

[TP] Which energy change has the smallest E_{photon}?

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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Lecture 32 CH101 A1 (MWF 9:05 am)

Wednesday, November 29, 2017

For today ...

- H atom energy diagrams: Beyond Balmer's formula
- H, He^+ , Li^{2+} , etc., photon energies

Next lecture: Ionization (photoelectric effect); Review: Lewis structures, formal charge and oxidation number; Review: Electron clouds; More than one electron: Orbital (yikes!) approximation

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H atom photon energies: Beyond Balmer's formula

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H atom photon energies: Beyond Balmer

Sketch the H atom energy diagram and include the energy-change arrows corresponding to the red and violet lines of the emission spectrum.

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H atom photon energies: Beyond Balmer

Balmer's formula always involves $E_2 = -\frac{\text{Ry}}{2^2}$.

What about extending the formula in terms of $E_1 = -\frac{\text{Ry}}{1^2}$, as

$$\Delta E_{\text{light}} = E_{\text{photon}} = \frac{hc}{\lambda} = \left|-\frac{\text{Ry}}{1^2} + \frac{\text{Ry}}{n^2}\right| = \text{Ry}(\frac{1}{1^2} - \frac{1}{n^2}),\ n = 2, 3, 4, 5, ..., \infty\ ?$$

Where in the spectrum would absorption $n = 1 \rightarrow 2$ be?

$\lambda = 121$ nm, so in the UV.

It turns out this "line" is there!

H atom photon energies: Beyond Balmer

Balmer's formula always involves $E_2 = -\frac{\text{Ry}}{2^2}$.

What about extending the formula in terms of $E_1 = -\frac{\text{Ry}}{1^2}$, as

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Where in the spectrum would absorptions $n = 1 \rightarrow 3, 4$, etc., be?

$\lambda < 121$ nm, so also in the UV.

It turns out the "lines" are there!

H atom photon energies: Beyond Balmer

What about extending the formula in terms of $E_3 = -\frac{\text{Ry}}{3^2}$, as

$$\Delta E_{\text{light}} = E_{\text{photon}} = \frac{hc}{\lambda} = \left|-\frac{\text{Ry}}{3^2} + \frac{\text{Ry}}{n^2}\right| = \text{Ry}(\frac{1}{3^2} - \frac{1}{n^2}),\ n = 4, 5, 6, 7, ..., \infty\ ?$$

Where in the spectrum would lines given by this formula occur?

In the IR.

It turns out the lines are there!

H atom photon energies: Beyond Balmer

In a similar way, H atom electron cloud motion occurs for all combinations

$n \rightarrow n + 1, n + 2, ...$

$$\Delta E_{\text{light}} = E_{\text{photon}} = \frac{hc}{\lambda} = \left|-\frac{\text{Ry}}{n^2} + \frac{\text{Ry}}{n'^2}\right| = \text{Ry}(\frac{1}{n^2} - \frac{1}{n'^2}),\ n' = n + 1, n + 2, ...$$

For example, the series of lines for combinations $n = 4 \rightarrow 5, 6, 7, ...$, occurs in the microwave region of the spectrum.

Etc.

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

The H atom expressions for E_{photon} also work for all one-electron ions, when multiplied by the square of the nuclear charge of the ion.

For He^+, $Z = 2$; for Li^{2+}, $Z = 3$; etc.

$E_{\text{photon}} = \frac{hc}{\lambda} = \text{Ry}\, Z^2 (\frac{1}{1^2} - \frac{1}{n^2})$, $n = 2, 3, 4, \ldots$

$E_{\text{photon}} = \frac{hc}{\lambda} = \text{Ry}\, Z^2 (\frac{1}{2^2} - \frac{1}{n^2})$, $n = 3, 4, 5, \ldots$

$E_{\text{photon}} = \frac{hc}{\lambda} = \text{Ry}\, Z^2 (\frac{1}{3^2} - \frac{1}{n^2})$, $n = 4, 5, 6, \ldots$

etc.

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

Practice: What is E_{photon} and the corresponding wavelength and spectral region for He^+ $n = 3 \rightarrow 5$ absorption?

$E_{\text{photon}} = \text{Ry}\ 4\ (\frac{1}{9} - \frac{1}{25}) = \text{Ry} \times 0.284$

$\lambda_{\text{photon}} = \frac{hc}{E_{photon}} = \frac{hc}{\text{Ry}\ 0.284} = 321\ \text{nm}$

UV region

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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

He^+: $n = 2 \rightarrow 3$, $\lambda = 164$ nm (1/4 of H: $n = 2 \rightarrow 3$, 656 nm)

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