[TP] What electron cloud has 3 radial loops and 1 nodal plane?

10% 1. 1s
10% 2. 2s
10% 3. 2p
10% 4. 3s
10% 5. 3p
10% 6. 3d
10% 7. 4s
10% 8. 4p
10% 9. 4d
10% 10. None of the above

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Lecture 29 CH101 A2 (MWF 11:15 am)

Wednesday, November 14, 2018

For today ...

- Energy of hydrogen atom electron clouds
- Revisit: How light and matter exchange energy

Next lecture: Electron motion ; He^{+} , Li^{2+} , etc., photon energies; Ionization (photoelectric effect); Review: Lewis structures, formal charge and oxidation number

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Loops, planes, and quantum number *n*

Electron wave	Radial loops	Nodal planes	n = loops + planes
1s	1	0	1 = 1 + 0
2s			
2p			
3s			
3p			
3d			

$E_n = -13.6 \text{ eV}/n^2 \rightarrow E_1 = -13.6 \text{ eV}$

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eV (electron volt) energy unit

The electron volt, eV, is the energy of one unit of electron charge in a field of one volt, 1 V = 1 J/C.

energy = "charge" × "voltage"

"charge" = electron charge $e = 1.6021766 \times 10^{-19}$ C

"voltage" = 1 V = 1 J/C

eV = $e \times 1$ J/C = $1.6021766 \times 10^{-19}$ J

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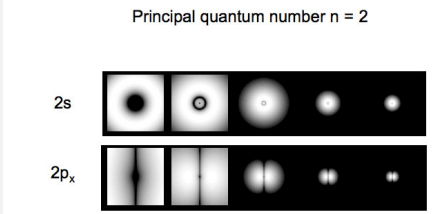
Ry (Rydberg) unit of energy

The Rydberg unit of energy, Ry, is the ionization energy of one H atom.

$$\text{Ry} = 2.17987 \times 10^{-18}\ \text{J}$$

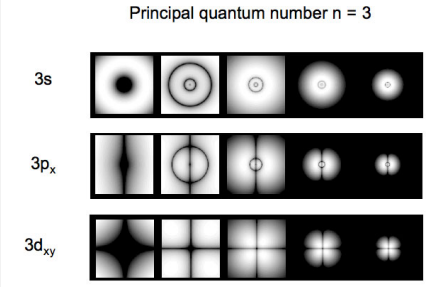
$$\text{Ry} = 2.17987 \times 10^{-18}\ \text{J} \times \frac{1\ \text{eV}}{1.6021766 \times 10^{-19}\ \text{J}} = 13.6\ \text{eV}$$



Loops, planes, and quantum number *n*

Electron wave	Radial loops	Nodal planes	n = loops + planes
1s	1	0	1 = 1 + 0
2s	2	0	2 = 2 + 0
2p	1	1	2 = 1 + 1
3s			
3p			
3d			

$$E_n = -13.6\ \text{eV}/n^2 \rightarrow E_2 = -13.6/4\ \text{eV}$$



Loops, planes, and quantum number *n*

Electron wave	Radial loops	Nodal planes	n = loops + planes
1s	1	0	1 = 1 + 0
2s	2	0	2 = 2 + 0
2p	1	1	2 = 1 + 1
3s	3	0	3 = 3 + 0
3p	2	1	3 = 2 + 1
3d	1	2	3 = 1 + 2

$E_n = -13.6 \text{ eV}/n^2 \rightarrow E_3 = -13.6/9 \text{ eV}$

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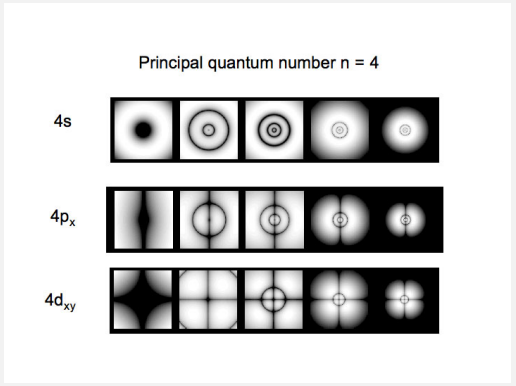

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[TP] What electron cloud has 3 radial loops and 1 nodal plane?

10% 1. 1s
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10% 6. 3d
10% 7. 4s
10% 8. 4p
10% 9. 4d
10% 10. None of the above

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Revisit: Light and matter exchange energy

The CDF animation at http://goo.gl/Ac4HGM, illustrates that light and matter exchange energy smoothly and slowly.

We can now determine the frequency of the light at resonance in the animation.

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Revisit: Light and matter exchange energy

Sketch the electron cloud at the start of the animation.

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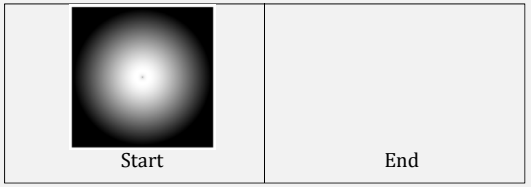
Revisit: Light and matter exchange energy

Sketch the electron cloud at the start of the animation.
What electron cloud is it?



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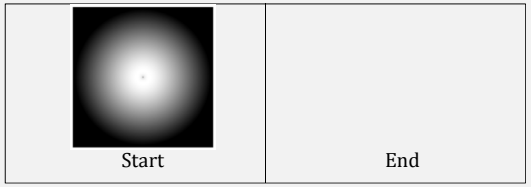
Revisit: Light and matter exchange energy

Sketch the electron cloud at the start of the animation.
What electron cloud is it?
Sketch the electron cloud at the end of the animation.



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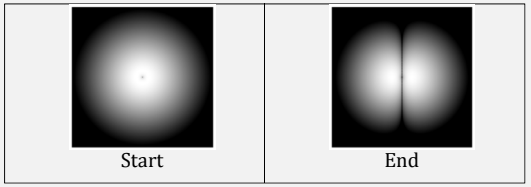
Revisit: Light and matter exchange energy

Sketch the electron cloud at the start of the animation.
What electron cloud is it?
Sketch the electron cloud at the end of the animation.
What electron cloud is it?



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Revisit: Light and matter exchange energy

Write an expression for the wavelength of the light at resonance in the animation.

$h = 6.62607004 \times 10^{-34}$ J s

$c = 2.99792458 \times 10^{8}$ m/s

$Ry = 2.17987 \times 10^{-18}$ J

$\Delta E = h\nu = hc/\lambda$

$\lambda = hc/\Delta E$

Revisit: Light and matter exchange energy

Write an expression for the wavelength of the light at resonance in the animation.

$$\lambda = \frac{hc}{|E_f - E_i|} = \frac{hc}{\mathrm{Ry}|-1/4 - (-1)|} = 121 \text{ nm}$$

So, in the UV region of the spectrum.

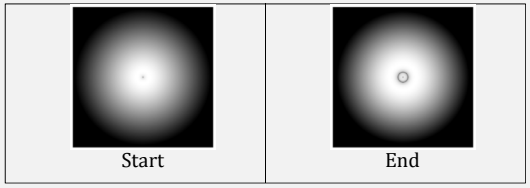
Revisit: Light and matter exchange energy

What about transformation between 1s and 2s?

Not possible since electric field of light tugs left and right, not in and out.

For this reason we say the s → s transition is forbidden by symmetry.

The directionality of light means it always adds or removes one nodal plane.

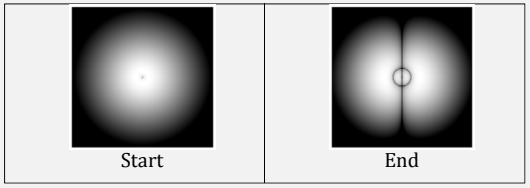


Revisit: Light and matter exchange energy

What about transformation between 1s and 3p?

What is necessary for the additional radial loop to form?

More loops, more energy! So higher frequency light needed.



Revisit: Light and matter exchange energy

Write an expression for the wavelength of the light at resonance in the 1s → 3p transformation.

$$\lambda = \frac{hc}{|E_f - E_i|} = \frac{hc}{\text{Ry}|-1/9 - (-1)|} = 103 \text{ nm}$$

So, also in the UV region of the spectrum.

Revisit: Light and matter exchange energy

The set of lines for transformations

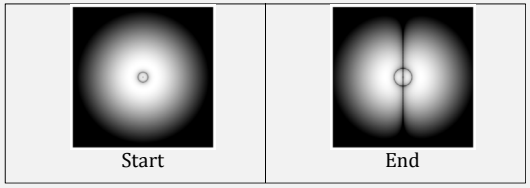
1s → 2p (121 nm)
1s → 3p (103 nm)
1s → 4p (434 nm)
etc.,

is known as the Lyman series.

Revisit: Light and matter exchange energy

Let's now use this approach to understand the effect of light in the visible spectrum of hydrogen atom.

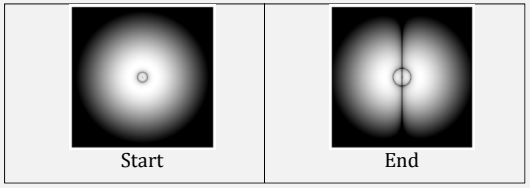
It turns out the 656 nm (red) line is due to transformation between 2s and 3p, 2s → 3p for absorption and 3p → 2s for emission.



Revisit: Light and matter exchange energy

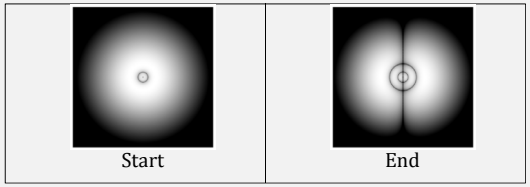
Evaluate the wavelength of the light at resonance with 2s → 3p transformation.

$$\lambda = \frac{hc}{|E_f - E_i|} = \frac{hc}{\text{Ry}|-1/9 - (-1/4)|} = 656 \text{ nm (red)}$$



Revisit: Light and matter exchange energy

Similarly the 486 nm (teal) line is due to transformation between 2s and 4p,
2s → 4p for absorption and 4p → 2s for emission.



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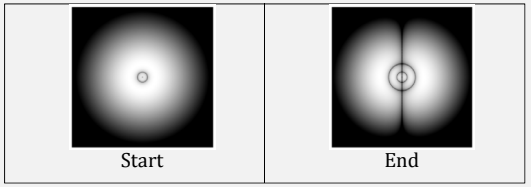
Revisit: Light and matter exchange energy

Evaluate the wavelength of the light at resonance with 2s → 4p transformation.

$$\lambda = \frac{hc}{|E_f - E_i|} = \frac{hc}{\text{Ry}|-1/16 - (-1/4)|} = 486 \text{ nm (teal)}$$



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Revisit: Light and matter exchange energy

The set of lines for transformations

2s → 3p (656 nm)
2s → 4p (486 nm)
2s → 5p (434 nm)
etc.,

is known as the Balmer series.

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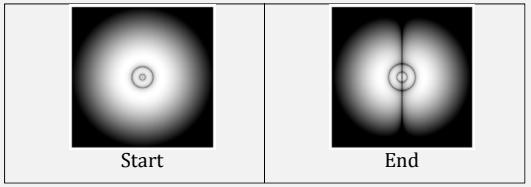
Revisit: Light and matter exchange energy

There is also a family of lines in involving transformation between
3s → 4p, 3s → 5p, etc.

The wavelengths are 1875 nm, 1281 nm, etc.

This family of lines in the IR is known as the Paschen series.



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