What is the wavelength of the line in the Balmer series of hydrogen that is comprised of transitions from the \( n = 4 \) to the \( n = 2 \) level? (\( R = 1.097 \times 10^7 \text{ m}^{-1} \) and \( 1 \text{ nm} = 10^{-9} \text{ m} \))

a. 380 nm
b. 486 nm
c. 523 nm
d. 630 nm

\[
\frac{1}{\lambda} = R \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = 1.097 \times 10^7 \left( \frac{1}{2^2} - \frac{1}{4^2} \right)
\]

\[
\frac{1}{\lambda} = 1.097 \times 10^7 \left( \frac{1}{4} - \frac{1}{16} \right) = 2.06 \times 10^6
\]

\[
\lambda = 4.86 \times 10^{-7} \text{ m}
\]

The Lyman series of hydrogen is made up of those transitions made from higher levels to \( n = 1 \). If the first line in this series has a wavelength of 122 nm, what is the wavelength of the second line?

a. 49 nm
b. 103 nm
c. 364 nm
d. 486 nm

First line: Lowest energy from \( n \) to 1

\( n = 2 \) will be lowest

Second line: 2nd lowest from \( n \) to 1

\( n = 3 \) will be next

\[
\frac{1}{\lambda} = R \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = R \left( \frac{1}{4} - \frac{1}{1^2} \right)
\]

\[
\frac{1}{\lambda} = R \left( 1 - \frac{1}{3^2} \right) = 1.097 \times 10^7 \left( 1 - \frac{1}{9} \right) = 9.71 \times 10^6
\]

\[
\lambda = 1.03 \times 10^{-7} \text{ m}
\]

Or

\[
\frac{\lambda_1}{\lambda_2} = \frac{\frac{1}{n_f^2} - \frac{1}{n_i^2}}{\frac{1}{n_f^2} - \frac{1}{n_i^2}} = \frac{1 - \frac{1}{4}}{1 - \frac{1}{9}} = 1.19
\]

\[
\lambda_2 = \frac{\lambda_1}{1.19} = \frac{12.2 \text{ nm}}{1.19} = 103 \text{ nm}
\]
3. The Paschen series of hydrogen corresponds to electron transitions from higher levels to \( n = 3 \). What is the shortest wavelength in that series? \((R = 1.097 \times 10^7 \text{ m}^{-1} \text{ and } 1 \text{ nm} = 10^{-9} \text{ m})\)

\[
\frac{1}{\lambda} = R \left( \frac{1}{n_2^2} - \frac{1}{n_1^2} \right) \rightarrow \text{HIGHEST ENERGY CHANGE}
\]
\[
\frac{1}{\lambda} = R \frac{1}{n_e^2} = 1.097 \times 10^7 \frac{1}{3^2} = 1.22 \times 10^6
\]
\[
\lambda = 8.20 \times 10^{-7}
\]

4. The ionization energy of the hydrogen atom is 13.6 eV. What is the energy of the \( n = 5 \) state?

\[
E_n = -13.6 \frac{1}{n^2} \text{ eV for HYDROGEN}
\]
\[
E_5 = -13.6 \cdot \frac{1}{25} = -0.544
\]

**Note:** Ionization energy depends on the level of the electron.

\[
\text{IONIZATION ENERGY} = -E_n
\]

= Energy required to get electron to zero energy.
In the hydrogen atom the potential energy is negative, but the absolute value of the potential energy:

- is equal to the kinetic energy of the electron.
- is twice the kinetic energy of the electron.
- is half the kinetic energy of the electron.
- is equal to \(n^2\) times the kinetic energy of the electron.

A muon behaves like an electron except that it has 207 times the mass of the electron. If a muon were bound to a proton, how would the energy levels in the Bohr model compare to those for a bound electron?

- They would be the same.
- They would be \((207)^2\) times as much as those for the electron.
- They would be 207 times as much as those for the electron.
- They would be \((1/207)\) times as much as those for the electron.

Look at Bohr formula for energy levels

Hydrogen: \(E_n = -\frac{m_e^2 c^2}{2 \hbar^2} \left( \frac{1}{n^2} \right)\)

Replace \(m_e\) with \(m_\mu = 207 \times m_e\), everything else is the same:

\[ E_{\eta\mu} = -\frac{207 m_e^2 c^2}{2 \hbar^2} \left( \frac{1}{n^2} \right) \]

\[ E_{\eta\mu} = 207 E_n \]
7) A hydrogen atom in the ground state absorbs a 12.75-eV photon. To what level is the electron promoted? (The ionization energy of hydrogen is 13.6 eV).

- a. $n = 2$
- b. $n = 3$
- c. $n = 4$
- d. $n = 5$

\[ E_{n_1} = -13.6 \text{ eV} \]
\[ E_{n_2} = E_{n_1} + 12.75 \text{ eV} \]
\[ E_{n_2} = -13.6 + 12.75 = -0.85 \text{ eV} \]
\[ \frac{1}{n_2^2} = \frac{12.6}{0.85} = 16 \]
\[ n_2 = 4 \]

8) What is the energy needed to change an He$^+$ ion into an He$^{++}$ ion? (The ionization energy of hydrogen is 13.6 eV).

- a. 13.6 eV
- b. 54.4 eV
- c. 92.9 eV
- d. 112.4 eV

For hydrogen-like atoms:
(1 electron, multiple protons)

\[ E_n = -13.6 \left( \frac{Z}{\sqrt{n^2}} \right) \text{ eV} \quad Z = \# \text{ of protons} \]

In ground state:

\[ E_{n} = -13.6 \left( \frac{2}{1} \right) = -54.4 \text{ eV} \]

Need $-E_n$ to free the electron (or more)
9) If the principal quantum number for hydrogen is 5, which one of the following is not a permitted orbital magnetic quantum number for that atom?

- a. 6
- b. -2
- c. 0
- d. 3

\[ n = 5 \rightarrow l = 0, 1, 2, 3, 4 \text{ are possible} \]

\[ -l \leq m_e \leq l \text{ so } |m_e| \text{ can't be larger than } l \]

\[ \max l \text{ is } 4 \]

\[ |m_e| \leq 4 \]

11) How many electrons are in bromine's (atomic number 35) next to outer shell (n = 3)?

- a. 2
- b. 4
- c. 8
- d. 18

\[ n = 3 \]

\[ \begin{array}{c|c c c}
0 & 0 & 0 \\
1 & -1 & 0 & 1 \\
2 & -2 & -1 & 0 & 1 & +1 & 2 \\
\end{array} \]

9 \( l, m_e \) combinations

Each can have \( m_s = \pm \frac{1}{2} \)

So \( 2 \times 9 \) total if shell is filled

= 18

Or

Each \( l \) has \( 2(2l+1) \) possible states

\[ \begin{align*}
l = 0 & \quad 2(2(0) + 1) = 2 \\
l = 1 & \quad 2(2(1) + 1) = 6 \\
l = 2 & \quad 2(2(2) + 1) = 10 \\
\end{align*} \]
Characteristic x-rays are the result of:

a. outer electron transitions.
b. inner electron transitions.
c. nuclear electron states.
d. bucky tubes.

SEE EXAMPLE 28.4

The stimulated emission of photons from the excited atoms in a gas laser is prompted by which of the following?

a. high voltage
b. high flux of electrons
c. nearby presence of photons of same wavelength as those emitted
d. high temperature

Electrons can drop from higher to lower energy levels either spontaneously or if "nudged" by a photon of exactly the same energy as the difference in levels.

(SEE FIG. 28.19)