Bohr model & atomic transitions

Late 1800s / Early 1900s, we started taking spectra of hydrogen (& other gases).
Found that if you burn H & ~~[illegible]~~ observed through spectrograph,
you didn't just see a continuum of light, you instead saw only very specific lines.
why??

* Show picture of H in emission through spectrograph.

Aside: spectrographs. Basically fancy prisms. Use the fact that ~~[illegible]~~ $n = n(\lambda)$
to split light into component wavelengths.

~~[illegible]~~ At turn of century (~1900) Rutherford discovered e^- ~~cloud~~ around atomic nuclei.
(gold foil experiment).

This motivates Bohr model of atom. Let's pretend e^- in orbit around
the nucleus (exactly analogous to star-planet).

Bohr's hypothesis: the angular momentum of the e^- can only
take on very specific values.

In day to day life - can take on any infinity of values (walk faster, slower)

Specifically, Bohr says L comes in "packets" of $\hbar$. It can have values of
$\hbar$, $2\hbar$, $3\hbar$ ... but not $1.5\hbar$, $7.24\hbar$ ...

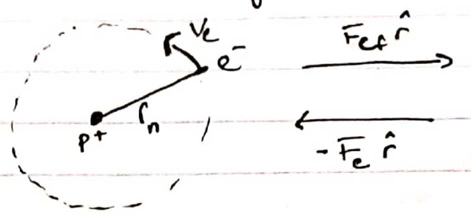
Fancy lingo: "quantized"

Since L is quantized, it implies E is quantized. ~~[illegible]~~ Energy of e^-
can only take on very specific values too (we will derive these).

~~[illegible] E is quantized,~~

E quantized explains observations if, as e^- jumps (somehow!) to a lower
energy level - that energy has to go somewhere - it
goes into a photon! Therefore, only photons
of very specific energies (ΔE b/w levels e^- jumped) are produced.

Now we derive those energy levels E_n, using just the angular momentum quantization.



The energy levels are $E_n = -\frac{e^2}{2r_n}$ Ⓐ (total energy of e^-; factor of 2 from V.T)

CGS Rant: I will drop $\frac{1}{4\pi\varepsilon_0} \to 1$ in CGS. E & B have same units ("equal footing" as it should be.)

What is r_n? Need to use another eqn to go any further.

Use force balance:

$$\frac{e^2}{r_n^2} = \frac{m_e v_e^2}{r_n} \quad \text{Ⓑ}$$ by force balance.

Need expression for v_e too. Use ang. mom:

$$L = n\hbar = m_e v_e r_n \longrightarrow v_e = \frac{n\hbar}{m_e r_n} \quad \text{Ⓒ}$$

Ⓒ into Ⓑ & solve for r_n:

$$\text{Ⓓ} \quad \boxed{r_n = \frac{n^2\hbar^2}{m_e e^2} = 0.5\,\text{Å}/n^2}$$

"Bohr radius"

$n=1$ "ground state"

$a_0 \equiv 0.52\,\text{Å}$

Comment: a_0 is a good OOM scale to consider/think about when [illegible] working with atoms/molecules. "Characteristic lengthscale"

Now E_n is easy:

$$E_n = -\frac{e^2}{2r_n} = \boxed{-\frac{e^4 m_e}{2n^2\hbar^2}} = \boxed{\frac{-13.6\,\text{eV}}{n^2}}$$

Burn into your brain

(plug in Ⓓ)

[illegible]

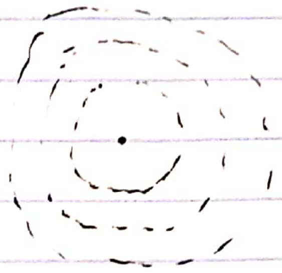
We have E_n but we observe $\Delta E \longleftrightarrow \lambda$.

$$E_f - E_i = -13.6\,\text{eV}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

[illegible]

~~[illegible] ΔE can go up or down in E. if gain.~~

Comments:



① e^- can go up or down in energy levels.

a.) if it goes down it spits out a photon (it lost energy) ↳ emission

b.) if it goes up ... how does it go up?

→ has to eat a photon. → absorption

→ Must be photon of exactly the right energy difference ΔE.

$\Delta E = \frac{hc}{\lambda}$ to calculate wavelength of emitted / absorbed photon.

② It goes up when hit by a photon ... but why does it go down?
Has anything hit it?

One way to think about it: in nature, things prefer to be in lowest possible energy state.

For the aficionados only: jump energy levels when you have a time dependent perturbation to the Hamiltonian (like an EM wave!)
there is a "vacuum field" that produces EM waves briefly
(subject of QED)

③ $E_n \propto \frac{1}{n^2}$. So, as $n\uparrow$, $|\Delta E|\downarrow$. We say energy levels are "closely spaced".

So, λ corresponding to high n transitions is large.

④ A few special transitions:

a.) Arbitrary n → 2. ("Balmer series)

$\lambda = 6562 Å$ Super important → n=3 → n=2 "Balmer-α" or Hα (more often)

n=4 → n=2 Hβ (because so common)

b.) Arbitrary n → n=3 Paschen etc.

c.) → n=1 Lyman

⑤ Ionization: Corresponds to $n_{fin} \to \infty$.

Any E @ $E > \Delta E_{ionize}$ allowed. Extra energy to e^- KE.

⑥ I derived Z=1. Case. For HW need to use arbitrary Z. "Bohr-like"