to a mixture of inert gases. When the mercury atoms are excited, they emit photons in the ultraviolet range. To convert this UV light into visible light, a **phosphor** coating is applied to the glass tube. These phosphor atoms absorb the UV photons from the mercury vapor and release a photon with lower energy, heating up in the process. The newly released photon has a wavelength in the visible light region. The chemical makeup of the phosphor can be changed to produce different colours of light.

References

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