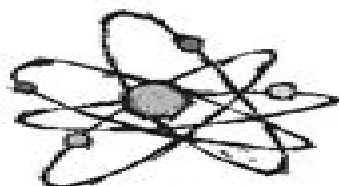


# Quantum Leap Lab

## Probability and Electron Structure

### Introduction

The picture below illustrates a popular view of the electron structure of the atom—electrons orbiting the nucleus in fixed paths. The picture is wrong! It is impossible to know the precise location of an electron around the nucleus of an atom at any given time. The location of an electron can only be described in terms of the total probability of finding an electron within a region of space.



Bohr Model of Atom

### Concepts

- Quantum mechanics
- Heisenberg uncertainty principle
- Electron energy levels
- Atomic orbitals

### Background

Throughout the years, significant progress has been made in our knowledge of the atom. Atoms were originally described as the smallest particles of matter. The discoveries, in turn, of the electron, the proton and the neutron destroyed the notion of the indivisible atom. Knowledge of the subatomic particle make up of the atom raised new questions—where are the electrons? In 1913, Niels Bohr developed a model for the hydrogen atom in which the electron was assumed to move in definite orbits, called energy levels, about the atomic nucleus. The amount of energy the electron possessed depended on its distance from the nucleus, with the outer electrons having the more energy. While Bohr's theory for the structure of the hydrogen atom was very successful, it failed to hold true for atoms with two or more electrons. Hence there was a need for an improved model of electron structure.

The quantum mechanical model, or quantum mechanics, was developed as a way to describe the motion of small particles (elemental) confined to tiny regions of space. The exact position of an electron at any given instant is not specified, nor is the exact path that the electron takes about the nucleus. The exact location of the electron at any given time can never be known with certainty. The *Heisenberg uncertainty principle* states that there is a fundamental limitation to how precisely both the position

and the momentum of an electron can be known. Quantum mechanics describes the probability of finding an electron within a given region of space. In other words, no longer should we think of definite orbits of electrons around the nucleus (as in the Bohr model). Rather, we should think of regions of space, commonly called atomic orbitals or electron clouds, which represent the most probable areas where an electron may be found, depending on the amount of energy that the electron possesses. The size and shape of atomic orbitals are derived from calculations that assume that the electron acts as a wave rather than as a particle.

### Experiment Overview

The purpose of this activity is to investigate by analogy the relationship between probability and the electronic structure of an atom. A marble will be dropped repeatedly onto a bullseye target. The regions of space around the central bull's-eye will be defined, as shown on the target sheet (Areas 1–6). In each region, there will be a specific probability of locating a spot resulting from the impact of the marble drop. The activity will be carried out at two distances from the target to represent different energy levels. A small-scale version of the target is shown in Figure 1.

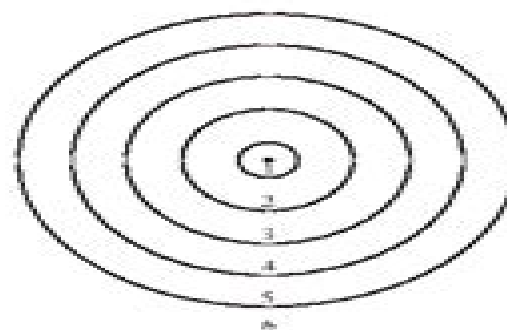


Figure 1. Target areas (1–6).

The pattern of spots on each target sheet will be used to imagine the three-dimensional properties of an atomic orbital. Thus, each spot will represent a point in three-dimensional space around the bullseye (analogous to the center) where the marble (analogous to the electron) is capable of landing (or most likely to be found). The region of space (analogous to an atomic orbital) in which the marble has a high probability of landing will define the size and shape of the orbital.

# Flinn Chemtopic Labs Quantum Leap Answers

**Scott C. Dulebohn**



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