

Quantum Leap Lab

Probability and Electron Structure

Introduction

The picture at the right 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.

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 bull's-eye 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 representing different energy levels. A small-scale version of the target is shown in Figure 1.

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 bull's-eye (analogous to the *nucleus*) 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.

Materials

Target Sheet, Knee-Level, carbonless, 2-sheet set
Target Sheet, Eye-level, carbonless, 2-sheet set
Marble
Meter stick

Procedure

Knee-Level Target (Target Distance = .5 m)

1. Obtain a piece of carbon paper – only one per group is necessary.
2. Tape the carbon paper upside-down on the Knee-Level Target, and then tape the other Knee-Level Target on top. The imprints should be made onto the bottom target, while the target on top is for you to make sure you know where to aim.
3. Choose one person to be the “Dropper” and one person to be the “Catcher”. Lay the knee-level target sheet on a smooth, hard floor.
4. The “Dropper” should hold the marble in one hand and bend down on one knee over the center of the target. The approximate distance or height from which the marble should be dropped is .5 m.
5. Have the “Catcher” sit down next to the target sheet and be prepared to catch the marble immediately after the first bound. Note: Practice bouncing the marble on the floor first to be sure the “Catcher” can catch it before the second bounce.
6. The “Dropper” should carefully drop (do not throw!) the marble from the waist (about .5 m), aiming for the bull's-eye. The “Catcher” should catch the marble immediately after the first bounce to be sure the marble doesn't leave more than one mark per drop on the target sheet.
7. Repeat this procedure approximately 100 times over the same target. For ease of counting, the “Dropper” should make a tally mark after each drop in the Tally Box on the Quantum Leap Data Table. Each hit will leave a mark on the bottom target.

- After 100 drops, carefully separate the bottom target sheet from the carbon paper and top target. Note the pattern of marks on the bottom target.

Eye-Level Target (Target Distance = 1.5 m)

- Repeat steps 1-8 using an eye-level target sheet set, with the “Dropper” and “Catcher” switching jobs. The “Dropper” should drop the marble with the arm fully extended from eye level, aiming for the bull’s-eye. Try to drop the marble from a distance of about 1.5 m.
- Carefully separate the bottom target sheet from the carbon paper and top target. Again, note the pattern of marks on the bottom target.

Pre-Lab Questions

- In this activity, the marble will be dropped from two heights – knee-level (.5 m) and eye-level (1.5 m). Which height represents a higher energy level? Explain.
- Form a hypothesis to predict how increasing the energy of the marble will affect the overall size of the area where the marble is likely to land.

Quantum Leap Data Table

Knee – Level

Tally

Eye -Level

Tally

Results Table

Knee – level Target Distance = .5 m		Eye – level Target Distance – 1.5 m	
Area Number	Number of Hits	Area Number	Number of Hits
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	

Post – Lab Questions

- Circle each mark made by the marble on both target sheets. For each sheet, count the number of hits in each target area (1-5) by counting the number of circles. Count any hits made outside area 1-5 as area 6. If a marble landed exactly on the line between two areas, count its location as the higher number area. Record the results in the Results Table.
- Construct a bar graph for each target sheet. Label the horizontal axis as the area number (1-6) and the vertical axis as the number of hits. Space the bars evenly, making each the same width. Draw the height of each bar proportional to the number of hits in that area.
- Which area on each target sheet (Areas 1-6) received the most hits?
- Why don’t all the marbles dropped from a specified height land in the same spot?
- As the distance from the bull’s eye (nucleus) increases, what happens to the probability