Outline for Day 15

Office hours: 1 - 2
3 – 3:45

In which we learn about the atom using the ψ_{210} solution.

- Visualizing the probability density
- What fraction of the time does the electron spend within a_B of the nucleus?
- What is the most likely value of r for the electron?
- What is the average value of r for the electron?
- Spectroscopy of atoms

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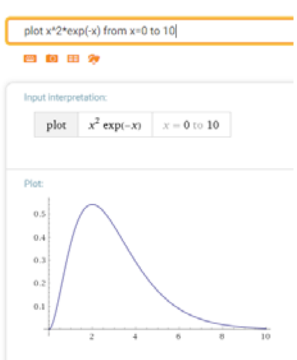
$$|\psi_{210}|^2 = A\left(\frac{r}{a}\right)^2 e^{-r/a} cos^2\theta$$



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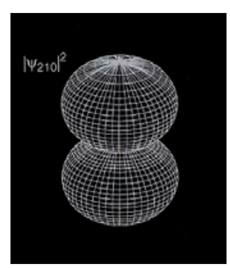


Radial Probability Density

$$P(r,\theta,\varphi) = |\psi_{nlm}|^2 dV = |\psi_{nlm}|^2 r^2 sin\theta dr d\theta d\varphi$$

$$P(r) = B(\theta,\varphi)|R_{nl}|^2 r^2$$

$$|\psi_{210}|^2 = A\left(\frac{r}{a}\right)^2 e^{-r/a} cos^2\theta$$

$$P_{210}(r) = B(\theta)\left(\frac{r}{a}\right)^2 e^{-r/a}\, r^2$$ Plotted on figure below as 2p

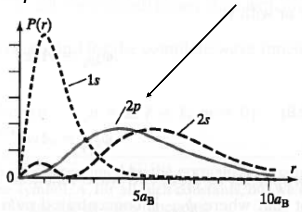
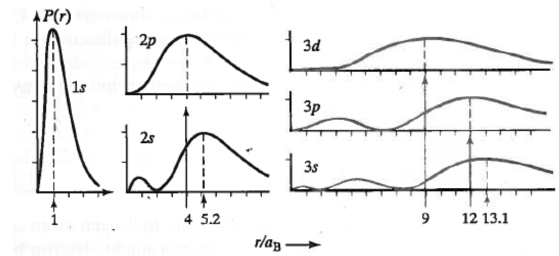


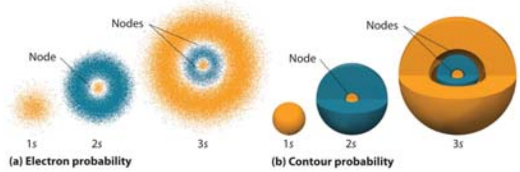
FIGURE 8.22
The radial probability density for the 2*p* states (solid curve). The most probable radius is $r = 4a_B$. For comparison, the dashed curves show the 1*s* and 2*s* distributions to the same scale.

Radial Probability Density

$$P(r) = B(\theta,\varphi)|R_{nl}|^2 r^2$$



most probably radius indicated for each state



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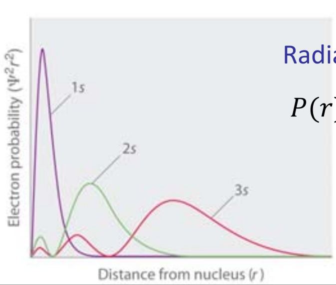

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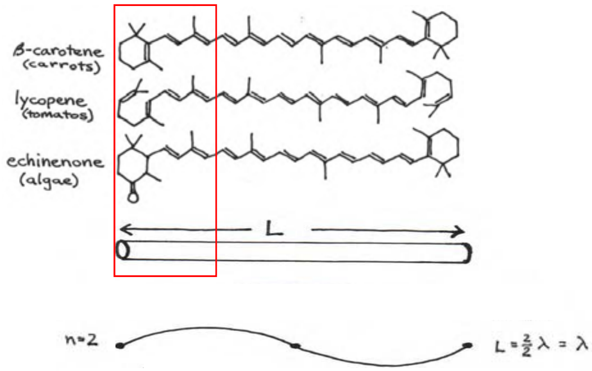
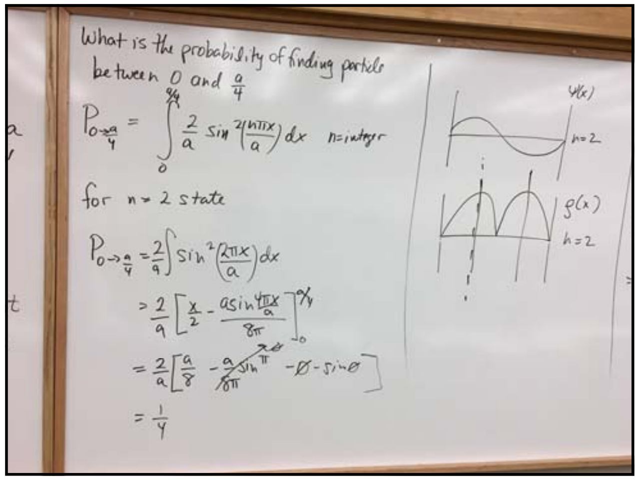
Probability to find electron in region inside red box?





Probability to find electron in 2p state inside Bohr radius in hydrogen atom?

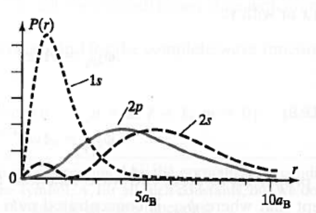


FIGURE 8.22
The radial probability density for the $2p$ states (solid curve). The most probable radius is $r = 4a_B$. For comparison, the dashed curves show the $1s$ and $2s$ distributions to the same scale.

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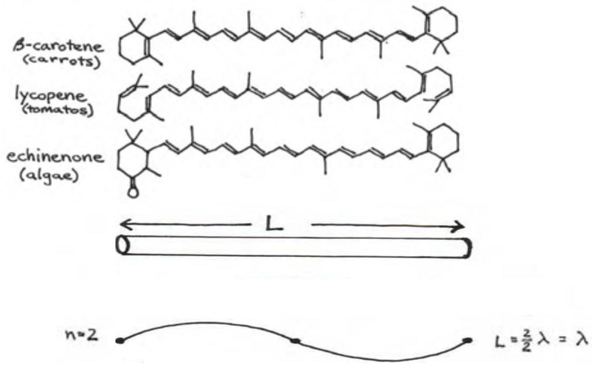
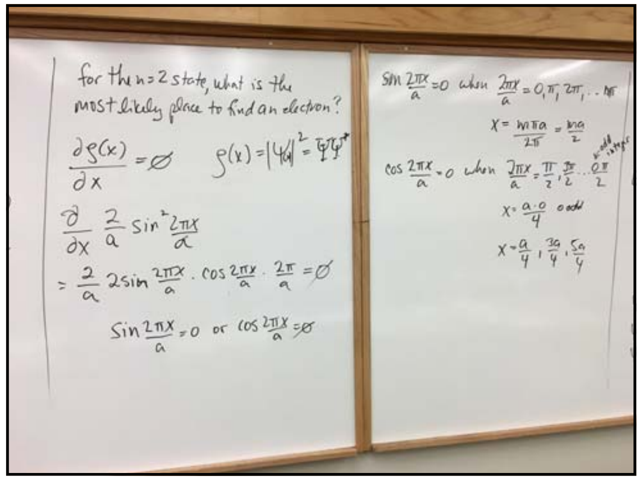
Most likely place to find the electron?





Most likely r value for the electron in 2p state?

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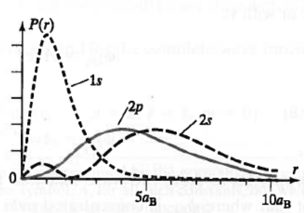

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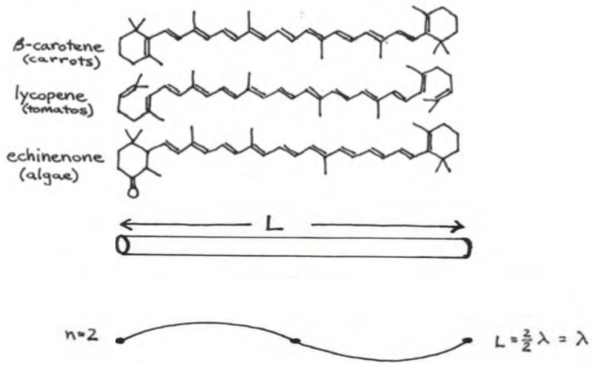
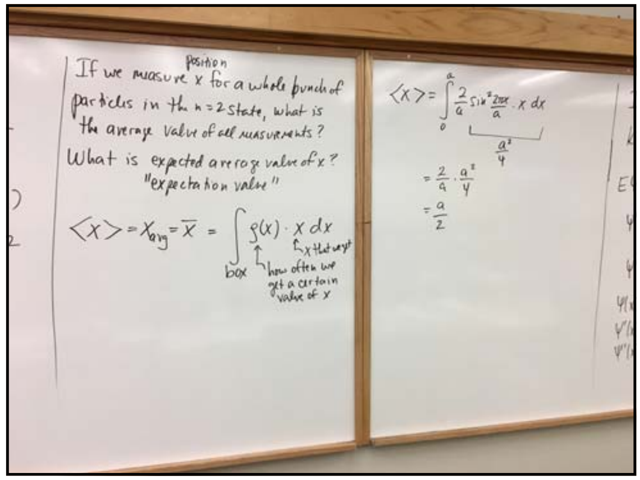
Average electron position?





Average value of r for the electron in 2p state?

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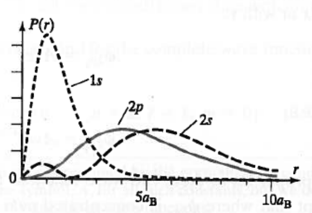

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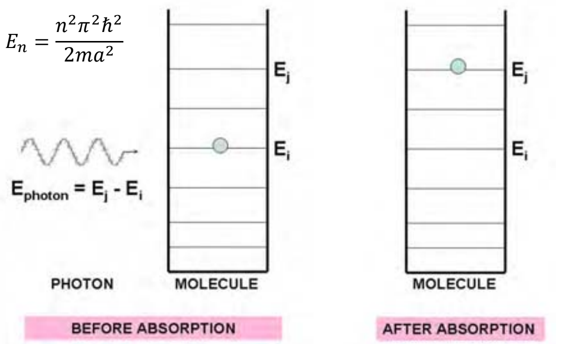
Absorption of Photons

Energy spacing given by:

$$E_n = \frac{n^2\pi^2\hbar^2}{2ma^2}$$



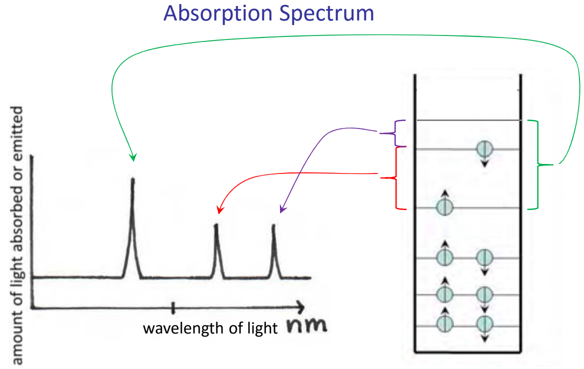
What is the wavelength of a photon that can excite a particle from the m to n state? n>m

$$\Delta E_{nm} = E_n - E_m = (n^2 - m^2)\left(\frac{\pi^2\hbar^2}{2ma^2}\right)$$

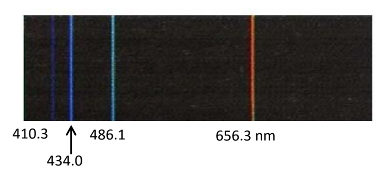
$$\Delta E_{nm} = hf_{nm} = \frac{hc}{\lambda_{nm}}$$

$$\lambda_{nm} = \frac{8cma^2}{h(n^2 - m^2)}$$

Absorption Spectrum



Balmer series: A closer look at the spectrum of hydrogen



Balmer (1885) noticed wavelengths followed a progression

$$\lambda = \frac{91.19\text{nm}}{\frac{1}{2^2} - \frac{1}{n^2}}$$ where n = 3, 4, 5, 6, ….

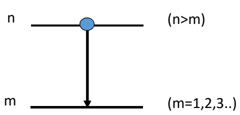
Balmer used this formula to predict additional lines in the hydrogen spectrum.

How Rydberg equation and Bohr Atom fit together

Balmer-Rydberg Formula

$$\lambda = \frac{91.19\text{nm}}{\frac{1}{m^2} - \frac{1}{n^2}}$$

Predicts λ of n→m transition:



Hydrogen energy levels