Orbitals and Bonds

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This lecture should be given after the Force and Acceleration, and the Table of Elements lecture

Materials (See picture below):

Tennis ball on string that can be slipped onto a finger
Piece of charcoal
Balloons (Make 2 small and one larger balloon)
Jump rope
Molecular model kit
Timer
Periodic Table of Elements (enough copies for small groups of students to share)
White board or other writing surface

Preparation before the lesson:

Blow up 2 small balloons into equal sized spheres. Partially inflate a larger balloon to a larger sphere so that it can be twisted into a dumbbell shape (see picture). Also prepare a model of a glucose or water molecule.

Key Words for use by children in discussion:

Atom, sharing electrons, orbital, and bond

1) Mention the Neutelpro trading card to the students and ask them, "What makes up everything in the universe?" Illustrate and discuss that atoms are made up of electrons spinning around a nucleus containing protons and neutrons. Discuss the source of the difference between different atoms (different atoms have different numbers of protons, neutrons and electrons).
2) Hold up the piece of charcoal and ask the students how many carbon atoms are in a piece of charcoal (a trillion trillion atoms) to remind the students how small atoms are.
3) Ask the students for hypotheses to explain the finding that spinning electrons do not fly away from the nucleus of the atom. Conclude that protons are pulling on electrons and keeping them close. Ask the students, "but then why aren't the electrons sucked into the nucleus where the protons are?" Discuss hypotheses.
4) Draw the moon going around the Earth and ask, "Why doesn't the Moon accelerate towards the Earth, since we know the Earth is pulling on it with gravity?" Mention the Forcen card and ask why the Moon does not accelerate towards the Earth, noting that the net force must be zero. After some discussion, have the students consider making a sharp turn in a car. Have them recall that they feel like they are being pushed to one side of the car. Discuss the fact that spinning objects (like the moon and electrons) have a "force" pushing them outward.
5) Indicate that, similar to the moon, the force pulling electrons towards the protons in the nucleus is balanced by the spinning force pushing the electrons out. So as long as electrons are spinning, they will not be sucked into the nucleus because the net force is zero.
6) Ask the students about the path of the electrons moving around the nucleus. Is it a circle? Are the electrons going fast or slow? Using the tennis ball on a string, illustrate that the tennis ball looks like a spot when it is not spinning. But when it spins quickly it forms a donut shape. Tell the children that in science this donut shape is called the tennis ball's "orbital". Ask the children, "do electrons spin around the nucleus as fast as the tennis ball to form an orbital, or do they travel very slowly and look like a spot?"
7) With the children, measure how many times the tennis ball goes around your finger when it is spinning by counting the revolutions while the ball is spinning for 10 seconds. Write the answer on the board in units of revolutions per second (rev/sec). Ask the children, "How many times does the ball go around in 1 second?"

8) Ask the students how many times an electron goes around a nucleus in an atom, in one second. Answer: about a billion billion times per second. To give the children a feeling for the magnitude of this number, ask them if you made a tower of a billion billion pencils, how many times would you go to the sun and back. Answer: 500,000 times! Conclude that electrons also form orbitals around the nucleus since they are traveling so fast.
9) Ask the students, "can the electron orbitals be any size and shape; triangle, square, big, small?" After discussion, have two students hold either end of a jump rope. Instruct one of the students to hold their side in place, while the other student swings the rope around. They should be able to form orbitals with 1, 2, or maybe even 3 circle-like forms. Note with the students that the jump rope can only form certain orbitals: It cannot form square orbitals and can only form circles, and these circles can only be certain sizes.
10) Tell the students that with an electron it is similar. There are only special orbitals that an electron can have. Show the class one smaller and one larger spherical balloon, and tell the class that these balloons are models for 2 acceptable orbitals for electrons in atoms. Illustrate the orbitals on the board, with a nucleus surrounded by two concentric circular orbitals, and label the smaller orbital "1s" and the larger orbital "2s." Importantly, note that electrons cannot go around the nucleus in a circle between the 1s and 2 s orbitals, and this is explained in a science called Quantum Physics.
11) Remind the students of the Neutelpro trading card. Review that the Atomic Number in the Table of Elements indicates the number of protons in the nucleus, which is usually equal to the number of electrons spinning around the nucleus. Use the drawing on the board from step 10 to build atoms, starting with hydrogen. Ask the students, "How many electrons are spinning around the nucleus of a hydrogen atom? "
12) Discuss whether the one electron in hydrogen will use the 1s or 2s orbital. During the discussion, ask the students whether there is something pulling on the electrons. Tell the children that because the proton in the nucleus is pulling on the electron it will end up using the orbital closer to the nucleus, the 1s.
13) Using the Table of Elements and illustrating on the board, make helium from the hydrogen atom. Ask, "Which orbital will the second electron of helium use?" (Answer: 1s also). Next locate and discuss Lithium in the Table of Elements. Ask the students where the third electron in Lithium will go. During the discussion inform the children that each orbital can only fit 2 electrons (Answer: third electron in Lithium goes in the 2s orbital because the 1s is full). Indicate to the students that elements with larger numbers of electrons will keep adding electrons to available orbitals.
14) Hold up two 1s orbitals (two smaller balloons) and tell the students that when you find hydrogen in the air, two hydrogen atoms are stuck together (write H_2 on the board). Ask the children, "What orbitals will the two electrons from the two hydrogen atoms utilize?" Hold up two 1s orbitals, explaining that the electron clouds are surrounding the 1 proton nuclei of each hydrogen atom. Discuss whether the atoms would just stick together and the orbitals would look the same, with each electron staying with its nucleus. Pass the 2 hydrogen atom models around and ask for ideas about how the two hydrogen atoms could become one H_2 molecule.
15) After some discussion of ideas, explain to the students that acceptable orbitals are determined by all the forces that the electron is feeling. Draw two hydrogen atoms next to each other, each with a nucleus and electron. Note that each electron now feels a force from 2 protons, not one. Because of the new force, the acceptable orbitals are now different than when it was just one electron and one proton. Illustrate a dumbbell shaped orbital on the board surrounding the two nuclei. Then make the larger spherical balloon into a dumbbell shape by carefully twisting it at the middle. Have the children describe the H_2 molecule you have modeled with the balloon, including the location of the nuclei and electrons. Note that the electrons are now being shared by the two nuclei in H_2.
16) Tell the students that many different atoms can form bonds by sharing electrons to form a huge number of different molecules in the Universe. Show a molecular model of glucose (sugar) to the students and ask them to describe it, with guidance as necessary. Alternatively or in addition, water can be made as H_2O, with an oxygen atom attached to two hydrogen atoms. Have many students point out the elements/atoms in the molecule, the bonds formed by sharing electrons, the location of protons, neutrons and electrons, and any other points of interest. Ask the students if the actual molecules look like the models, noting that they do not, but the models have allowed scientists to better understand molecules and to make predictions that were accurate.

Orbitals and Bonds lesson highlights checklist

- ☐ Review and illustrate atoms (Neutelpro card)
- ☐ Discuss reasons electrons do not fly off, and do not get pulled into the nucleus (Forcen card: net force)
- ☐ Begin discussion of electron path and speed around nucleus: fast spinning results in orbitals
- ☐ Compare revolutions per second: tennis ball vs electrons. Conclude electrons have orbitals
- ☐ Can electrons have any shaped orbital? Illustrate spinning jump rope can only form certain shapes
- ☐ Electrons can only have orbitals of certain shapes (Quantum Physics)
- ☐ Illustrate 1s and 2s orbitals of electrons with balloons then on the board
- ☐ Have students use Table of Elements and hypothesize orbitals for electrons in elements:
    1. Hydrogen: One electron selects orbital closest to the nucleus, 1s, because proton is pulling on it
    2. Helium: 2^{nd} electron selects 1s orbital too
    3. Lithium: 3^{rd} electron selects 2s orbital because orbitals can only fit 2 electrons each
- ☐ Discuss electron orbitals for two bonded hydrogen atoms, H_2 in the air with two 1s balloons
- ☐ Discuss new orbitals formed for electrons because two protons are now pulling on them.
- ☐ Illustrate that two hydrogen atoms share electrons in dumbbell shaped orbital to form a bond
- ☐ Students take turn describing molecular models of glucose and/or H_2O