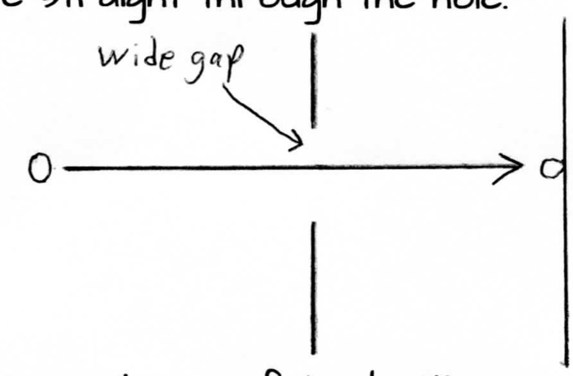
Chemistry Lecture #26: Shape of the s, p, d, and f orbitals.

Early models of the atom stated that electrons orbit the nucleus like planets orbiting the sun. This model is not correct. Electrons *do not* move around the nucleus in nice, circular paths. In fact, they move in *random* paths around the nucleus.

Why do electrons move in random paths? It has to do with the Heisenberg uncertainty principle. This states that you cannot know both the position and velocity of an object at the same time. The velocity of an object is its speed *and direction.*

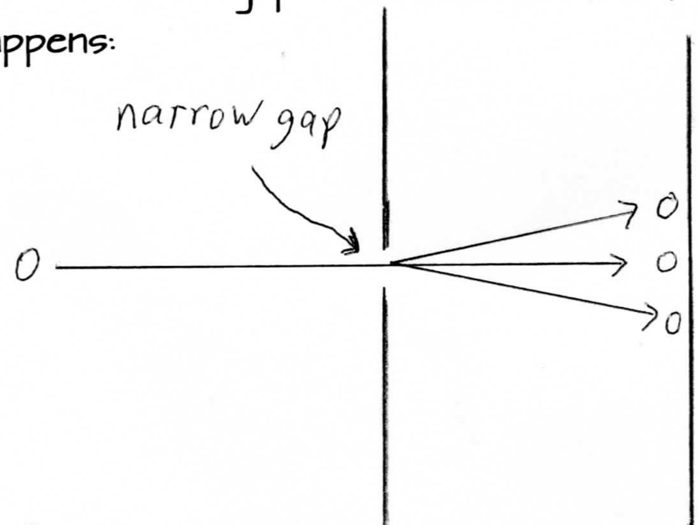
To illustrate what this means, suppose we shoot electrons through a hole in the wall. The electrons pass through and hit a second wall. Assume we know the speed and direction of the electrons before it goes through the hole. If the hole is big, the electrons will just move straight through the hole.



Now suppose you have a friend with an active imagination. He says, "I know the electron passed through that big gap and went to the other side, but what happened when the electron entered the gap? Maybe it is possible that the electron started bouncing up, down, left and right, and then left the gap. We don't know where it was in that big gap before it left and hit the second wall."

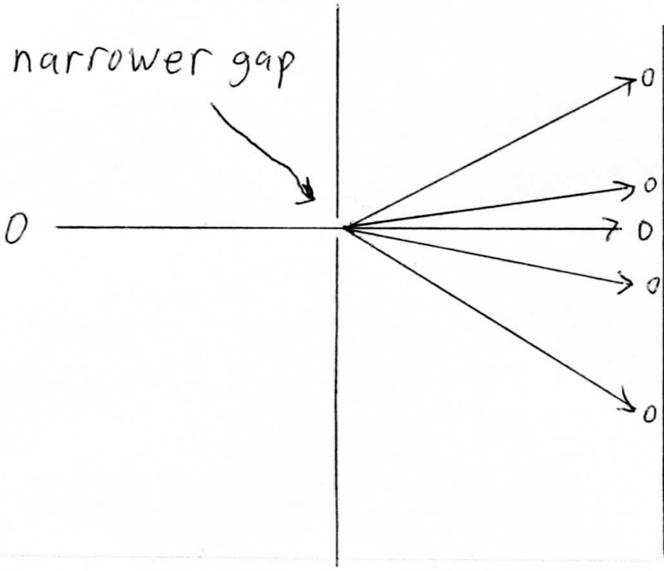
You reply, "You're crazy! You can draw a straight line from where the electron started to where it ended up! But just to prove that we can pinpoint its position while it is in the gap, we'll narrow the gap and make it smaller."

So you narrow the gap and shoot electrons through it, and this is what happens:



Instead of landing in one spot, the electrons appeared to have changed direction while they were in the gap, and landed at different locations. The region where they landed has spread out.

You then decide to make the gap even smaller. Here's what happens when electrons are shot through an even smaller gap:

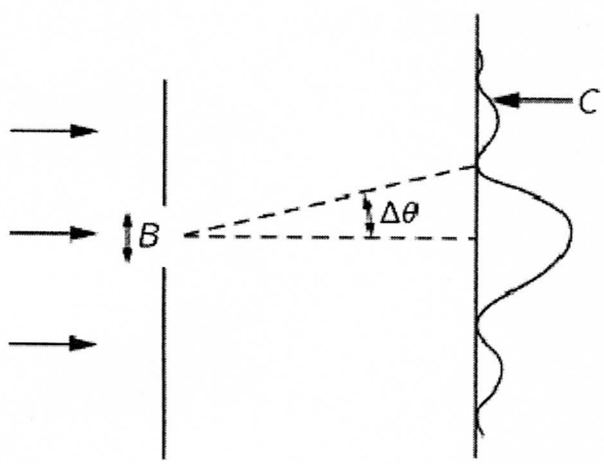


We see that the electrons spread out even more when the gap gets smaller! Thus, the smaller the gap (or the more we know about the electron's location), the less we know about the direction it will take (or its velocity).

Conversely, when the gap is wide, we know less about the electron's position, but it is more likely to keep the same direction or velocity, which means we know more about its velocity.

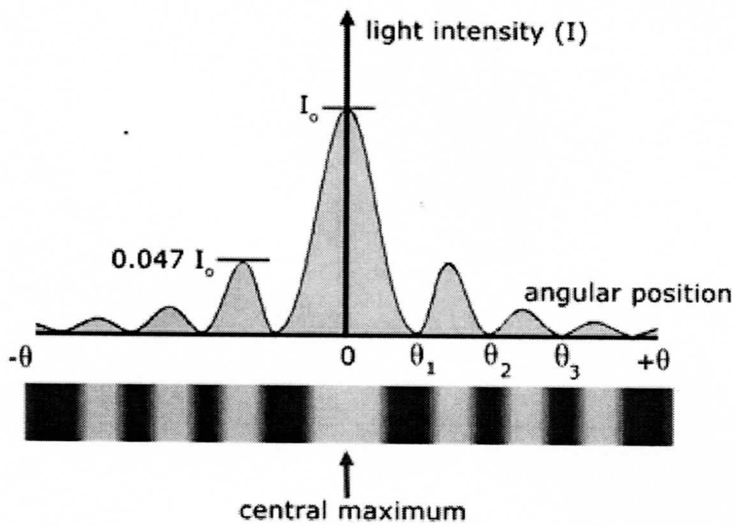
Although we cannot predict the direction an electron will take when it passes through a narrow gap, we can predict the probability that it will move in a certain direction.

Photons also behave like electrons when passing through a narrow gap. The diagram below shows the distribution of photons through a narrow gap. Most of the photons will go straight, a smaller number will move left and right, and an even smaller number will go further left and right.



We can't predict which ones will go straight, left or right, but we know the percentage that will take a certain direction.

Below is a picture showing the light pattern made when photons pass through a narrow gap or slit.



Notice that most of the photons went straight to the center, and number of photons that go left or right decreases as you move further from the center.

Thus, when placed in a confined space, we can predict the likelihood that a photon or an electron will move in a certain direction.

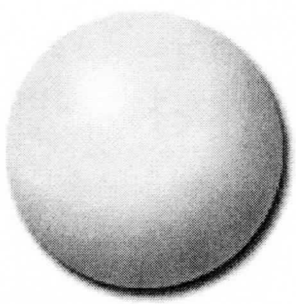
Why does the electron "choose" a certain direction? Why would it go left instead of right? WE DON'T KNOW! The best we can do is to predict the likelihood that it will choose a certain direction.

This bothered Albert Einstein, who said, "God does not play dice with the cosmos." Physicist Niels Bohr responded by saying something like, "Stop telling God what to do."

Anyway, an electron moving within the tiny, confined space of an atom will move in a random direction, so we'll never know exactly where it is located. We can, however, express the probability of finding the electron at a certain location.

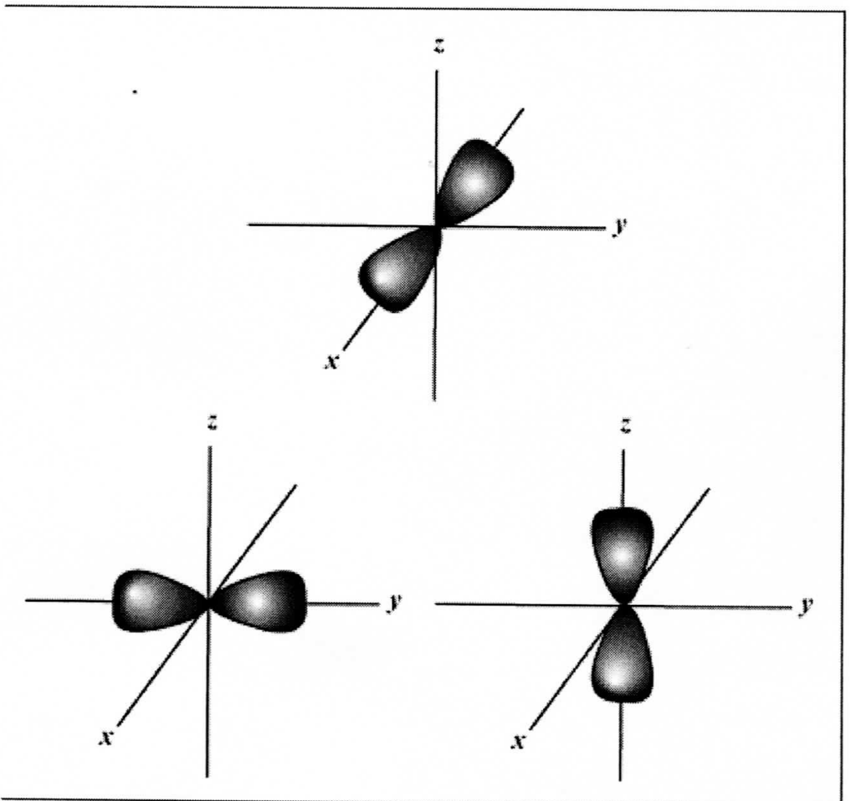
In fact; the s, p, d, and f energy sublevels have specific shapes that show where the electron is likely to be found.

Below is a picture of an s orbital. It is a sphere that surrounds the nucleus. This means that the electron can be found within the region of the sphere.

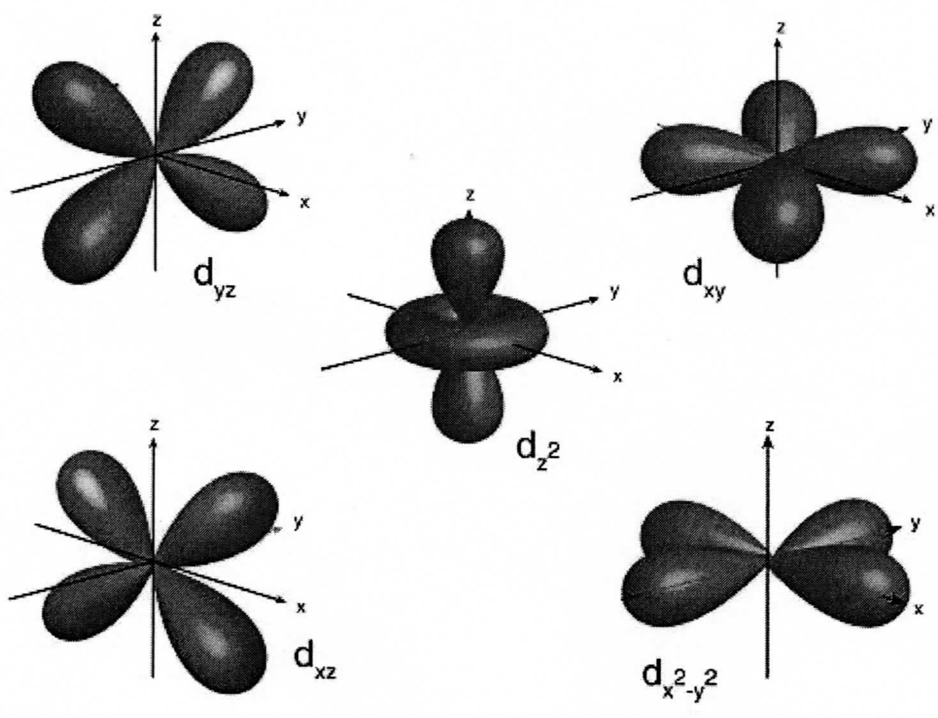


The shape of s orbitals is a sphere. Electrons can move anywhere within the sphere.

Below is a picture of the p orbitals. Remember that the p sublevel has 3 orbitals, so there are 3 orientations for the p orbitals.



Below is a picture of the d orbitals. Remember that the d sublevel has 5 orbitals, so there are 5 orientations for the d orbitals.



Finally, we have the shapes of the f orbitals. Remember that the f sublevel has 7 orbitals, so we have 7 shapes.