19-3 Energy Level Diagrams

Each atom has its own characteristic set of “fingerprints” or allowed energy states that its electrons can occupy. An energy level diagram is a representation of these allowed energy states. The electrons in an atom cannot occupy any level between these allowed states, but instead “jump” from level to level. This is analogous to a person trying to stand between, rather than on, the rungs of a ladder. It is impossible to do so!

Generally, electrons are found at the lowest energy level or ground state. However, when an electron absorbs a photon from its surroundings, it becomes excited and jumps up to a higher energy level. Since the photon is removed from the incident light, this produces an absorption spectrum.

When the electron returns to a lower energy level, it emits one or more photons in the process, producing a bright line or emission spectrum. If these emitted photons fall in the visible portion of the spectrum, the characteristic spectral lines of the material are seen.

The energy level diagram for hydrogen is shown. Because hydrogen is the most abundant gas in the universe, the hydrogen spectrum has been studied very closely and names have been given to the transitions between energy levels.

**Lyman series:** Electrons jump to or from the \( n = 1 \) level. The electromagnetic radiation emitted or absorbed is characterized as ultraviolet.

**Balmer series:** Electrons jump to or from the \( n = 2 \) level. The electromagnetic radiation emitted or absorbed is characterized as visible light.

**Paschen series:** Electrons jump to or from the \( n = 3 \) level.

**Brackett series:** Electrons jump to or from the \( n = 4 \) level.

**Pfund series:** Electrons jump to or from the \( n = 5 \) level. The electromagnetic radiation emitted or absorbed from these three series is characterized as infrared.
Solved Examples

Example 6: a) What wavelengths of light are emitted by an electron jumping from \( n = 2 \) to \( n = 1 \), and from \( n = 4 \) to \( n = 3 \)? b) To what portion of the electromagnetic spectrum do these wavelengths correspond?

a. From \( n = 2 \) to \( n = 1 \)

Given: \( E_2 = 10.2 \text{ eV} \)
\( E_1 = 0 \text{ eV} \)
\( h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \)
\( c = 3.00 \times 10^8 \text{ m/s} \)

Unknown: \( \lambda = ? \)

Original equation: \( \frac{hc}{\lambda} = E_2 - E_1 \)

Solve: \( \lambda = \frac{hc}{E_2 - E_1} = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{(10.2 \text{ eV} - 0 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})} = 1.22 \times 10^{-7} \text{m} \)

From \( n = 4 \) to \( n = 3 \)

Given: \( E_4 = 12.75 \text{ eV} \)
\( E_3 = 12.09 \text{ eV} \)
\( h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \)
\( c = 3.00 \times 10^8 \text{ m/s} \)

Unknown: \( \lambda = ? \)

Original equation: \( \frac{hc}{\lambda} = E_4 - E_3 \)

Solve: \( \lambda = \frac{hc}{E_4 - E_3} = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{(12.75 \text{ eV} - 12.09 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})} = 1.88 \times 10^{-6} \text{m} \)

b. 122 nm is ultraviolet and 1880 nm is infrared.

Practice Exercises

Exercise 9: Use the energy level diagram for hydrogen on page 241 to determine the shortest wavelength in the Paschen series of hydrogen.

Answer: ________________________________

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Exercise 10: The sun’s spectrum is made up of many absorption lines called *Fraunhofer lines*. How many electron volts of energy are absorbed in order to produce the H $\alpha$ line whose wavelength is 657.7 nm?

Answer: _____________________

Exercise 11: A stellar spectrum shows three absorption lines of hydrogen produced as electrons move from the $n = 2$ state to higher energy levels ($n = 3$, $n = 4$, $n = 5$). What are the wavelengths and colors of the three lines missing from the continuous spectrum?

Answer: _____________________

Exercise 12: On June 24, 1999, NASA launched FUSE (the Far Ultraviolet Spectroscopic Explorer) to explore the universe using high-resolution spectroscopy in the far ultraviolet spectral region. If FUSE records radiation of wavelength 102.8 nm, between what two energy levels must the electron jump in the hydrogen atom to produce this line? (Read more about the FUSE spacecraft at http://fuse.pha.jhu.edu)

Answer: _____________________