Last time talked about Bohr's model for atom

- Assumed Stable orbits (Quantized r_n E_n)
- Crazy But reproduces data.
- Ad hoc. No first Principles.

Today
- Talk about some direct evidence for Quantization of Energy levels
- Use Bohr model to understand X-rays / Nuclear Charge.

Franck-Hertz Experiment

- Can we directly probe the Quantized Energy levels using something other than light?

Yes! Shoot e^-'s w/ varying E_e and see if scattering is
- elastic
- inelastic

Incoming e_I can only give E to e_A if it is enough to excite e_A to $n=2$ orbit

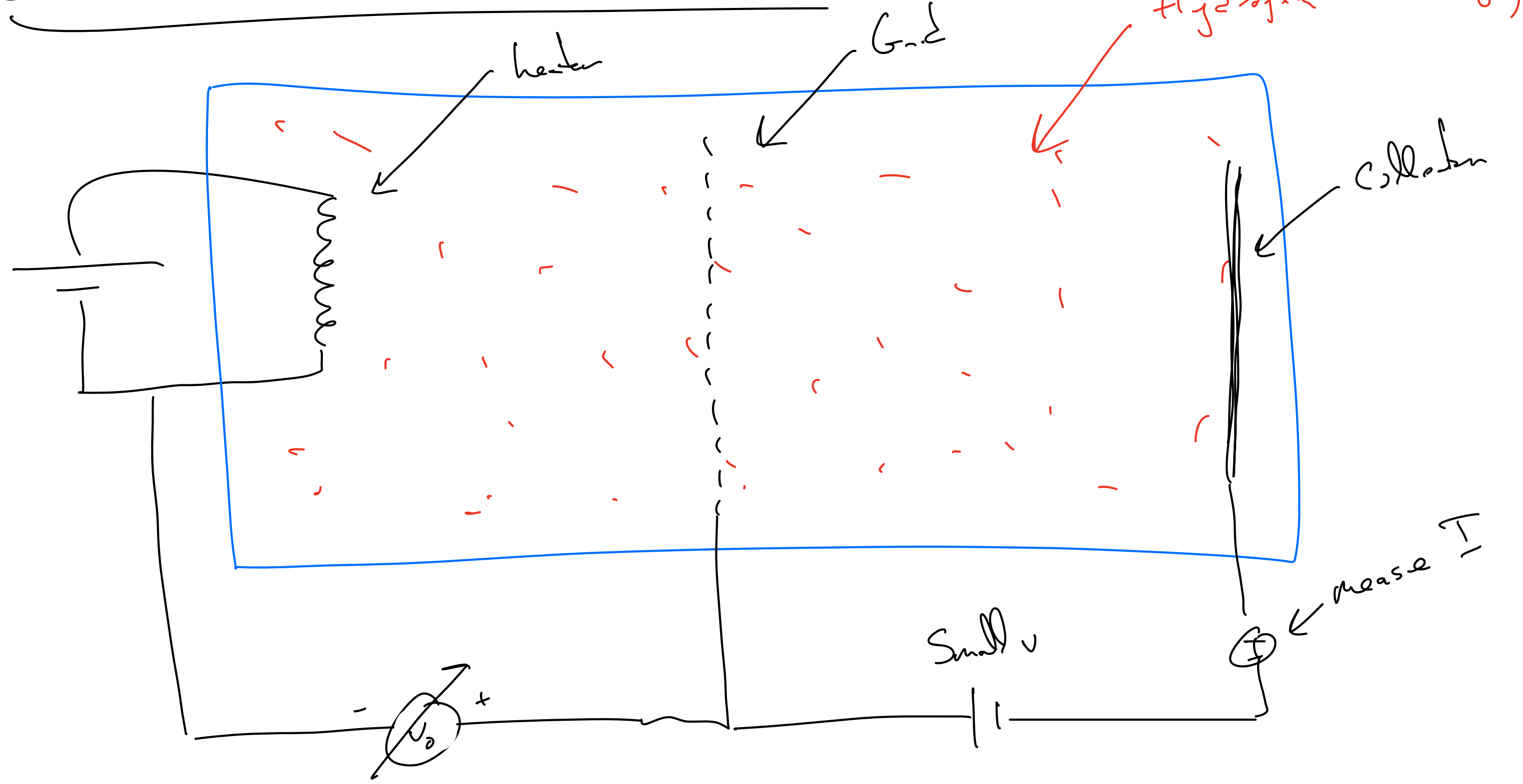
ie

$$E_{min} = E_0\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 13.6\,eV\left(\frac{3}{4}\right) = 10.2\,eV$$

if $E_e < E_{min}$ then the scattering must be elastic

ie No ΔE_I.

Ok So how to test this



-) will measure I vs V.

what is going to happen?

-) e's spit off from heater w/ $E_e \sim 0$

-) Gain energy eV_0 from electric potential on grid

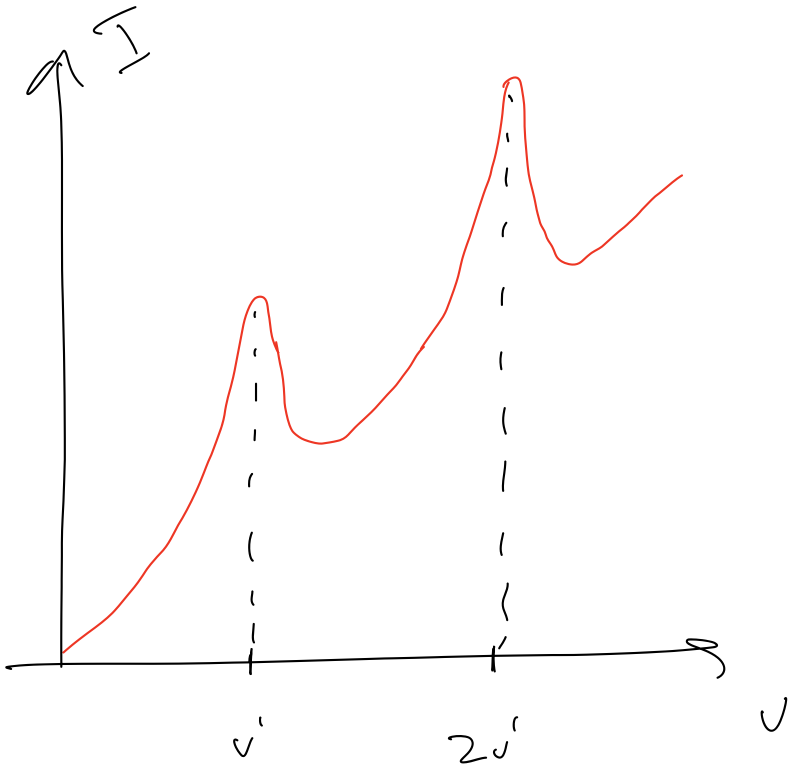
-) Some pass through the grid & are counted in I.

-) Larger V_0 => larger I

-) Now put atoms in chamber H (In reality used Hg)

-) Some e's will hit atoms

→ only lose E if $E_e = eV_0 > 10$ eV



→ If lose all E in scatter event get ~ ΔV.

⇒ Current drops.

<u>These dips seen!!</u>

Not only that ... Now expect to see a light signal

<u>Expect</u>

- No light when $eV_0 < 10.2$
- start seeing light as soon as current drops w/ $f = \frac{E_2 - E_1}{h}$ (this also seen)

Very Compelling!

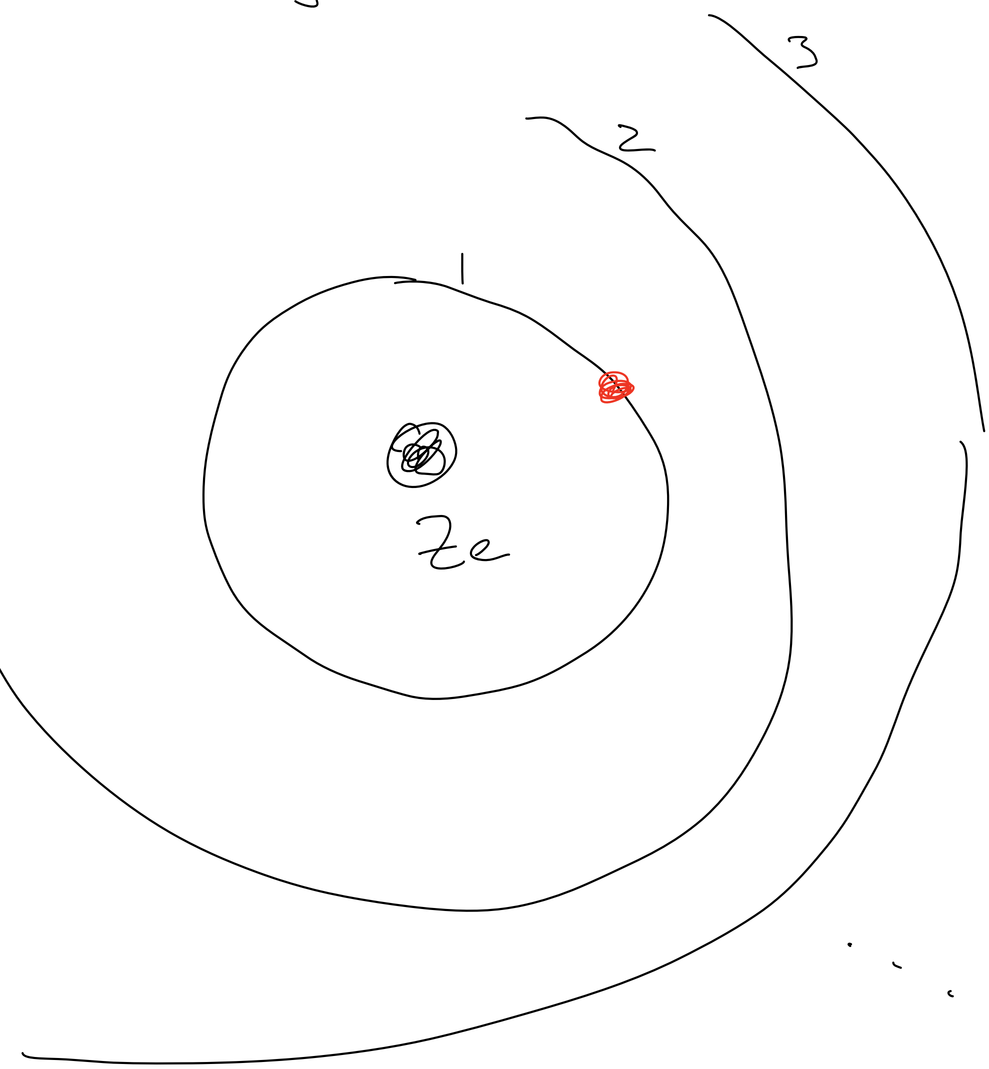
(Other Atoms Discuss)

More Complicated Atoms

- Apply Bohr's model to more complicated atoms don't work.

- Except in limits where can ignore other e⁻'s

- Apply it to inner e⁻'s

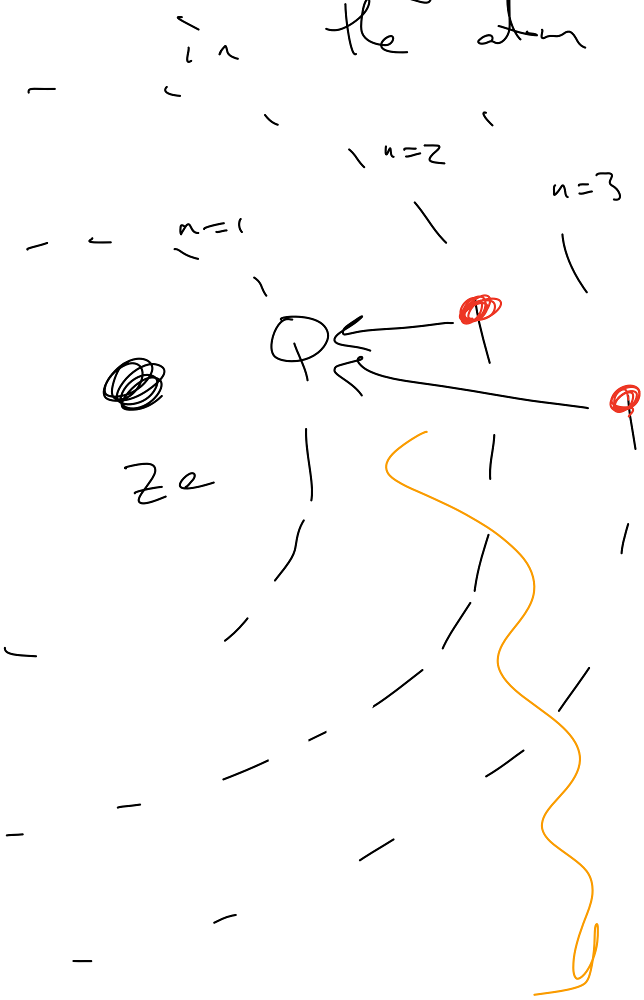


- Inner e⁻'s only "see" central charge

Maybe Bohr OK.

How could you this?

- Shoot high energy e at an atom (keV)
- Occasionally will eject an n=1 electron in the atom



- An electron in higher orbital will fall in & emit light
- Bohr Says:

$$E_n = -E_0 Z^2 \frac{1}{n^2}$$

n = 2

$$\gamma \rightarrow E_\gamma = E_0 Z^2 \left(1 - \frac{1}{2^2}\right)$$

n = 3

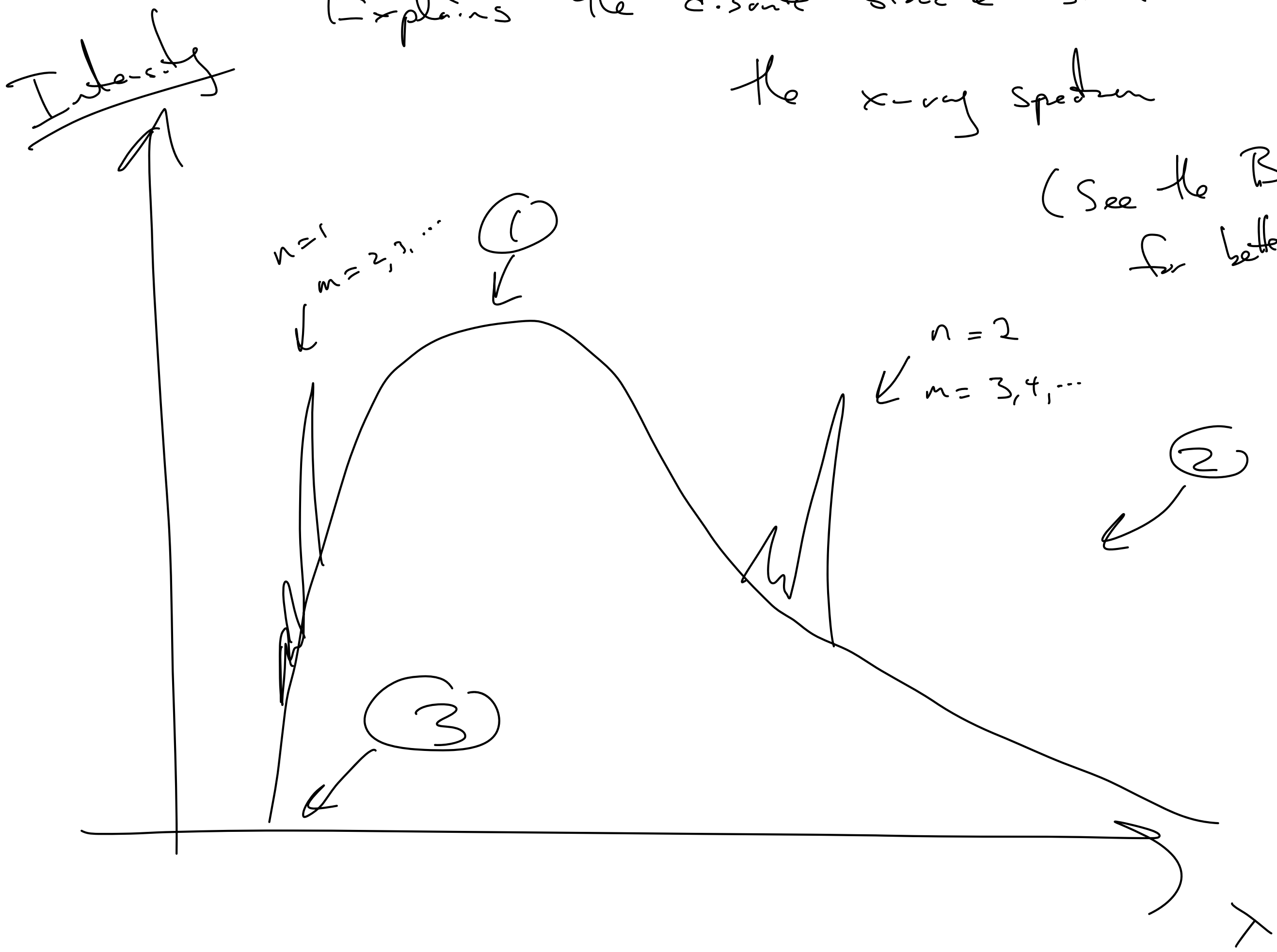
$$= E_0 Z^2 \left(1 - \frac{1}{3^2}\right)$$

Pick an element + Put in some #'s.

Turns out $E_\gamma = \frac{hc}{\lambda}$ $\Rightarrow$ γ's are X-rays!

Explains the discrete structure seen in the x-ray spectrum

(See the Book for better plots)

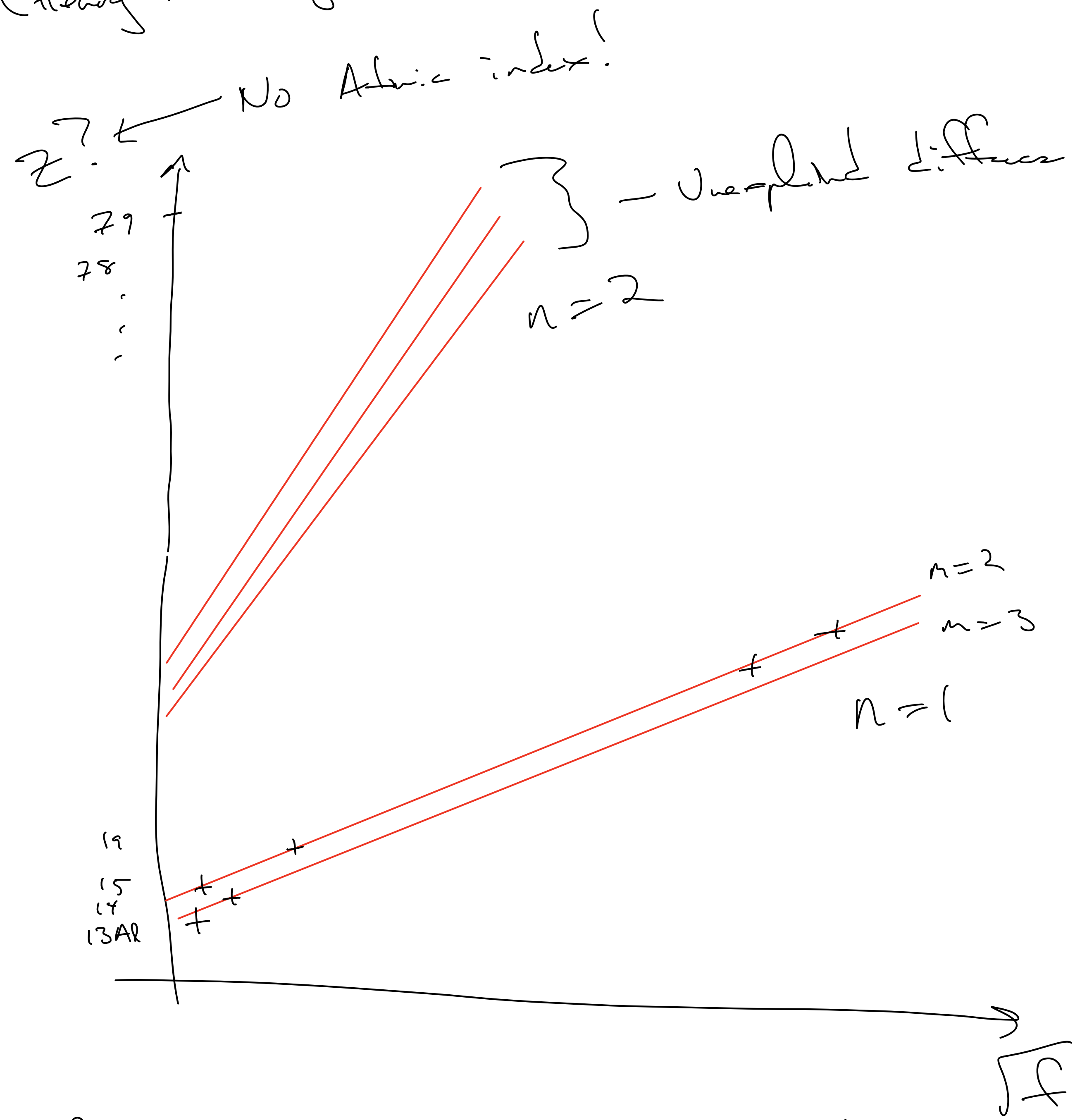


Can now get quantitative

$$E_\gamma \sim Z^2 \Rightarrow \sqrt{f} \sim Z$$

One of the most underrated Plots in Physics

(Henry Moseley)



Moseley plotted the $\sqrt{f}$ vs order in list sorted by atomic weight

found Straight line!

$\Rightarrow$ $Z \sim A$!!

- Bohr's Model could be used to measure Z from X-ray's
  - → Surprise that just goes up +1 for all elements
  - # in ordered list gives the electrical charge of nucleus

Could now know: nuclear charge
# of e's
by looking at a sorted list!

Found "gaps" where elements were missing.
Subsequently found w/ predicted X-ray spectrum!

<u>Even more important</u>

Could now understand that the particular set of elements found on earth is not some random sampling of an infinitely diverse menu of elements, but comprises <u>all</u> the elements that could possibly <u>exist</u>.!

Use Bohr's Model

$$f^{1/2} = A_m (Z - b) \qquad E_n = -E_0 \frac{Z^2}{n^2}$$

$$f = \frac{E_0}{h} Z_{eff}^2 \left(1 - \frac{1}{m^2}\right) \qquad \underline{m \to 1}$$

$$= f_0 (Z - N_{screen})^2 \left(1 - \frac{1}{n^2}\right)$$

$$\Rightarrow \quad f^{1/2} = \sqrt{f_0\left(1 - \frac{1}{n^2}\right)} \, (Z - N_{screen})^2$$

for $n = 1$ fit found $N_{screen} = 1$

$\Rightarrow$ another electron in $n = 1$ state!

for $n = 2$ fit found $N_{screen} = 7.4$

multiple inner e's

Mosley cleared up periodic table.

- Before place determined by mass.

$\Rightarrow$ Some "flips" $\quad Ar = 39.9 \quad Z = 18$

$K = 39.0 \quad Z = 19$

- Ordering by Z removed all these anomalies (Ar is noble gas K not!)