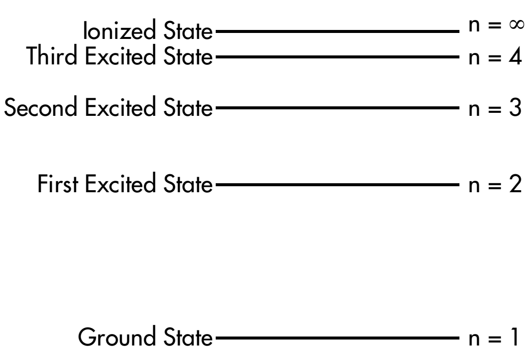
PhyzGuide: The Bohr Atom

MYSTERIOUS PATTERNS

Consider the following observations.
1. When white (full-spectrum) light is passed through a vacuum then dispersed into its constituent colors, a full spectrum of colors is seen.
2. When white light is passed through a sample of a gas then dispersed into its constituent colors, some colors are missing.
3. When the same sample of gas is exposed to a high-voltage alternating current, it emits light made up of the same colors that were missing in the previous observation.

THE BOHR MODEL

One of the early attempts to explain these observations was the Bohr Model of the Atom. The Bohr Model says that electrons in an atom exist at specific energy levels. The lowest energy level is referred to as the ground state. Higher levels are referred to as excited states (e. g., the first excited state, the second excited state, and so on). The highest energy level is reserved for the ionized state—wherein the electron is free of the nucleus. A typical diagram showing the energy levels is shown.



When exposed to energy sources such as light (photons) or energetic electrons (in the case of the high-voltage alternating current), an electron in an atom can absorb some of that energy. But it only absorbs energy in amounts equal to the spaces between the energy levels in the Bohr Model.

PLANCK'S PHOTON ENERGY

Max Planck discovered that the energy associated with photons ("particles of light") was proportional to the frequency of that light.

$E = hf$

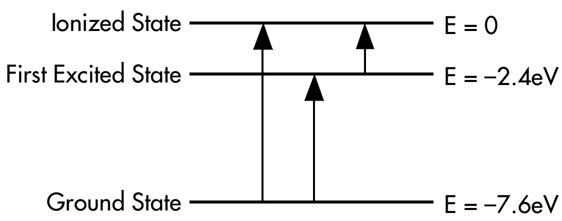
The constant of proportionality is Planck's constant. In photon work, a common unit of energy is the electron-volt (eV). It represents the work to move a single electron through one volt of electric potential difference.

MYSTERIES SOLVED

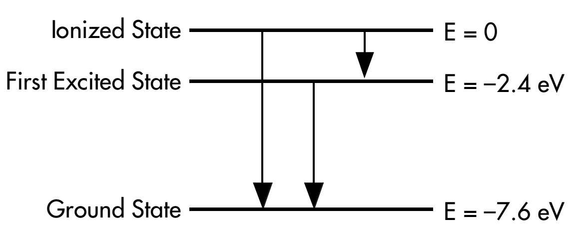
The colors that are missing when light is passed through a sample of gas or vapor have corresponding frequencies. When those frequencies are multiplied by Plank's constant, we are given a glimpse into the energy level structure of the atoms of that gas.

Consider the imaginary atom whose energy level structure is shown below. If full-spectrum light (i. e., light with a wide variety of possible photon energies) is incident upon it, the photons absorbed are those with energies 2.4 eV, 5.2 eV and 7.6 eV. Those photons are absorbed while all others pass through.

A 7.6 eV photon can ionize a ground state electron. A 5.2 eV photon can raise a ground state electron to the first excited state. A 2.4 eV electron can ionize an electron in the first excited state.



If that same gas is then exposed to high-voltage alternating current, it emits light with photon energies of 2.4 eV, 5.2 eV, and 7.6 eV. This is because the energetic electrons that slosh back and forth in the high-voltage alternating current kick ground state electrons into higher energy levels. But the electrons soon drop back to the ground state. And as they fall, they emit photons. The emission of photons allows the electron to shed enough energy to allow it to drop to a lower energy state.



A 7.6 eV photon is emitted when a free electron (an electron in ionized state) drops to the ground state. A 5.2 eV photon is emitted when an electron in the first excited state drops to the ground state. A 2.4 eV electron is emitted when a free electron drops to the first excited state.