IV. Light + Matter: Atomic Spectroscopy

DEMO

> Excited (i.e. energized) gas-phase atoms emit characteristic, discrete wavelengths of light.

"characteristic": different for each element

"discrete": unlike atoms in the solid phase (eg light bulb)

"wavelengths": an observed color is actually a mixture of different λ's

Try to explain with Bohr Model

(works for anything with 1 e^- : H, He^+, Li^{2+}, ...)

(1) The e^- travels around the nucleus in a circular orbit of radius

$$r = a_0 \left(\frac{n^2}{Z} \right)$$

$a_0 = 0.5292$ Å (Bohr radius)

(1 Å $\equiv 10^{-10}$ m)

Z : atomic number

n : the quantum number; a positive integer

i.e. the e^- is restricted to only certain distances from the nucleus

$\uparrow Z \Rightarrow \ldots$

(2) Energy of the e^-:

$$E = -\mathcal{R}\left(\frac{Z^2}{n^2}\right) \qquad \mathcal{R} = 2.179 \times 10^{-18}\,J\ \text{particle}^{-1}$$

(Rydberg constant)

↑ e^- attracted to nucleus

Since n is an integer, only certain energies are allowed.

(3) The e^- can change its energy
(i.e. change its quantum number from n_i to n_f)
by emitting or absorbing a photon:

$$\Delta E_{atom} = -\mathcal{R} Z^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = E_{photon}$$

i.e. E_{photon} matches energy gap between
2 "levels" or "states"
(compare to photoelectric effect)

* Explains discrete λ's *

Emission: $\Delta E_{atom} < 0 \Rightarrow E_{photon} = -h\nu$
(atom is losing energy)

Absorption: $\Delta E_{atom} > 0 \Rightarrow E_{photon} = +h\nu$
(atom is gaining energy)

Verdict on Bohr

(+) Accurately predicts all λ's of light absorbed/ emitted by 1-e^- species

(−) Fails if atom/ion has more than 1 e^-

(what is Bohr model missing?)

(−) Can't explain why n is an integer

(−) Can't explain why n can't equal zero

(i.e. why e^- can't collapse into nucleus)

(−) Picture of the e^- (an orbiting particle) fundamentally flawed

So, how lucky is Neils Bohr?