Particle Historical Background:
1. Goldstein (1886): detection of rays in gas tubes cathode negative/canal positive ⇒ various charge/mass ratio
2. Thomson (1897): quantitation of cathode rays ⇒ negatively charged and behave like particles ⇒ mass of the electron
3. Milliken (1903): oil drop experiment ⇒ cathode rays ionize oil drop suspended in electrostatic field (U) ⇒ varying U, rate of the dropping changes ⇒ charge of the electron
4. Moseley (1910): X-ray emission from metals bombarded with high energy electrons ⇒ extra atomic weight in the nucleus (half of the total mass) ⇒ neutrons

Atomic Models:
1. Thomson (1900): static model – atom is a ball build from + and - fragments
2. Rutherford (1911): α particles deflected at large angles as passing through metal foils ⇒ most of the foil is empty space ⇒ a small nucleus is at the center of the atom – why the electron does not fall into the nucleus
3. Bohr (1913): accepted Rutherford’s nucleus model ⇒ electron is on a quantized circular orbit ⇒ electromagnetic radiation emitted or absorbed only if orbit changes ⇒ classical mechanics laws

Considering orbiting electron around a proton (H atom) the Coulomb force equal with centrifugal force of a particle on a quantized orbit

\[ r = \frac{n^2 \hbar^2}{4\pi^2 mZe^2} = a_o n^2 \] ; where \( a_o \) is the Bohr radius (52.9 pm)

\[ \nu = Ze^2 \frac{2\pi}{nh} ; \text{ the electron is traveling close to the speed of light (2.187 \cdot 10^8 \text{ cm s}^{-1})} \]

\[ E = -\frac{2\pi^2 mZ^2 e^4}{n^2 \hbar^2} = \frac{E_{n=1}}{n^2} ; \text{ where } E_{n=1} \text{ is the ground state energy (-13.6 eV)} \]

Bohr model explains spectral features of hydrogen-like atoms:
- Ground and excited states; ionization and separation energy
- Rydberg’s empirical formula ( \( \Delta E = T_1 - T_2 = \frac{R}{n_1^2} - \frac{R}{n_2^2} = \tilde{\nu} = \frac{1}{\lambda} \) ) for the term values of the hydrogen (\( R = 109.677.6 \text{ cm}^{-1} / 8065 \text{ eV cm} = 13.6 \text{ eV} \))
- Moseley’s empirical formula ( \( \nu = k (Z - \sigma)^2 \) ) for the relationship between X-ray emission frequency and atomic number ⇒ shielding (\( \sigma \)) by the core electrons \( k = \frac{-2\pi^2 m(Z - \sigma)^2 e^4}{h^3} \)
- Try to describe He atom with the Bohr model. How do you treat the second electron particle?

Wave Historical Background:
1. Planck (1900): black body problem ⇒ light entering into a hollow sphere through a small hole ⇒ cannot escape, absorbed by tiny oscillators ⇒ experimental emitted radiation curve has a maximum ⇒ the oscillators can vibrate only at discrete frequencies ⇒ light comes in packets/quantized ⇒ \( E = h \cdot \nu \).
2. Einstein (1905): photoelectric effect ⇒ light below certain \( \lambda \) (blue vs. red), regardless of the intensity can eject electron from metals ⇒ photon has kinetic energy \( E = m \cdot c^2 \).
3. DeBroglie (1910): studying electron diffraction suggests that all moving particles have an associated wave ⇒ connects wavelength of a photon and its momentum \( \lambda = h / m \cdot \nu \). ⇒ reciprocal relationship between wavelength and momentum or energy and periodicity.
4. Heisenberg (1927): particle is a wave and does not have a well defined simultanous position and momentum ⇒ position and momentum cannot be determined at the same time with higher accuracy than the
Planck constant \( (h) \) ⇒ reciprocal relationship between position and momentum \( \Delta p_x \cdot \Delta x \geq \hbar / 4\pi \)

“digestable” example: listening to the radio ⇒ want to know the exact frequency at an exact moment ⇒ this is impossible: need to sample over time to have an accurate measurement of frequency

5. Schrödinger (1925): wave mechanical definition of the electrons

\[
\text{Total Energy} = \text{Kinetic} + \text{Potential}
\]

Bohr model: \( E = \frac{1}{2} m v^2 - \frac{Z e^2}{r} \) hydrogen like atoms

For an electron wave, define a wavefunction \( \Psi \) and use Maxwell’s equation of motion for waves

\[
E \Psi = -\frac{\hbar^2}{8\pi^2 m} \left( \frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} + \frac{\partial^2 \Psi}{\partial z^2} \right) + V \Psi
\]

Simplest solution: Particle in a box ⇒ \( V = 0 \) inside the box, only one dimensional \( y = z = 0 \)

\[
E \Psi = -\frac{\hbar^2}{8\pi^2 m} \frac{\partial^2 \Psi}{\partial x^2} \Rightarrow \text{second derivative of a function is the function itself}
\]

\[
\Psi = A \sin kx, \text{ for a box with one particle and } \text{max}(x) = L,
\]

\[
\text{after normalization } \Psi = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L}
\]

\[
E = \frac{n^2 \hbar^2}{8mL} \text{ and for a 3D box } E = \frac{(n_1^2 + n_2^2 + n_3^2) \hbar^2}{8mL} \text{ - note the 3 quantum numbers}
\]

Concluding words about \( \Psi \) or electron orbit

\[
\Psi(x,y,z) = \text{general form of } \sin x \cdot \cos y \cdot e^{-z}
\]

- must be normalized = probability of finding and electron \( \int \Psi \Psi^* dr = 1 \)
- boundary conditions require introduction of quantum numbers