

4.3: Atomic Emission Spectra



Figure 4.3.1 (Credit: Department of Defense Warrior Games; Source: [Commons Wikimedia, Archery at the 2017 Warrior Games](#) (opens in new window) [commons.wikimedia.org]; License: Public Domain)

How much energy does it take to shoot an arrow?

Archery as a sport or a means of defense has existed for centuries. At rest, there is no tension on the bowstring and no force on the arrow. When the string and arrow are pulled back, we now have a situation where kinetic energy (pulling of the string) has been converted to potential energy (the tension on the string). The archer releases the arrow and the potential energy is translated into kinetic energy as the arrow moves. It turns out that electrons behave the same way when energy is put into the system or released from the system.

Atomic Emission Spectra

The electrons in an atom tend to be arranged in such a way that the energy of the atom is as low as possible. The **ground state** of an atom is the lowest energy state of the atom. When those atoms are given energy, the electrons absorb the energy and move to a higher energy level. These energy levels of the electrons in atoms are quantized, meaning again that the electron must move from one energy level to another in discrete steps, rather than continuously. An **excited state** of an atom is a state where its potential energy is higher than the ground state. An atom in the excited state is not stable. When it returns back to the ground state, it releases the energy that it had previously gained in the form of electromagnetic radiation.

So how do atoms gain energy in the first place? One way is to pass an electric current through an enclosed sample of a gas at low pressure. Since the electron energy levels are unique for each element, every gas discharge tube will glow with a distinctive color, depending on the identity of the gas (see below).



Figure 4.3.2: Gas discharge tubes are enclosed glass tubes filled with a gas at low pressure, through which an electric current is passed. Electrons in the gaseous atoms first become excited, and then fall back to lower energy levels, emitting light of a distinctive color in the process. Shown are gas discharge tubes of helium, neon, argon, krypton, and xenon. (Credit: User:Jurii/Wikimedia Commons, Heinrich Pniok (Wikimedia: Alchemist-hp); Source: [Commons Wikimedia, Glowing noble gases](#)(opens in new window) [commons.wikimedia.org]; License: CC by 3.0(opens in new window))

"Neon" signs are familiar examples of gas discharge tubes. However, only signs that glow with the red-orange color seen in the figure are actually filled with neon. Signs of other colors contain different gases or mixtures of gases.

Scientists studied the distinctive pink color of the gas discharge created by hydrogen gas. When a narrow beam of this light was viewed through a prism, the light was separated into four lines of very specific wavelengths (and frequencies since λ and ν are inversely related). An **atomic emission spectrum** is the pattern of lines formed when light passes through a prism to separate it into the different frequencies of light it contains. The figure below shows the atomic emission spectrum of hydrogen.

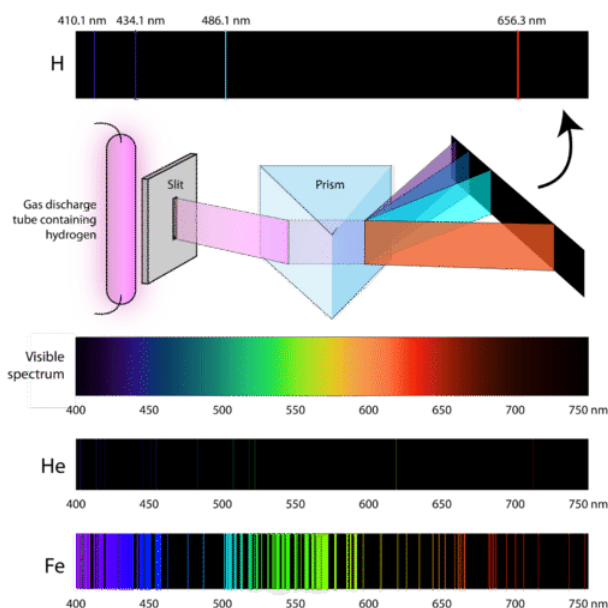


Figure 4.3.3: When light from a hydrogen gas discharge tube is passed through a prism, the light is split into four visible lines. Each of these spectral lines corresponds to a different electron transition from a higher energy state to a lower energy state. Every element has a unique atomic emission spectrum, as shown by the examples of helium (He) and iron (Fe). (Credit: Christopher Auyeung, using emission spectra available in the public domain; Source: CK-12 Foundation; H spectrum: [Commons Wikimedia, Emission Spectrum- H](#)(opens in new window) [commons.wikimedia.org]; visible spectrum: [Commons Wikimedia, Linear Visible Spectrum](#) (opens in new window) [commons.wikimedia.org]; He spectrum: [Commons Wikimedia, Helium Emission Spectrum](#)(opens in new window) [commons.wikimedia.org]; Fe spectrum: [Commons Wikimedia, Emission Spectrum-Fe](#)(opens in new window) [commons.wikimedia.org]; License: [CC BY-NC 3.0](#)(opens in new window))

Classical theory was unable to explain the existence of atomic emission spectra, also known as line-emission spectra. According to classical physics, a ground state atom would be able to absorb any amount of energy rather than only discrete amounts. Likewise, when the atoms relaxed back to a lower energy state, any amount of energy could be released. This would result in what is known as a **continuous spectrum**, where all wavelengths and frequencies are represented. White light viewed through a prism and a rainbow are examples of continuous spectra. Atomic emission spectra were more proof of the quantized nature of light and led to a new model of the atom based on quantum theory.



Summary

- Atomic emission spectra are produced when excited electrons return to the ground state.
- The emitted light of electrons corresponds to energies of the specific electrons.

Review

1. What is the ground state of an atom?
2. What is an excited state?

3. Why do we see emission lines when electrons return to the ground state?

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