Educational Innovations

#PLS-110
Plasma Globe Experiment Kit

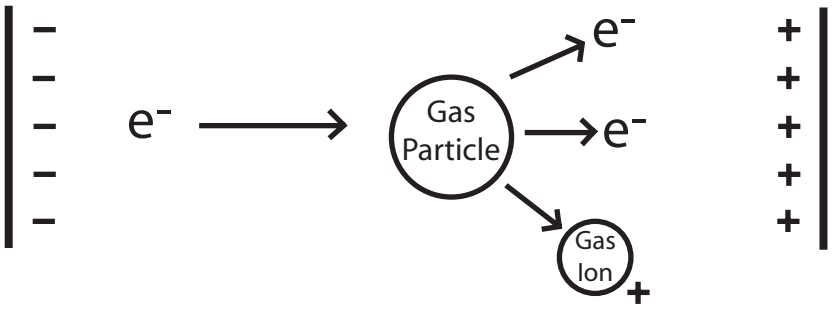
(1 fluorescent tube; 10 neon lamps; diffraction grating; and guide)

I. Background Information

A. Why do we see light from atmospheric lightning, neon signs, fluorescent bulbs, and plasma globes?

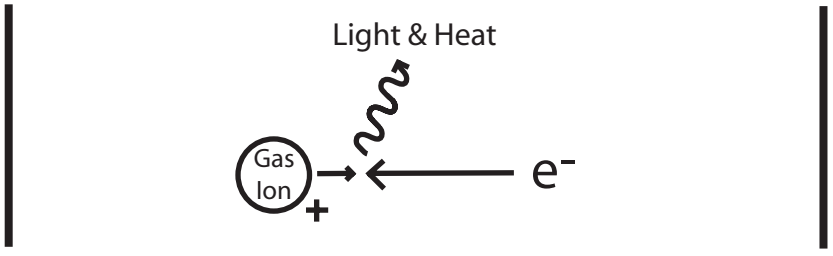
In all of these examples the explanation is the same two-step process. In the first step, energy is used to remove electrons from gas particles. This is called ionization. In the second step, the pieces recombine giving back the energy in the form of light. This is called emission.

Step #1 Ionization



When a charge separation (potential difference) becomes great enough, negatively charged electrons accelerate toward the positive charge. When the electrons travel toward the positive charge, they sometimes collide with neutral gas particles, knocking out negatively charged electrons. This results in positively charged gas particles called ions, as well as extra free electrons.

Step #2 Emission



Whenever the charge separation (potential difference) stops or reverses, the electrons recombine with the positive gaseous ions, releasing energy in the form of light and heat. This results in the light that we see from lightning, neon signs, fluorescent lamps, and plasma globes.

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B. What is a plasma?

Materials on earth can be classified into one of the four states of matter: solid, liquid, gas, or plasma. A plasma is a group of ionized, gaseous particles. It is often referred to as the fourth state of matter. The surface of our sun is so hot the electrons from the particles have enough energy to leave the atoms. The surface consists of glowing positively charged gaseous particles, called plasma. In the plasma globe, however, you can not see the plasma because the particles are not hot enough. However, any light that you do see being emitted is due to electrons recombining with the invisible positive ions of the plasma. Streams of electrons continually produce new plasma particles when the device is activated.

C. What is a Plasma Globe?

A Plasma Globe consists of a glass container of gas at reduced pressure with a high voltage source in the center that produces a charge difference between the center tower and the inside surface of the outer glass wall. In order for the positively charged ions to recombine with their electrons, the charge has to either alternate between positive and negative or pulse. In other words, the potential difference has to continually be changing.

D. What is the difference between a Plasma Globe and a Tesla Coil?

A Tesla Coil produces a high voltage, changing field. It is not uncommon for Tesla Coils to produce 70,000 volts at a frequency of 100,000 hertz. Since it takes approximately, 10,000 volts to ionize dry air at atmospheric pressure, a 70,000 volt Tesla Coil will produce a spark of about 7 inches. The current in such a device is quite small. The electronics in the plasma globe are essentially the same, although on a much smaller scale. At a reduced gas pressure, the voltage needed to produce a long emission streamer is quite low.

E. Why don't I feel an electrical shock when touching a spark from a Tesla Coil or the outside of the Plasma Globe.

Rather than the electrons penetrating your body to produce a shock, the electrons find it easier to travel over the surface of your skin. This is often called *the skin effect*. It is due to the extremely high frequency of the oscillating charge. Although you won't get shocked, you may feel the bulb becoming quite warm if you draw a spark for a significant period of time.

F. Why does one see different colors of emitted light?

When the electrons return to the positive ions of the plasma, they fall from one energy level to another within the ionized particles. Each change requires the emission of energy in the form of light and heat. Since the energy levels are different in each type of atom, different colors are emitted. Each type of particle emits its own characteristic series of colors or line spectra. Most plasma globes seem to use a mixture of argon and nitrogen gas. The following table indicates some of the colors that are possible

GAS	PLASMA GLOBE COLOR
Argon	Somewhat bright, violet-lavender streamers
Argon-Nitrogen Mixture	White, pink, or orange streamers with blue-violet –lavender ends
Carbon Dioxide	Very bright, whitish or blue-white streamers
Helium	Very bright, blue-purple color streamers
Krypton	Low brightness, white streamers, with faint blue-green tinge.
Neon	Extremely bright, red-orange streamers
Nitrogen	Somewhat bright, white or pink or blue/violet streamers

G. What causes lightning?

It is normal for a charge differential to develop between the earth and the moving clouds, one becoming negative and the other positive. When this potential difference becomes great enough, electrons accelerate toward the positive charges, ionizing the air molecules in-between. Then, when these gaseous positive ions regain their missing electrons, light and heat are released.

H. How does a fluorescent bulb work?

A fluorescent bulb is simply a tube filled with mercury vapor with an electrode at each end. The inside of the tube is coated with a white powder that is a mixture of substances that fluorescence to give white light. When the tube is activated with a fluctuating high voltage, first the mercury vapor is ionized. Then, when the charge on the electrodes decrease, light is emitted as the positive mercury ions regain their electrons. This invisible UV light excites the white powder to emit visible white light.

I. Why do the streamers in a Plasma Globe arc upwards?
As the electrons accelerate toward the positive charge on the inside surface of the outer globe, they travel along a path of least resistance. Several factors account for the upward arc of the streamers, often referred to as Jacob's Ladder. These factors include the following:

- The gas is not all the same temperature inside the globe.
- Gas which has undergone previous ionization and emission is at a higher temperature.
- The higher the temperature, the higher the conductivity of the gas.
- Hot gases rise.

J. Why are the streamers attracted to my finger or an object placed on the outside of the glass globe?
Touching the outside of the globe provides a ground. A ground can be thought of as either a source or a sink of electrons.

K. Why do neon lamps light when brought close to the Plasma Globe?
As you bring the neon bulb close to the Plasma Globe a potential difference occurs between the electrodes of the neon bulb and the surface of the Plasma Globe. When the difference is great enough, electrons inside the neon bulb will accelerate toward the positive charge and ionize neon atoms. When the cycle changes one observes the emission of bright orange light.

L. How can you observe that the field in the Plasma Globe is cycling on and off.
In a darkened room, holding the neon bulb by the end of the electrodes, move the neon lamp rapidly back and forth above the plasma globe. Although the frequency is high, you can observe a pulsing of light. Interestingly, you can even obtain a beautiful sine wave pattern. Alternatively, place black tape over the fluorescent bulb so that only a narrow slit of light can be seen. Moving this rapidly back and forth over the Plasma Globe results in an intermittent pattern.

M. Why is it easier to obtain light from the fluorescent bulb if the end is touched?
The ionization of the gas inside the tube requires a charge separation, a potential difference. The greater the charge separation the more likely the gas is ionized. By touching the contact at the end of the bulb or even the glass bulb itself, your body provides a ground.

N. How can I tell what gas is inside the plasma globe?
Examine the light through a diffraction grating. You will find it easier to examine the light coming through a narrow slit in a large piece of black paper. Each different gas has its own characteristic emission spectrum. Photographing the emission spectrum will make it possible to compare the lines with a reference spectrum chart.

II. ACTIVITIES

The background information given above suggests many different things to try. Using the materials in this kit, what can you discover about the plasma globe? Carefully record your observations. There are over one hundred observations that can be made on a burning candle. How many can be made on the Plasma Globe? How many can you explain?

