

Section 3.3: The Quantum Mechanical Model of the Atom

Mini Investigation: Modelling Standing Electron Waves, page 149

A. Nodes appear to be points on the wire that do not oscillate up and down like other portions of the string. Antinodes appear to be points on the wire between nodes that are oscillating up and down at the maximum amplitude.

B. Not all frequencies result in standing wave patterns because some frequencies have interference patterns that do not allow for the formation of nodes and antinodes.

C. Answers may vary. Answers may include n nodes and $n-1$ antinodes.

D. The waves produced by the oscillator are similar to the waves in an atom because they exist as standing waves and have nodes and antinodes. Atoms differ in that they contain circular standing waves. The standing wave model of the atom is limited because it cannot locate where the electron is in a hydrogen atom.

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1. (a) An orbital is a region around the nucleus where an electron has a high probability of existing. The size and shape of orbitals contributes to the geometry of the atom.

(b) Electron probability density is the probability of finding an electron at a given location, derived from wave equations and used to determine the shapes of orbitals; it is also called electron probability distribution. Electrons have a greater probability of being within an orbital than being outside an orbital.

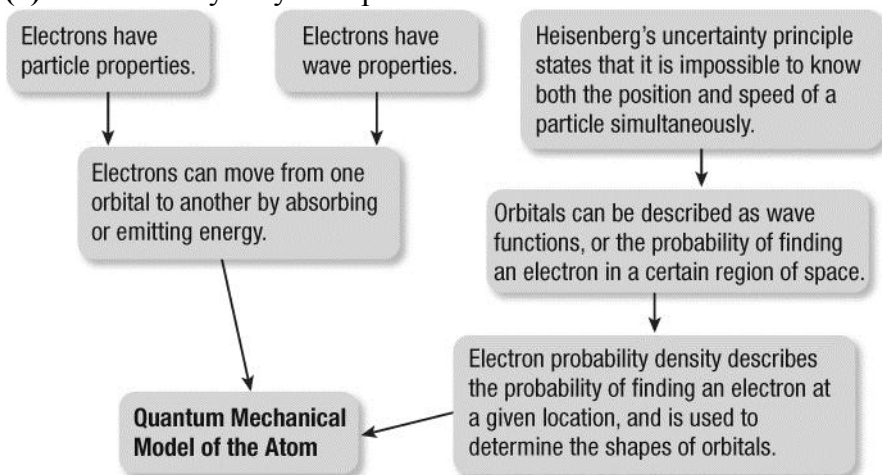
(c) Quantum mechanics is the application of quantum theory to explain the properties of matter, particularly the properties of electrons in atoms.

(d) A wave function represents the mathematical probability of finding an electron in a certain region of space.

(e) A quantum mechanical model is a model for the atom that is based on quantum theory and the calculation of probabilities for the location of electrons.

(f) Heisenberg's uncertainty principle is the idea that it is impossible to know both the exact position and the speed of an electron at a given time.

2. (a) Answers may vary. Sample answer:



(b) Answers may vary. Students should add the following information to their concept maps: Louis de Broglie believed that all entities have wave-like properties but these properties are only significant and measurable for tiny, fast-moving particles like the electron.

Erwin Schrödinger imagined electron behaviour within the atom structure as a wave phenomenon, described by a wave mechanical equation. Werner Heisenberg thought that electron behaviour could not ever be exactly described, but only discussed as a probability system, within limits imposed by his “uncertainty principle.”

3. An electron orbital describes the three-dimensional region of space occupied by an electron, that is, the region in which we calculate a high probability (usually > 90 %) of detecting an electron of a specific energy. An orbit is a simplified (incorrect, but useful) idea describing electrons as orbiting nuclei in circular or elliptical paths.

4. Quantum mechanics says nothing about either the position or the motion of an electron within an orbital.

5. Answers may vary. Sample answer: Scientists rely on the information provided by others to build upon and generate new knowledge to reach new levels of scientific understanding.

6. Answers may vary. Despite being physicists, the work of Heisenberg, de Broglie, and Schrödinger is studied in chemistry courses because it fundamentally changed our understanding of the nature of electron within an atom.

7. (a) Answers may vary. Sample answer: Science has been divided into the arbitrary groups of biology, chemistry, and physics because much of the research that generates knowledge is very specific and only encompasses a portion of all scientific knowledge. It can help us to understand research results if we categorize them. At the same time, not all science fits neatly into these three groups.

(b) Answers may vary. Sample answer: Pharmacy is an overlap of biology and chemistry. MRI imaging technology is an overlap of physics and biology. Environmental science is an overlap of biology and chemistry.

(c) Answers may vary. Sample answer: It makes sense to divide up science into these groups because the terminology and lexicon of each is different. However, it is important to remember that the groups are all artificial subdivisions of the complete scientific body of knowledge that humanity possesses.

8. Answers may vary. Sample answer: Most people visualize the Bohr-Rutherford model because they are already familiar with the concept of planetary orbits, so they can relate the model to something they already know. Also, the model has been continually reproduced in pop culture.

9. Dr. Richard Bader researches the nature of atoms and bonds within molecular structures, attempting to achieve a level of understanding that will allow predictions of the properties of materials to be made by theory using computer calculations. His theory of molecular topologies is directly related to the quantum mechanics of atoms.

10.

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{8\pi^2 m}{h^2} (E - V) \psi = 0$$

Labels and arrows in the diagram:
- "Second derivative with respect to X" points to $\frac{\partial^2 \psi}{\partial x^2}$
- "Schrodinger Wave Function" points to ψ
- "Position" points to x
- "Energy" points to E
- "Potential energy" points to V

11. Schrödinger’s cat tells us how the wave properties of an electron in an atom collapse into a fixed point if we observe the electron.