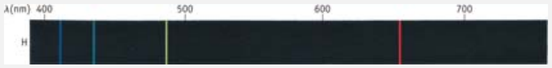
[TP] What electron cloud energies account for the 486 nm line in the gas discharge spectrum (Balmer series) of H atoms?



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

BOSTON UNIVERSITY Response Counter 10 1

Lecture 31 CH101 A1 (MWF 9 am)

Monday, November 28, 2016

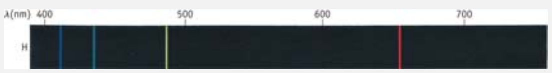
- Complete: H atom photon energies
- He^+, Li^{2+}, etc., photon energies
- Photoionization (photoelectric effect)

Next lecture: Hydrogen atom electron clouds http://goo.gl/XPkcxv; Review of electron clouds; Orbital (yikes!) approximation

BOSTON UNIVERSITY

Lecture 31 CH101 A1 (MWF 9 am) Fall 2016
Copyright © 2016 Dan Dill dan@bu.edu

[TP] What electron cloud energies account for the 486 nm line in the gas discharge 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

BOSTON UNIVERSITY Response Counter 10 5

Lecture 31 CH101 A1 (MWF 9 am) Fall 2016
Copyright © 2016 Dan Dill dan@bu.edu

What about clouds made from a single *n*?

It turns out that clouds made from a single electron wave do not move.

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.

BOSTON UNIVERSITY 6

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 states of energy E_i and E_f.

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

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

BOSTON UNIVERSITY

H atom photon energies

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

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

$$\Delta E_{light} = E_{photon} = h\,c / \lambda = \text{Ry}\,(\tfrac{1}{1^2} - \tfrac{1}{n^2}),\ n = 2, 3, 4, 5, \ldots, \infty$$

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

UV

It turns out the lines are there!

BOSTON UNIVERSITY

H atom photon energies

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

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

$$\Delta E_{light} = E_{photon} = h\,c / \lambda = \text{Ry}\,(\tfrac{1}{3^2} - \tfrac{1}{n^2}),\ n = 4, 5, 6, 7, \ldots, \infty\ ?$$

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

IR

It turns out the lines are there!

BOSTON UNIVERSITY

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,

$$E_{photon} = h\,c / \lambda = \text{Ry}\,Z^2(\tfrac{1}{1^2} - \tfrac{1}{n^2}),\ n = 2, 3, 4, \ldots$$

$$E_{photon} = h\,c / \lambda = \text{Ry}\,Z^2(\tfrac{1}{2^2} - \tfrac{1}{n^2}),\ n = 3, 4, 5, \ldots$$

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

etc.

BOSTON UNIVERSITY

Ionization

What happens if an H atom absorbs a photon of energy greater than

$$E_{\text{photon}} = E_{\text{cloud},\infty} - E_{\text{cloud},1} = (0 + \text{Ry}) = \text{Ry}?$$

BOSTON UNIVERSITY

Ionization

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

This is called ionization.

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

BOSTON UNIVERSITY

Ionization

Since $\Delta E_{\text{atom}} = -\Delta E_{\text{light}}$ and energy ΔE_{light} has been lost by the light, the energy in excess of the ionization energy is carried away as electron kinetic energy, *KE*,

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

BOSTON UNIVERSITY

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

BOSTON UNIVERSITY

Lecture 31 CH101 A1 (MWF 9 am) Fall 2016

Ionization

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

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

The photon energy is $E_{\text{photon}} = h\,c/(310\text{ nm})$

The kinetic energy of the electron is

$KE = E_{\text{photon}} - IE$

$= h\,c\,[1/(310\text{ nm}) - \text{Ry}/4]$

$= 9.6 \times 10^{-20}\text{ J} = 0.60\text{ eV}$

BOSTON UNIVERSITY

31