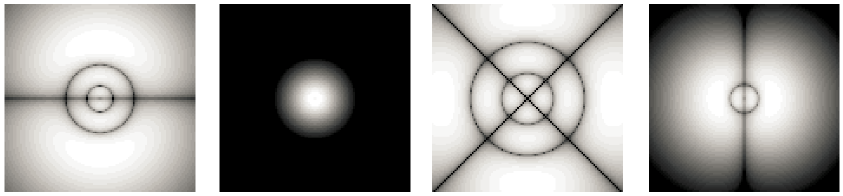


Hydrogen atom electron waves worksheet

1. The following are slices (A–D) through the center of hydrogen atom electron orbitals (clouds).

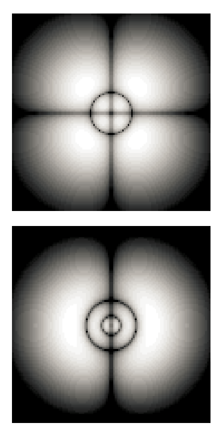


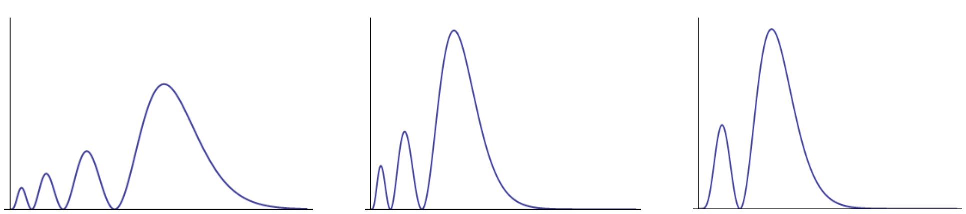
(A) (B) (C) (D)

   a. In your own words, what do these images represent?
   b. How many electrons are being depicted in image "A"?
   c. For each image (A–D), what is the name we give this electron orbital? Give the principal quantum number (n), azimuthal quantum number (l), and orbital shape (s, p, or d) for each orbital.
   d. Draw an energy level diagram to rank the relative energies of the orbitals (A-D) in the *hydrogen atom*. Recall: the energy of an electron wave with n loops is $E_n = -(2.18 \text{ aJ})Z^2/n^2$.
   e. The "ground state" of an atom is the state that it exists in the absence of absorbing energy from external sources. Which of the images (A–D) depicts the ground state of the hydrogen atom?
   f. Using a precisely-tuned light source, the electron cloud "B" can be transformed to an electron with shape "D". Describe the process by which B is transformed to D. How does it happen? What is required?
   g. Is the process in (f) instantaneous or slow? Explain.
   h. The orbital "B" cannot be transformed into the orbital "C" directly. Why?
   i. Calculate the energy that would be required (in J) for this transformation (from "B" to "D"). What is this amount of energy called?
   j. What is the wavelength of this light? Would you be able to see it? (Visible light spectrum is 380-750 nm)
   k. What would happen if the frequency of the light were increased slightly? Explain.

2. Let's dissect a common textbook problem: "A hydrogen atom absorbs a photon and is excited to the n =3 state. What is this state called? If the electron relaxes from this state down to the $n = 2$ state, will the wavelength of light emitted be greater or less than it would be if the electron were to relax directly back to the $n = 1$ state?"
   a. How is the "$n = 2$" state different from the $n = 3$ state?
   b. What are the possible *orbitals* with $n = 2$? What are the possible *orbitals* that have $n = 3$? What's an orbital?
   c. What does "relaxation from $n = 3$ to $n = 2$" mean? Describe what change is taking place and how this change is taking place. Is this process absorption or emission? How do you know?
   d. Calculate the energy change of the electron (in J) for the process of an $n = 3$ electron becoming an $n = 2$ electron ("relaxation")? Draw an energy level diagram showing the change in the electron's energy.
   e. If the electron relaxes from this state to the $n = 2$ state, will the wavelength of light emitted be greater or less than it would be if the electron were to relax directly back to the $n = 1$ state?
   f. Prove to yourself that you answered (e) correctly by calculating the energy change of the electron and wavelength of light associated with the $n = 3$ to $n = 1$ process.

3. Consider the two orbital depictions to the right.
   a. For each orbital: what is the principal quantum number (n)? The azimuthal quantum number (l)? What is the name of the orbital?
   b. Match each orbital (to the right) to the corresponding radial electron density diagram (below). What does the white and black in each diagram represent?
   c. There is one radial electron density diagram that was not assigned – what other orbital (that isn't depicted to the right) would match this diagram?
   d. Which one of these hydrogen atom electrons requires more energy to ionize? Why?





4. Electrons are described by their quantum numbers. These unique values describe everything about an electron wave. Consider the following: $n = 4, l = 1, m_l = 0, m_s = -1/2$.
   a. What does $n = 4$ tell you about the electron? What is a <u>shell</u>? Explain.
   b. What does $l = 1$ tell you about the electron? What is a <u>subshell</u>? Explain.
   c. How many different orientation orbitals are there with $n = 4$ and $l = 1$? How do you know?
   d. What is the name of the "orbital"? Also, what do we mean by "<u>orbital</u>"?
   e. How many other possible electron waves (orbitals) are there with the same energy and shape as this one? Name them. What do these have in common? What is different about them?
   f. What does $m_s = -1/2$ tell you about the electron?
   g. Can a hydrogen atom have a $4p$ electron? Explain your answer. Is a hydrogen $4p$ electron higher, lower, or the same energy as a hydrogen $4s$ electron?
   h. Consider now a helium atom where one of its electrons is transformed from $1s$ to $n = 4$. In this case, is there a difference in the energy of a $4s$ electron and $4p$ electron in such an atom?