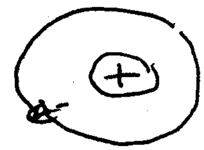
LECTURE #10, Fri., 10/21

10/21 Go back to 1913

What was known about structure of atom?

1911 Rutherford

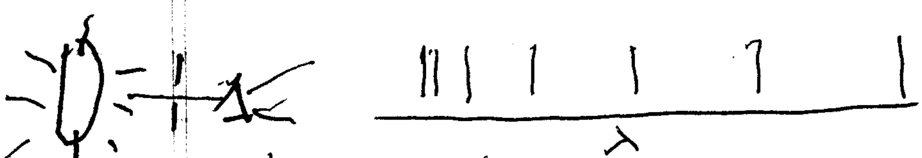


orbiting electron

1901 Planck, 1905 Einstein

$$E_{photon} = h\nu = hc/\lambda$$

1885 Balmer, spectrum of H



$$1/\lambda = C\left(\frac{1}{4} - \frac{1}{n^2}\right) \qquad n = 3, 4, 5 \ldots$$

1890 Rydberg similar series

1913 Niels Bohr 28 years old

Had worked with Rutherford --

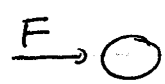
Let's look at his paper.

<u>Problem</u> Atoms stable, but classical electrodynamics says accelerated e^- in ~~[illegible]~~ should emit energy and spiral into nucleus

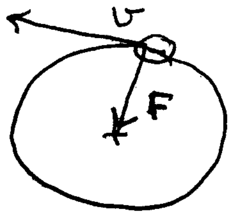
Why if Rutherford model is correct, is e^- being accelerated?

First consider linear motion

$$KE = \tfrac{1}{2}mv^2 \qquad F = ma \qquad p = mv$$



constant linear motion -- no acceleration constant acceleration



① $\boxed{F = \frac{m_e v^2}{r}}$ $\qquad a = \frac{v^2}{r}$

② $\boxed{p = m_e v r}$

Now follow Bohr's arguments for H.

Total energy of e^- = $\underset{\text{motion}}{\text{Kinetic}}$ + $\underset{\text{fields}}{\text{Potential}}$

Potential energy is Coulombic

$$PE \propto \frac{Q_1 Q_2}{r} = \underset{\substack{\uparrow \\ \text{attraction, opposite charges}}}{-}\frac{Ze^2}{r}$$

I will forget constants in derivation

Kinetic energy $= \frac{1}{2} m_e v^2$

So total energy

③ $$\boxed{E = \frac{1}{2} m_e v^2 - \frac{Ze^2}{r}}$$

If orbit is stable, Coulombic force must equal force due to circular motion

$\frac{\Delta E}{\Delta r}$ $\quad F_{coul} = \frac{dE_{cou}}{dr} = \boxed{\frac{Ze^2}{r^2} = \frac{m_e v^2}{r}}$ ④

Key Assumption electron angular momentum is quatized

$\boxed{m_e v r = n\hbar}$ ⑤

From ⑤ and ④

$$r = \frac{n\hbar}{\cancel{m_e} v} = \frac{Ze^2}{\cancel{m_e} v^2}$$

$$v = \frac{Ze^2}{n\hbar} \quad \text{Put back in ⑤}$$

$$r = \frac{n\hbar}{m_e v} = \frac{(n\hbar)^2}{m_e Z e^2}$$

$$\boxed{\begin{array}{c} r \propto n^2 \\ E \propto \frac{1}{n^2} \end{array}}$$

only certain values of r & n

3

Now put r and v back into 3

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

Measure E from $n = \infty$, unbound e^-

$$E_1 = -\frac{RZ^2}{1}$$

$$E_2 = -\frac{RZ^2}{4}$$

$$E_3 = -\frac{RZ^2}{9}$$

etc

$$E_\infty = 0, \quad r = \infty$$

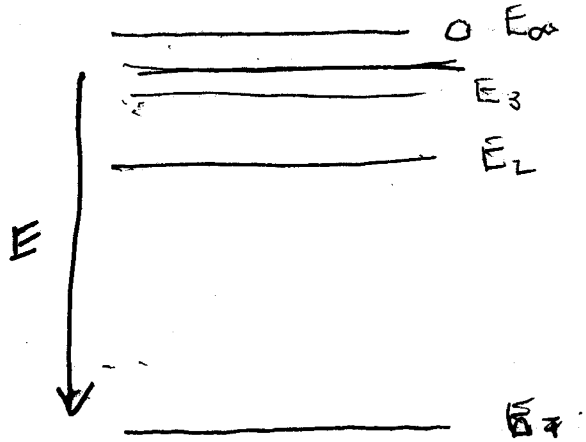


Fig 15.19.

$$\Delta E = -RZ^2\left(\frac{1}{n_i^2} - \frac{1}{n_j^2}\right) =$$

$$= \cancel{/RZ^2)(\,)}$$

Consider transitions from higher levels to $n=2$

$$\Delta E = RZ^2\left(\frac{1}{4} - \frac{1}{n^2}\right) \qquad n = 3, 4, 5$$

Balmer series

Should be a series

$$\Delta E = RZ^2\left(\frac{1}{1} - \frac{1}{n^2}\right) \qquad n = 2, 3 \cdots$$

predicted and found by Lyman

Whats wrong with theory?

Ad hoc assumption, can't generalize to multi-electron atoms – doesn't account for many features of expts.

Need quantum theory