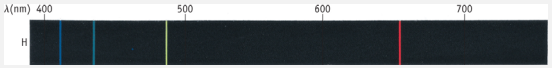
[TP] What electron cloud energies account for the 434 nm (blue) line in the emission spectrum (Balmer series) of H atoms?



17% 1. Only the $n = 3$ cloud energy
17% 2. Only the $n = 4$ cloud energy
17% 3. Only the $n = 5$ cloud energy
17% 4. The $n = 2$ and $n = 4$ cloud energies
17% 5. The $n = 2$ and $n = 5$ cloud energies
17% 6. None of these

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Lecture 30 CH101 A2 (MWF 11:15 am)

Friday, November 16, 2018

For today ...

- Questions about the H atom
- Electron motion
- He^+ , Li^{2+} , etc., electron clouds and energies

Next lecture: Ionization (photoelectric effect) ;Review: Lewis structures, formal charge and oxidation number ; Review: Electron clouds; More than one electron: Orbital (yikes!) approximation; Electron shielding of one electron by others: http://goo.gl/hMNPLA; Building electron configurations

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Reminder

Be sure to know the material in

Glossary of electron waves in atoms, https://goo.gl/oACWb1

Shells: K, L, M, etc.

Subshells: s ($l = 0$), p ($l = 1$), d ($l = 2$), etc.

Number of orbitals in a subshell: $2l + 1$

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Questions about the H atom

Question: Since the H atom has just one electron, isn't that electron always a 1s cloud?

Answer: No!

The atom with the 1s cloud electron can absorb a photon of energy from light of frequency

$\nu = |E_{2p} - E_{1s}|/h$, or $\nu = |E_{3p} - E_{1s}|/h$, etc.,

and thereby the electron will be transformed into a 2p cloud, or a 3p cloud, etc.

Only if the atom emits any excess energy (a photon) will the electron be a 1s cloud.

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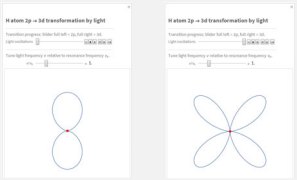
Questions about the H atom

Question: Since light transforms the 1s cloud into a p cloud, how can the electron be in a d cloud?

Answer: First, use light to form a p cloud, say as 1s → 2p.
http://quantum.bu.edu/CDF/101/1sTo2pTransition.cdf

Then, use light to transform the p cloud into a d cloud,
http://quantum.bu.edu/CDF/101/2pyTo3dxyTransition.cdf



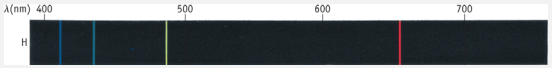
Questions about the H atom

Question: I see 1s → 2p and 2p → 3d, but how to get to 2s?

Answer: First, use light absorption to form a higher p cloud, say as 1s → 3p.

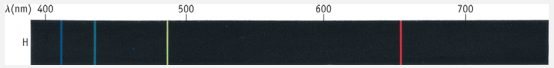
Then, light emission achieves 3p → 2s.

[TP] What electron cloud energies account for the 434 nm (blue) line in the emission spectrum (Balmer series) of H atoms?



0% 1. Only the $n = 3$ cloud energy
0% 2. Only the $n = 4$ cloud energy
0% 3. Only the $n = 5$ cloud energy
0% 4. The $n = 2$ and $n = 4$ cloud energies
0% 5. The $n = 2$ and $n = 5$ cloud energies
0% 6. None of these

[Quiz] What electron cloud energies account for the 410 nm (violet) line in the gas discharge spectrum (Balmer series) of H atoms?



0% 1. Only the $n = 3$ cloud energy
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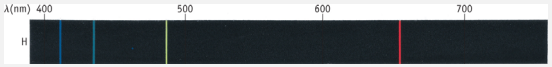
0% 5. The $n = 2$ and $n = 5$ cloud energies
0% 6. None of these

Electron motion



Since exchange of energy with light always involves transformation between two different numbers of electron cloud loops, in an atom it must be that it is …

the mixture of electron waves that moves …

in resonance with the electric field of light.

What about clouds made from a single *n*?

Clouds made from a single electron wave do not move.

If they did move, the cloud would lose energy (by causing other electrical charges to move) and therefore the cloud would collapse into the nucleus.

That they do not move is why the electrons in an atom do not collapse into the nucleus, and so why atoms exist!

It is only clouds resulting for the mixture of different electron waves that move.

And it is interaction with light that creates such mixtures.

Light-matter resonance questions

Question: We have said electrons in an atom are a non-moving cloud. Then, how can there be "jiggling" at the light frequency?

Answer: Clouds for electron energy states indeed do not "jiggle".

Rather, when light interacts with matter, it produces a mixture of electrons waves of energy E_i and E_f.

It is these mixtures whose clouds "jiggle" at the frequencies

$$\nu_{\text{light}} = \nu_{\text{cloud}} = \frac{|E_f - E_i|}{h}$$

H, He^+, Li^{2+}, etc., photon energies

We have learned that the energy of an H-atom electron cloud with principal quantum number n is

$$E_n = -Ry/n^2$$

H, He^+, Li^{2+}, etc., photon energies

For one-electron ions (He^+, Li^{2+}, Be^{3+}, etc.) with atomic number Z (number of protons), the energy expression is

$$E_n = -Z^2 Ry/n^2$$

For example, the energy of the 2s ($n = 2$) electron cloud in Li^{2+} ($Z = 3$) is

$$E_2 = -3^2 Ry/2^2 = -13.6 \times \left(\frac{3}{2}\right)^2 \text{ eV} = -30.6 \text{ eV}$$

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H, He^+, Li^{2+}, etc., photon energies

The reason the energy expression is proportional to Z^2,

$$E_n = -Z^2 Ry/n^2,$$

is that the more positive charge there is in the nucleus the more strongly the electron cloud is attracted to the nucleus.

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H, He^+, Li^{2+}, etc., photon energies

The increased attraction of the electron cloud to the nucleus means the electron cloud is drawn closer to the nucleus.

The approximate diameter of electron clouds is

$$\text{orbital diameter } \approx 100 \text{ pm} \times n^2/Z = 0.1 \text{ nm } \times n^2/Z$$

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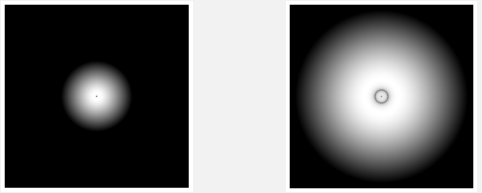
H, He^+, Li^{2+}, etc., photon energies

More loops (n), greater size; greater nuclear charge (Z), smaller size:

$$\text{orbital diameter } \approx 100 \text{ pm} \times n^2/Z = 0.1 \text{ nm } \times n^2/Z$$

The comparison of the 1s and 2s electron clouds of H shows how clouds grow quadratically (n^2) with n (frame edge 2 nm).



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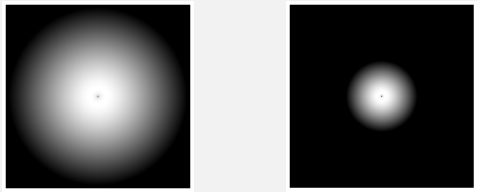
H, He^+, Li^{2+}, etc., photon energies

More loops (n), greater size; greater nuclear charge (Z), smaller size:

orbital diameter $\approx 100 \text{ pm} \times n^2/Z = 0.1 \text{ nm} \times n^2/Z$

The comparison of the 1s electron clouds of H and He^+ shows how clouds shrink linearly ($1/Z$) as nuclear charge increases (frame edge 1.2 nm).



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[TP] Which cloud transformation requires the smallest amount of energy?

25% 1. H: $n = 1 \rightarrow 2$
25% 2. H: $n = 2 \rightarrow 6$
25% 3. He^+: $n = 1 \rightarrow 2$
25% 4. He^+: $n = 2 \rightarrow 3$

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H, He^+ , Li^{2+} , etc., photon energies

H: $n = 1 \rightarrow 2, \lambda = 121$ nm

H: $n = 2 \rightarrow 6, \lambda = 410$ nm (violet)

He^+: $n = 1 \rightarrow 2, \lambda = 30.3$ nm ($1/2^2$ of H: $n = 1 \rightarrow 2$, 121 nm)

He^+: $n = 2 \rightarrow 3, \lambda = 164$ nm ($1/2^2$ of H: $n = 2 \rightarrow 3$, 656 nm)

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