Franck-Hertz Experiment

- Franck and Hertz wanted to show that energy transitions in an atom were quantized.
- They believed that electron's in a beam should transfer their energy to a gas in quantized steps.

\[ E_e + E_1 = E_e' + E_2 \quad \rightarrow \quad E_e - E_e' = (E_2 - E_1) = \Delta E_{21} \]

Conservation of Energy

**Hydrogen - like Atoms**

\[ E_n = -13.6 \frac{Z^2}{n^2} \text{ eV} \quad \text{where} \quad E_{n=1}^{\text{Hg}} = -10.38 \text{ eV} \]

**Hg\textsubscript{201} Atom**  Ground State  (Xe\textsuperscript{54} 4f\textsuperscript{14} 5d\textsuperscript{10} 6s\textsuperscript{2}  

**Na\textsubscript{23} Atom**  Ground State  1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{6} 3s\textsuperscript{1}

- Monatomic Hg, Ne, Ar are used so not to excite molecular transitions eg. N2, O2, etc.
Franck-Hertz Tube

- $V_H$ supplies current to the heated cathode creating electrons by thermionic emission.
- Electrons are accelerated to the anode by adjusting $V_a = 0 = 80V$ eg.
- Electrons reaching the anode grid are collected and establish an anode grid current $I_A$.
- Some electrons collide with Hg atoms and transfer energy $e + Hg \rightarrow e' + Hg^*$ (*excited).
  \[ E_e + E_{Hg} = E_{e'} + E_{Hg^*} \]
  \[ E_e = \Delta(E_{Hg^*} - E_{Hg}) \]
- $e'$ loses energy and stops accelerating, a drop in $I_A$ occurs creating an absorption dip.
- $e'$ re-accelerates and can collide with another Hg atom, again $e + Hg \rightarrow e' + Hg^*$ and a second absorption dip occurs.
- $\Delta(E_{Hg^*} - E_{Hg})$ represents a quantized energy transition in Hg!
$^\text{ss} \text{Hg Ground State}$ (Xe) $4f^{14} 5d^{10} 6s^2 6p_\text{..}$

$L = 0$ and $S = \frac{1}{2} + \frac{1}{2} = 1, 0$

$J = L + S = 0 + 1 = 1 \quad 2^{S+1} L_J = \frac{3}{3} S_1 \quad \text{not allowed}$

$J = L + S = 0 + 0 = 0 \quad 2^{S+1} L_J = \frac{1}{1} S_0 \quad \text{ground state}$

$1\text{st Excited State}$ (Xe) $4f^{14} 5d^{10} 6s^1 6p^1$

$L = 0 + 1 = 1 \quad \text{and} \quad S = \frac{1}{2} + \frac{1}{2} = 1, 0$

$J = L + S = 1 + 1 = 2, 1, 0 \quad 2^{S+1} L_J = \frac{3}{3} P_2, \frac{3}{3} P_1, \frac{3}{3} P_0$

$J = L + S = 1 + 0 = 1 \quad 2^{S+1} L_J = \frac{1}{1} P_1$

$\text{Electric Dipole Transitions}$

$\Delta L = 1 \quad \Delta m_L = 0, +1$

$\Delta J = 0, +1$

$J = 0 \leftrightarrow J = 0 \quad \text{not allowed}$

$\text{Hg Spectra}$

$1S_0 \leftrightarrow 1P_1 \quad 408 \text{ nm} \ (3.04 \text{ eV})$

$1S_0 \leftrightarrow 3P_0 \quad 254 \text{ nm} \ (4.88 \text{ eV})$

$1S_0 \leftrightarrow 1P_1 \quad 185 \text{ nm} \ (6.70 \text{ eV})$

$\text{A few energy levels for the mercury atom}$