Introduction to Quantum Theory

* Hydrogen Spectra - classical theory

- Lyman, Balmer, Paschen, Brackett, Pfund → Series of spectra
  1, 2, 3, 4, 5

Rydberg's formula — $\frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ $R_H = 1.097 \times 10^7\ m^{-1}$ — Energy conservation
Rydberg's constant

* Photo Electric Effect – Quantization

- $E_{max} = h\nu - \phi = h(\nu - f_0)$ ⇒ frequency decides energy of ejected e^-

  h = plank's constant — 6.63×10^{-34} units

* Blackbody Radiation

- Atoms vibrate with a frequency f, and they can exchange energy in multiples of hf, where h - plank's constant.

- Wein's Displacement Law → $\lambda_m T$ = constant = 2898 μm-K

  Stefan-Boltzmann Law ⟶ $P = \sigma A e T^4$; $\sigma = 5.67 \times 10^{-8}$ units

(1) Rayleigh-Jeans Law

- Given that mode density $N(\nu)d\nu = \frac{8\pi\nu^2}{c^3} d\nu$

  By equipartition theorem, each mode has avg energy $\frac{1}{2}K_BT$

  But the modes are caused due to vibration (PE+KE) = $2 \times \frac{1}{2}K_BT = K_BT$

  ∴ Energy density = $u(\nu)d\nu = \left[\frac{8\pi\nu^2}{c^3}\right](K_BT)$

- Valid only for Low ν, because we haven't considered that the atoms can emit/absorb only in multiples of $h\nu$.

* Plank's Law:-

- Emission of energy takes place in discrete multiples of $h\nu$, and the probability that energy E is emitted is proportional to e^{-E/k_BT}.

$$P(E) \propto e^{-E/k_BT}$$ — Boltzmann Distribution

$$\Rightarrow \langle E \rangle = \frac{\sum e^{-nh\nu/kT} \cdot nh\nu}{\sum e^{-nh\nu/kT}} \Rightarrow \langle E \rangle = \frac{h\nu}{e^{\frac{h\nu}{kT}} - 1}$$ (using GP and differential of GP)

- Using this, energy density $\Rightarrow$ $u(\nu) = \frac{8\pi\nu^2}{c^3} \cdot \frac{h\nu}{e^{h\nu/kT} - 1}$

- Represent Plank's energy density as $u_p(\nu)$, Rayleigh-Jean's as $u_{RJ}(\nu)$

$$u_p(\nu) = u_{RJ}(\nu) \cdot \frac{h\nu/kT}{e^{h\nu/kT} - 1}$$ → Quantum Correction.