Name: _____ Date: _____

Quantum Applications: Fluorescent Lamps

Learning goals
After completing this activity, you will be able to …

- Describe what occurs when atoms absorb and emit photons of light.
- Relate quantum theory to the function of a fluorescent lamp.

Vocabulary: electrode, filament, fluorescent, fluorescent lamp, incandescent lamp, infrared, orbital, photon, quantum mechanics, spectrum, ultraviolet radiation

Compact fluorescent lamp

Incandescent and fluorescent lamps
When Thomas Edison patented the first commercially successful light bulb in 1878, it was the culmination of years of research and experimentation with **incandescent lamps**. In an incandescent lamp, an electrical current is passed through a very thin wire, or **filament**, that has a high melting point. The wire heats up and glows brightly, casting a warm light.

Shortly after this breakthrough, a new form of lamp was invented. The first **fluorescent lamp** was developed in the 1890s by the American electrical engineer Daniel Moore. Moore lamps achieved modest commercial success and were the ancestors of both neon lights and modern fluorescent lamps.

Fluorescent lamps offer several advantages over their incandescent cousins. Fluorescent lamps tend to last much longer than incandescent lamps and are much more efficient. Much of the electrical energy in an incandescent light bulb is converted to heat rather than light—have you ever noticed how hot an incandescent light bulb gets when it has been turned on for a few minutes? In a fluorescent lamp, a much higher percentage of the input electrical energy is converted to visible light. For example, a 15-watt compact fluorescent lamp (CFL) produces as much visible light as a 60-watt incandescent bulb but uses only one quarter as much energy. Because of their energy-efficiency, fluorescent lamps are becoming increasingly popular as an alternative to incandescent lights. In fact, incandescent lamps will soon be illegal in the U.S.!

Why do you think fluorescent lamps are increasing in popularity? _____

_____

_____

_____

Absorption and emission of photons

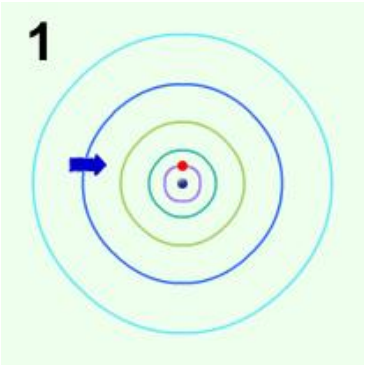
While the mechanics of an incandescent bulb are simple, fluorescent lamps are a bit more complex. To understand what occurs inside a fluorescent lamp, it is helpful to review the relationships between photons and electrons in an atom.

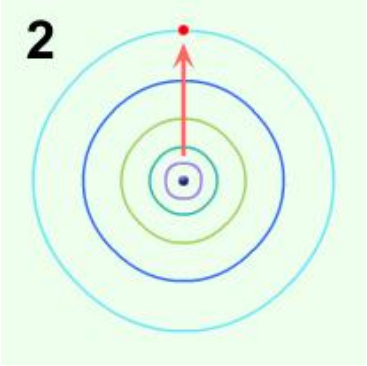
According to **quantum mechanics**, electrons orbit the nucleus in specific **orbitals**, represented by the circles in the diagrams at right (the nucleus is the small purple dot in the center of each diagram). In image 1, the electron (red dot) can be found in the first orbital. An electron can gain energy to move to a higher orbit or lose energy to move to a lower orbit.

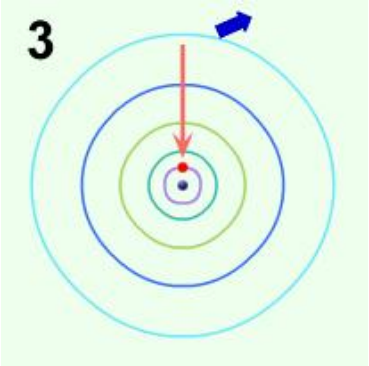
Quantum theory posits the light can be thought of as a stream of tiny massless particles called **photons**. The energy of a photon is inversely proportional to its wavelength. For example, blue photons (wavelength ~475 nm) are more energetic than red photons (wavelength ~650 nm).

When a photon (blue arrow) strikes an atom, it may be absorbed. This causes the electron to move to a higher orbit, as shown in image 2. A photon can only excite an electron from one level to another if its energy is very near the difference in energy between the levels. This means a particular atom can only absorb a small fraction of the photons it encounters.

Later on, the electron may spontaneously move down to a lower energy level, as shown in image 3. As it does this, it emits a photon whose energy is equal to the energy difference between the two orbitals. Thus the photons emitted by an atom are equal in wavelength to the photons that the atom can absorb. Different elements produce different **spectra** that consist of all of the wavelengths the atoms of that element can absorb or emit.







1. What happens when a photon is absorbed by an atom? _____

   _____

2. What happens when an atom emits a photon? _____

   _____

3. A photon causes an electron to move from orbital 1 to orbital 2. The electron then emits a photon to move back to orbital 1. What do you know about the energy of each photon?

   _____

Fluorescent lamps

Fluorescent lamps consist of a coated tube that contains a low-pressure gas mixture of mercury vapor and argon or another noble gas. At each end of the tube is an **electrode** that consists of a coiled wire that is coated with a substance that emits electrons. When the lamp is turned on, a voltage causes electrons to flow through the tube from one electrode to the other.

As the electrons pass through the gas mixture in the tube, they collide with the electrons in the atoms of the gas. Some of these collisions cause the electrons in the gas atoms to move into a higher orbital. These excited electrons then move back to their base orbital, releasing photons of **ultraviolet radiation**. (Ultraviolet light has wavelengths shorter than that of visible light and is not visible.)

The visible light produced by a fluorescent lamp is actually emitted by the **fluorescent** coating on the tube. Fluorescent materials are substances that absorb one form of radiation and emit another. The powder coatings of fluorescent lamps are composed of materials that absorb the ultraviolet photons emitted from the gas mixture and emit photons in the visible light spectrum. This means that, unlike an incandescent lamp, most of the light emitted by a fluorescent lamp is in a relatively narrow band of wavelengths within the visible light spectrum. This explains why fluorescent lamps are so much more energy efficient than incandescent lamps. An incandescent lamp gives off photons that have a wide variety of wavelengths, most of which are in the **infrared** range. (Infrared radiation is invisible but can be felt as heat.) Therefore only a small percentage of the energy emitted by an incandescent lamp is used to emit visible light.

While fluorescent lamps are longer lasting and more efficient than incandescent lamps, the presence of mercury and other potentially hazardous materials means that they must be disposed of carefully. Never discard a fluorescent lamp in the trash. Instead, bring fluorescent lamps to your local household hazardous waste facility so that the materials in the lamps may be recycled or properly disposed of.

1. What are the steps in the production of visible light in a fluorescent lamp? _____

2. Suppose a fluorescent lamp did not have a coating on its tube. What would you see if you turned this lamp on? What (if any) effect might this lamp have?