Answer on Question #62443, Chemistry / General Chemistry

State the modification that was needed for Bohr's atom model in view of Heisenberg's uncertainty principle.

Answer:

As we now know today Bohr's model of the atom was really an oversimplification of the way electrons truly behave in atoms. However, there were certain aspects of Bohr's model that were correct.

What was correct about Bohr's Model:

Electrons reside in quantized energy levels.

The Bohr model accurately and quantitatively predicts the energy levels of one electron atoms.

What was incorrect about Bohr's Model:

Electrons don't orbit the nucleus in well-defined circular orbits.

Fails to accurately predict the energy levels in multielectron atoms.

Heisenberg Uncertainty Principle

Somewhat ironically a young scientist named Werner Heisenberg, who was working in Bohr's lab as a postdoctoral researcher, developed the theory which showed that electrons do not orbit the nucleus in well-defined circular orbits. His theory is called the Uncertainty Principle.

Uncertainty Principle: It is not possible to precisely determine the momentum (hence the energy) and the position of a particle simultaneously. This is quantified in the mathematical expression:

$\Delta x \Delta p > h/4\pi$

$\Delta x \, m \, \Delta v > h/4\pi$

where Δx represents the uncertainty in the position of the particle and Δp represents the uncertainty in the momentum of the particle ($p = mv$).

The Heisenberg uncertainty principle can be understood from several points of view.

Pure waves are not localized in space. Consider a guitar string, we can tell the energy of the wave by the frequency of the sound eminating from the string, however, it is not possible to define a precise location of the wave. In fact, the wave exists along the entire length of the guitar string. If we extend this line of thinking to particles, such as electrons, we see that their locations cannot be exactly specified because they behave in part as waves (as shown by DeBroglie).

To conceptualize simultaneous measurement of the position and momentum of an electron consider the analogy to photographs taken at night in a busy intersection. If we use high speed film, a photograph will show us the positions of every car at a given moment, but it will not give us any information regarding their speed. On the other hand, if we use a long exposure time then the moving headlights will show up as streaks. The lengths of the streaks give us a good estimate of each car's speed (long streaks for fast moving cars, short streaks for slow moving cars), but now we are not able to identify the exact positions of the cars.

The uncertainty principle has important ramifications for our picture of the atom. In the Bohr model of the atom the energy (thus its momentum) of the electron and the radius of its orbit (thus its position) are precisely defined quantities. This is a direct violation of the Uncertainty Principle. Since the energy levels of the hydrogen atom had been shown to be experimentally well defined by Bohr's model ($\Delta p \sim 0$), we are left with the conclusion that we know very little about the exact location of the electrons in space ($\Delta x \sim$ infinity).