The Electron

THE ORBITAL WALK IS AN ACTIVITY designed to help students understand electron behavior. "Dancing to the music of the atom" gives students an opportunity to demonstrate, in a limited way, their understanding of electron behavior by moving their bodies to simulate electron motion.

Before beginning, students need a basic understanding of the wave mechanics model of the atom and, more specifically, of electron behavior. They have to be familiar with energy levels in the atom and orbital diagrams and also be aware that electrons in the same orbital have opposite spins. They must understand that electrons have a negative charge that makes them repel each other, and they should know that electrons in higher energy levels have more energy than do those closer to the nucleus. The concept that electrons can gain energy and jump to higher energy levels enhances the project; students will demonstrate that these electrons radiate energy (sometimes as visible light) as they return to a ground state.

All models have limitations, and without proper monitoring of student learning, models can lead to misconceptions. For example, it is difficult to demonstrate both the pairing of electrons and maximum repulsion in an orbital at the same time. Similarly, it is not possible to show random motion in space using a planar model. Because of these and other limitations, a follow-up activity ensures proper understanding and develops concepts.

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THE ORBITAL SETTING

To begin the activity, a school playing field is prepared with four or five large concentric circles that represent energy levels of the atom. The innermost circle is about 4 meters in radius, and each successive circle is drawn another 4 meters outside the next. I ask the school custodian to line the field in this way. Each concentric circle represents an energy level of the atom. In the very middle is a wooden stake with a pin pushed into the top. The pinhead represents the nucleus of the atom. The field I use for the activity has the advantage of being built

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Slide

Students "dance" to the rhythm of the atom to model electron behavior

into a small hill that creates an embankment on one side. I place a stepladder on the top of the embankment to give an aerial view of the field for videotaping.

STUDENTS AS ELECTRONS

The day before the activity, students draw cards from a box that contains one orbital assignment for each student in the class. For a class of 15 students, the box contains 15 cards: two cards of each 1s, 2s, $2p_x$, $2p_y$, $2p_z$, 3s (12 cards), and one card of each $3p_x$, $3p_y$, and $3p_z$. The students become electrons of an orbital indicated by the card they select. Students who have the same cards pair up; for example, a student who draws a 1s card is paired with the other student who draws a 1s card. The three students with the 3p designations remain unpaired. One or two of the 15 cards are embellished with several lightning strikes drawn on the card; the reason for this detail unfolds as the project develops.

After getting their orbital assignments and pairing up, students make posters bearing their orbital designations for the fronts and backs of their upper bodies. I encourage creativity; sometimes hats or bonnets are the way to go! We also go over the self-assessment questionnaire that will be used with the activity, and we practice "dancing" to the music of the atom.

CHOREOGRAPHING THE DANCE

To create the music of the atom, one student acts as the base drum player and as a cymbal player. The drummer maintains a rhythmic, slow beat on the base drum—the rhythm of a primal chant. Students in the first energy level pace their foot movements so that they march with each beat of the drum (beat, left, beat, right). Students in the second energy level march twice as fast. This means that they move both feet for every beat of the drum (beat, left-right, beat, left-right). And the third energy level students move their feet three times for every beat (beat, left-right-left, beat, right-left-right). Students practice marching in place for a few minutes.

The activity revolves around students simulating electron behavior, so students must make all their movements according to certain rules. Electrons repel each other, so students must maintain maximum distance from each other at all times. Within an orbital, electrons maintain maximum repulsion by spinning in opposite directions. To illustrate this, students are given a 4-meter piece of rope to tie loosely around their waists. Maximum repulsion means the rope between two pairs of students must be taut at all times. Students can rotate within the loosely tied rope around their waists; if one rotates to the left, the other rotates to the right, but they must always keep the rope taut.

Each pair of students in an orbital of an energy level must also maintain maximum distance from another pair of (or single) students within the same energy level or an adjacent energy level. Therefore, students must be careful not to get too close to other students.

When everyone is in place on the playing field, the base drum begins, as does the videotaping. Students are encouraged to add swaying or arm movements to their foot movements and bodily rotations to make the effect more dance-like. Some students really get into it!

Upon a signal by the teacher, the drummer crashes the cymbal! This sound is for the student who had the lightning strikes on the orbital assignment card. The cymbal crash signifies that energy is delivered to that electron, and the electron must literally "jump" to a higher energy level. After a momentary pause at the higher level, the student returns to the original energy level and shines a flashlight or flashes a small, hand-held mirror at the video camera to simulate the light energy given off in a bright-line spectrum.

Back in the classroom, I play the videotape so students can watch their movements and assess their ability to simulate electron behavior within the confines of the model. While they are watching the video, I pause it five times for students to answer the questions on the assessment questionnaire. When the tape is played in fast forward, the students' movements look like swarming bees, an analogy often used to describe electron movements in the atom.

CHEMISTRY STUDENT REACTIONS

Students love this activity! How often do students in chemistry classes get to perform outdoors, in front of a camera? The project leaves a lasting impression on students; they are able to answer questions about the activity on their semester examination and often comment on the activity when they return to school after graduation. All students come away from this project with some understanding of the complexity of electron theory, and because the project is aligned for kinesthetic learners, it encourages multiple intelligence learning. One student said, "I think this project worked out well, overall. Having an aerial view was good to see the atom as a whole." Another said, "I thought the Orbital Walk was a cool way to express what we know about electrons. I can see a bit more clearly now how the electrons act than I did before. I can see it, not just try to picture it in my head."

BEYOND THE ACTIVITY

After completing the activity, students need to understand the limitations of this model and be challenged to bring their understanding to a higher level. In a brainstorming session, I ask students to refer to each item of their assessment questionnaire and think about what limitations are created by the planar aspect of the activity. Some examples of possible misconceptions follow:

- Electrons are not limited in distance of repulsion as the taut rope may imply. In the atom, electrons maintain maximum displacement from all other electrons.
- The model suggests that electron movement doubles in the second energy level and triples in the third energy level. At the high school level, students need to understand that the energy of the second shell is greater than the first without necessarily attempting to quantify the difference.
- The distance of energy levels from the nucleus is not symmetric as the model implies. In reality, the probability of locating an electron goes to infinity in each energy level.
- In the simulation, electron motion appears linear. In the atom, electron motion is random.

With a list of misconceptions in hand, students expand their understanding through group discussion that challenges them to resolve each misconception. A reading assignment might be used to further clarify concepts, or the teacher and students might consider other modeling activities that take into account the three-dimensional aspects of the atom. A creative writing assignment that asks students to use their imagination to describe electron motion in three dimensions is another option for an extension activity.

This project is a wonderful way to engage student interest in the complexities of atomic theory and electron behavior because the activity encourages active retention and challenges students to achieve a depth of understanding. ✧

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ACKNOWLEDGMENT

I would like to thank my former students Kasey Gill and Laura Hogan for encouraging me with the title of the project. The science faculty of Litchfield High School helped me refine aspects of the project, and I would like to give special thanks to my former principal, Suzi D'Annolfo, for providing leadership by encouraging creativity in the classroom.