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CHEM 3420: Physical Chemistry II — Spring 2009

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Lecture 3: Early atomic models and the road to wave-particle dualtiy

References

1. Levine, *Physical Chemistry*, Sections 17.1–17.5

Key Concepts

- The Rutherford/nuclear model of atomic structure fails to account for (1) the eventual nuclear collapse due to the accelerating electron falling into the nucleus and (2) the discrete nature of atomic emission/absorption spectra (Rydberg equation).
- Bohr accounts for these problems with several assumptions. There is little physical reasoning behind these assumptions beyond that they fit the experimental evidence.
    1. The electrons can exist in stable states with energies E_n, where n is an integer.
    2. Transitions can occur between states through the absorptions or emission of photons.
    3. Angular momentum of the electron (still considered a particle) is quantized: $l = mvr$.
- These assumptions leads to the Bohr model, which does a good job at describing and predicting experiments involving one-electron atoms like hydrogen. The Rydberg equation is arrived at through Bohr's model.
- This all looks great, but there are problems, namely: (1) Bohr's model only works for a single electron atom, (2) there is little or no physical basis for the assumptions and (3) it cannot explain all experimental observations.
- To arrive at a better model, the concept of wave-particle duality must be employed. Both matter and light have wave-like and particle-like properties.
- The deBroglie relationship describes the relationship between the momentum (mass & velocity) of a particle to a wavelength: $\lambda = \frac{h}{mv} = \frac{h}{p}$
- The deBroglie wavelength of a particle (matter) becomes important only when it is on the same length scale as some experimental distance. If the wavelength is much smaller than this length scale, only particle properties (classical mechanics) need to be considered.
- If the wave length is on the same order as some experimental distance (ex. election & atomic size/spacing), then the wave properties become essential in modeling the particle behavior.
- The wave nature of electrons leads to a physical basis for Bohr's assumption of the quantization of linear momentum (which he arrived at assuming the electron was a particle). For the electron wave to be stable for a particular "orbit" then it must close on itself to avoid destructive interference: $l = mvr = n\hbar = \frac{nh}{2\pi}$

Related Exercises in Levine

Exercises 17.4, 17.5