Energy Calculation in the Bohr’S Model: Changing or Transitioning Electron States (For CBSE, ICSE, IAS, NET, NRA 2022)

- The energy of the emitted photon is equal to the difference in energy between the two energy levels for a specific transition.
- The energy can be calculated using the equation,

$$\Delta E = E\left(n_{\text{high}} - n_{\text{low}}\right)$$

$$\Delta E = \left(-\frac{1}{{n_{\text{high}}}^2} \times 13.6\ \text{eV}\right) — \frac{1}{{n_{\text{low}}}^2} \times 13.6\ \text{eV}$$

$$\Delta E = \left(\frac{1}{{n_{\text{low}}}^2} - \frac{1}{{n_{\text{high}}}^2}\right) 13.6\ \text{eV}$$

- As we also know the relationship between the energy of a photon and its frequency from Planck’s equation, we can solve for the frequency of the emitted photon:

$$\text{hv} = \Delta E = \left(\frac{1}{{n_{\text{low}}}^2} - \frac{1}{{n_{\text{high}}}^2}\right) 13.6\ \text{eV}$$

$$v = \left(\frac{1}{{n_{\text{low}}}^2} - \frac{1}{{n_{\text{high}}}^2}\right) \frac{13.6\ \text{eV}}{h}$$

- One can also find the equation for the wavelength of the emitted electromagnetic radiation using the relationship between the speed of light:

$$c = \lambda v$$

$$\frac{c}{\lambda} = v = \left(\frac{1}{{n_{\text{low}}}^2} - \frac{1}{{n_{\text{high}}}^2}\right) \frac{13.6\ \text{eV}}{h}$$

$$\frac{1}{\lambda} = v = \left(\frac{1}{{n_{\text{low}}}^2} - \frac{1}{{n_{\text{high}}}^2}\right) \frac{13.6\ \text{eV}}{\text{ch}}$$

Limitations of the Bohr Model of the Hydrogen Atom

- The Model doesn’t work well for complex atoms.

- It couldn't explain why some spectral lines are more intense than others.
- It could also not explain why some spectral lines split into multiple lines in the presence of a magnetic field.
- The Heisenberg's uncertainty principle contradicts Bohr's idea of electrons existing in specific orbits with a known radius and velocity.
- Although the modern quantum mechanical model and the Bohr Model of the Hydrogen Atom may seem more different, the fundamental idea is the same in both.
- Classical physics isn't sufficient to describe all the phenomena that occur on an atomic level.
- But, Bohr was the first to realize the quantization of electronic shells by fusing the idea of quantization into the electronic structure of the hydrogen atom and was successfully able to explain the emission spectra of hydrogen as well as other one-electron systems.

Conclusion

- The Bohr model worked beautifully for explaining the hydrogen atom and other single electron systems such as H^+
- But, it did not do as well when applied to the spectra of more complex atoms.
- The Bohr model had no way of explaining why some lines are more intense than others or why some spectral lines split into multiple lines in the presence of a magnetic field — the Zeeman effect.

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