8.E: The Hydrogen Atom (Exercises)

Q8.1

Calculate the probability density for a hydrogen 1s electron at a distance $3a_0$ from the proton along the z-axis (a_0 is the Bohr radius).

Q8.2

Calculate the radial probability density for a hydrogen 1s electron to be $3a_0$ from the proton.

Q8.3

Calculate the probability that a hydrogen 1s electron is within a distance $3a_0$ from the nucleus.

Q8.4

Calculate and compare the average distances of the electron from the proton for the hydrogen 1s orbital and the 2s orbital. What insight do you gain from this comparison?

Q8.5

What is the percent error in the energy of the 1s orbital if the electron mass is used to calculate the energy rather than the reduced mass?

Q8.6

Calculate the energies (in units of electron volts and wavenumbers) of the three 1s to 2p transitions for a hydrogen atom in a magnetic field of 10 Tesla.

Q8.7

Calculate the frequency of radiation that would be absorbed due to a change in the electron spin state of a hydrogen atom in a magnetic field of 10 Tesla. Compare the energy of this transition to the energy of the 1s to 2p transitions in the previous problem. What insight do you gain from this comparison?

Q8.8

Which is larger for the hydrogen atom, the Zeeman splitting due to spin motion (electron in the 1s orbital) or the Zeeman splitting due to orbital motion (electron in the 2p orbitals neglecting spin)? Why is one larger than the other?

Q8.9

What is the difference between the average value of r and the most probable value of r where r is the distance of the electron from the nucleus?

Q8.10

Show that orbitals directed along the x and y axis can be formed by taking linear combinations of the spherical harmonics Y_1^{+1} and Y_1^{-1}. These orbitals are called p_x and p_y. Why do you think chemists prefer to use px and py rather than the angular momentum eigenfunctions?

Q8.11

What are the expectation values of $\hat{L}_x$, $\hat{L}_y$, and $\hat{L}_z$ for the three 2p wavefunctions?

Q8.12

Why can $\hat{H}$, $\hat{L}^2$, and $\hat{L}_z$ have the same eigenfunctions?

Q8.13

Derive the selection rules for electronic transitions in the hydrogen atom. See Section 8.3 above and selection rules in Chapter 7. Use Mathcad to generate the radial probability densities for the 3s, 3p, and 3d atomic orbitals of hydrogen. What insight do you gain by comparing these plots?

Q8.14

Examine the Periodic Table and explain the relationship between the number and types of atomic orbitals, including spin, and the columns and rows.

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