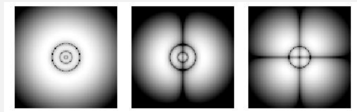
[TP] What is the *ionization energy* of these H atom electron clouds?



20% 1. 13.6 eV
20% 2. 13.6/4 eV
20% 3. 13.6/9 eV
20% 4. 13.6/16 eV
20% 5. They each have different ionization energies

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Lecture 31 CH101 A2 (MWF 11:15 am)

Monday, November 26, 2018

For today ...

- Review: Atom emission wavelengths
- Ionization (photoelectric effect);
- Review: Lewis structures, formal charge and oxidation number

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

We have learned that the energy of the electron cloud of a one-electron atom with principal quantum number n and nuclear charge Z is

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

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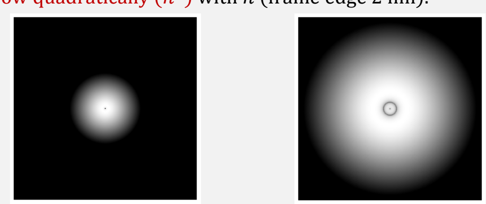
H, He^+, Li^{2+}, etc., photon energies

... that the electron cloud diameter is

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

For example, 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

... and that one-electron atoms can give of photon energies

$$\frac{hc}{\lambda} = \Delta E_{light} = -\Delta E_{atom} = -(E_{atom,f} - E_{atom,i}) = -Ry\, Z^2 \left(-\frac{1}{n_f^2} + \frac{1}{n_i^2}\right)$$

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

H ($Z = 1$): $n = 1 \to 2$, $\lambda = 121$ nm (Lyman α)

H ($Z = 1$): $n = 2 \to 6$, $\lambda = 410$ nm (violet, Balmer δ)

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

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

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Ionization

What happens if a ground-state ($n = 1$) H atom ($Z = 1$) absorbs a photon of energy greater than

$$\frac{hc}{\lambda} = \Delta E_{atom} = (E_{atom,\infty} - E_{atom,1}) = +Ry\, 1^2 \left(-\frac{1}{\infty^2} + \frac{1}{1^2}\right) = Ry?$$

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Ionization

The electron is ejected from the atom, leaving behind H^+.

This is called ionization, and ...

$E_{atom,\infty} - E_{atom,1} = Ry$ is called the ionization energy, IE.

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Ionization

Since $\Delta E_{\text{atom}} = -\Delta E_{\text{light}}$ and energy ΔE_{light} has been lost by the light, …

all energy in excess of the ionization energy is carried away as electron kinetic energy,

$$KE = \Delta E_{\text{atom}} - IE$$

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Ionization

Sketch the energy diagram for ionization of an electron from Li^{2+} in its $n = 6$ level by light of wavelength 310 nm.

Use your energy diagram to get the algebraic expression for the kinetic energy of the electron, using h, c, Ry, and 310 nm in your expression.

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Ionization

Answer: The ionization energy of Li^{2+} ($n = 6, Z = 3$) is

$$IE = E_{\text{atom},\infty} - E_{\text{atom},6} = 0 + Ry\frac{3^2}{6^2} = \frac{Ry}{4}$$

The photon energy is

$$\Delta E_{\text{atom}} = \frac{hc}{310\text{ nm}}$$

Therefore the kinetic energy of the electron is

$$KE = \Delta E_{\text{atom}} - IE = \frac{hc}{310\text{ nm}} - \frac{Ry}{4} = 9.6 \text{ x } 10^{-20}\text{ J} = 0.60\text{ eV}$$

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Ionization

ionization energy of Li^{2+} ($n = 6, Z = 3$) by 310 nm light produces electrons of kinetic energy

$$KE = \Delta E_{\text{atom}} - IE = \frac{hc}{310\text{ nm}} - \frac{Ry}{4} = 9.6 \text{ x } 10^{-20}\text{ J} = 0.60\text{ eV}$$

What are three changes that would result in less kinetic energy of the electron?

- Increase the wavelength if the light, lowering the photon energy.
- Prepare the electron in a cloud with lower principle quantum number n.
- Use a one-electron atom with more protons and so greater atomic number Z.

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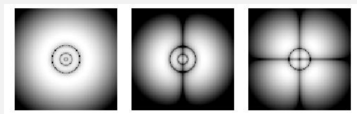
[TP] What is the *ionization energy* of these H atom electron clouds?



1. 13.6 eV
2. 13.6/4 eV
3. 13.6/9 eV
4. 13.6/16 eV
5. They each have different ionization energies

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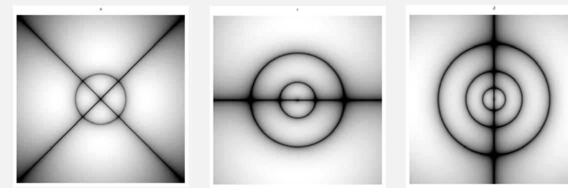
[Quiz] Which hydrogen atom electron cloud has the *smallest* ionization energy?



1. Left
2. Middle
3. Right
4. They all have the *same* ionization energy

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Example ionization problems

1. What is the wavelength of light needed to ionize an H atom in the $n = 2$ energy level?
Answer: 365 nm.

2. The ionization wavelength of H atom in the $n = 2$ energy level is 365 nm. What will be the kinetic energy of the electron ionized by 295 nm light? By 245 nm light?
Answer: 1.29×10^{-19} J; 2.67×10^{-19} J.

3. The ionization wavelength of H atom in the $n = 2$ energy level is 365 nm. Will light of this wavelength ionize He^+ in the $n = 1$ level? Answer: No, since the ionization wavelength is 22.8 nm.

4. Photons of energy Ry are able to ionize H in its $n = 1$ energy level. Are photons of this energy are able to ionize He^+ in its $n = 2$ energy level? Answer: Yes, since the ionization energy of He^+ in its $n = 2$ energy level is $0 - (-\text{Ry}\ 2^2/2^2) = \text{Ry}$.

5. Photons of energy Ry are able to ionize H in its $n = 1$ energy level. Are photons of this energy are able to ionize Li^{2+} in its $n = 2$ energy level? Answer: No, since the ionization energy of Li^{2+} in its $n = 2$ energy level is$0 - (-\text{Ry}\ 3^2/2^2) = 2.25$ Ry.

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Pictorial recipe for formal charge

Formal charge: Partition shared electrons equally.

$CH_3C(O)OH$

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Pictorial recipe for oxidation number

Oxidation number: More electronegative atom gets all shared electrons.

$CH_3C(O)OH$

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[TP] What is the oxidation number of the middle C in $CH_3CH_2C(O)OH$?

1. −4
2. −3
3. −2
4. −1
5. 0
6. +1
7. +2
8. +3
9. +4

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Pictorial recipe for oxidation number

Oxidation number: More electronegative atom gets all shared electrons.

$CH_3CH_2C(O)OH$

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