Physics 102 - October 7, 2009

- PDF Slides / Mp3 Audio lecture
- Exam 1 → 1 week from now same place

Exam 1
Oct 14 2 pM
HoyT Auditorium

  - Calculator powers of 10
  - 3x5 index card w/ notes / formulas
  - Formula sheet with exam
  - Previous P100 exams Similar
  - Loi wei's office hour Mon Oct 12, 6-7 pM Loc TBA
  - SM Q + A session ~4-5:30 Tues Oct 13 Loc TBA

- No Recitations Next week Tues - Fri - Mon
  Monday Oct 12 Recitation will happen

Exam 1 Material coverage

- Start of class through waves
- Recitations 1-4
- Prob sets 1 – 4 [problems 1-8]
- Lectures Thru Sept 28
  (NOT including black body radiation at end of 9/28/04 lecture)
- All reading thru Week of Sept. 28 except chapter 13 in Hobson

Last Time

[redacted]

Maxwell's equations
interference
diffraction
Refraction
dispersion
⋮

→ **light is a wave!**

Double Slit Applet

Planck

Blackbody Radiation

Einstein

Photoelectric effect

→ light comes in little packets with energy $E = h\nu$

→ **light is a particle!**

Louis Victor Pierre Raymond de Broglie

mid-1920's

de Broglie hypothesized matter can have wave characteristics with a wavelength given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

So-called de Broglie Wavelength

MATTER WAVES

Bohr model of the atom (1912)

1913

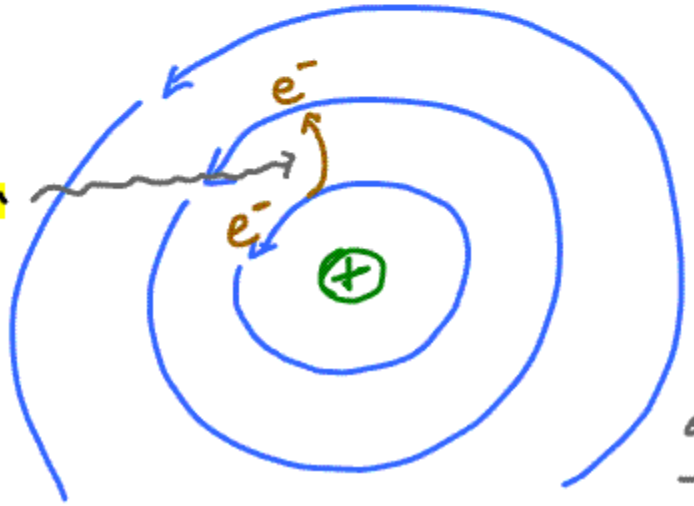
- Positive Nucleus
- electrons orbit in circles
- only particular "discrete" orbits

↑ known as quantization

- electric (Coulomb) force holds electron on circle as it orbits ... attracts electron toward Nucleus

- Nuclear ATOM
- Discrete STABLE circular orbits

Absorb γ (photon) – e⁻ makes transition from low Energy orbit to high energy orbit



possible orbits for electron

Transition from high energy orbit to low energy orbit → emission of photon

Discrete Atom Emission + Absorption lines come from e^- transitions between discrete Energy levels

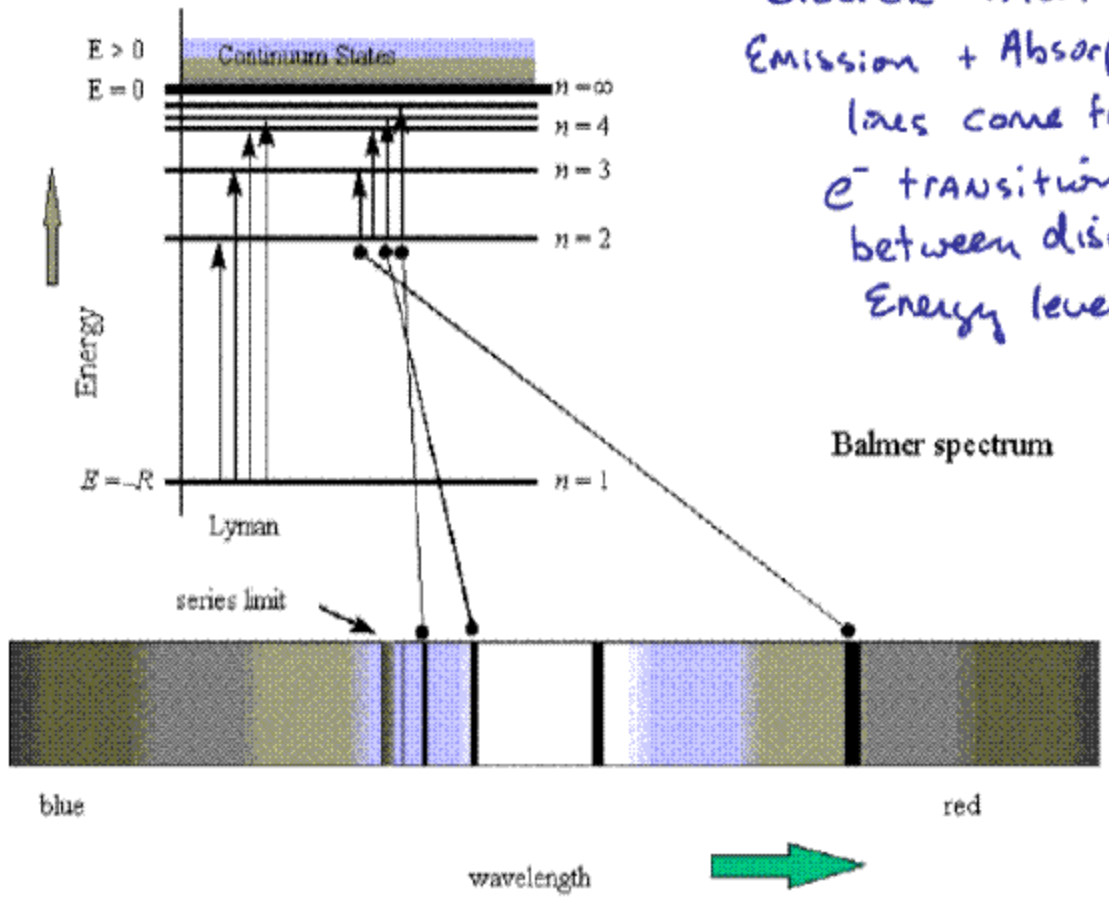
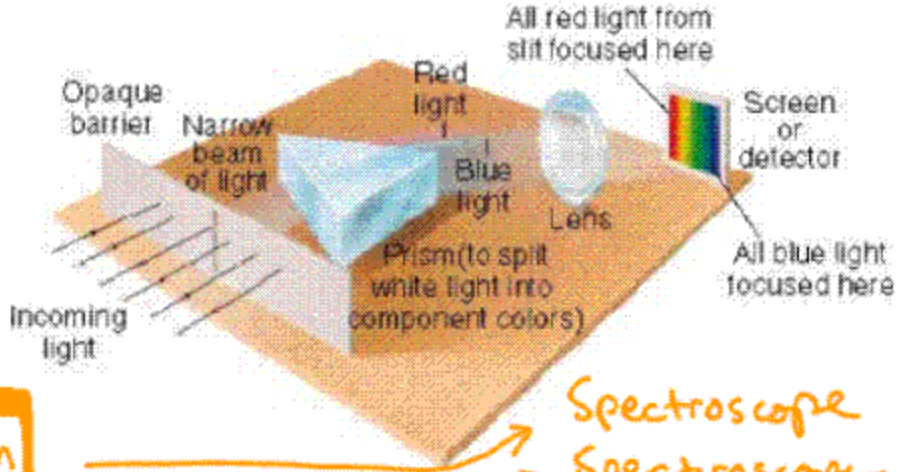


Figure from

http://www.uclan.ac.uk/facs/science/physastr/x99/PAM98/UCert/Ch06/6_6ato~1.htm

Can split light to study as a function of frequency (ν) [or Color]

Spectrum

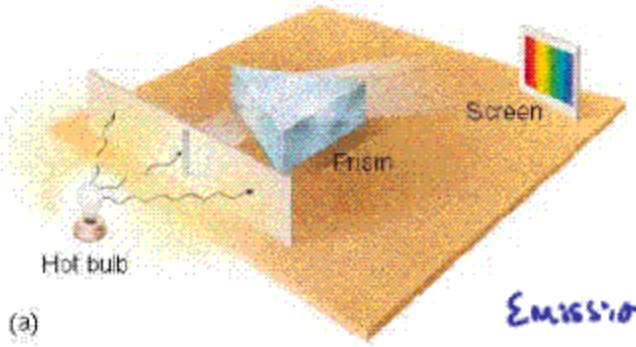


Spectroscope

Spectroscopy

Light from Many Atoms

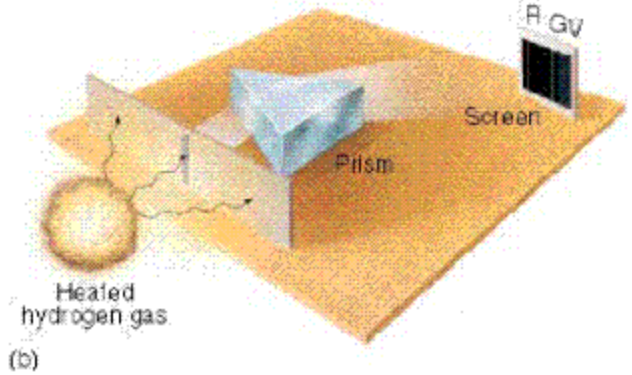
$\Rightarrow$ Continuous ν



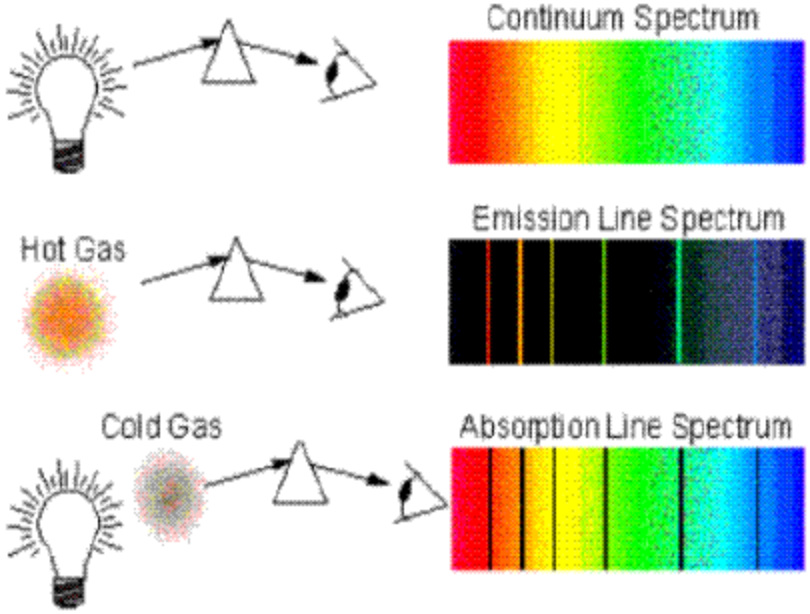
Emission Spectrum

Light from specific atoms

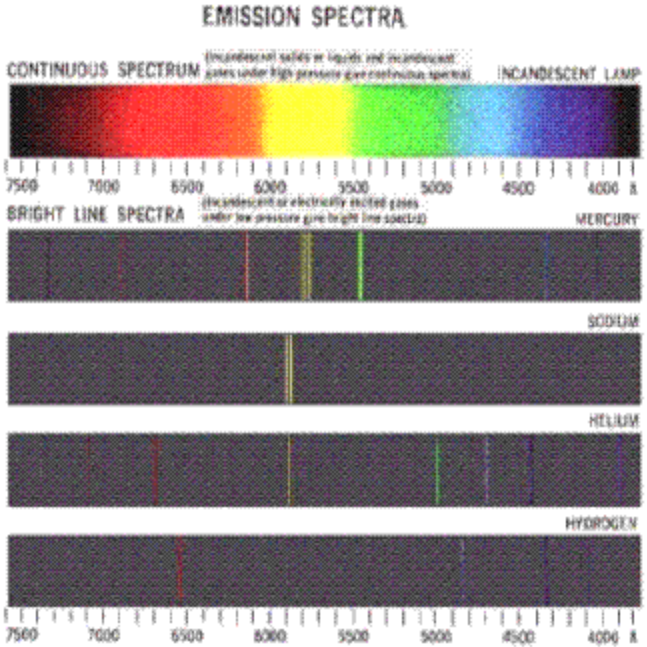
$\Rightarrow$ discrete ν



Emission vs. Absorption



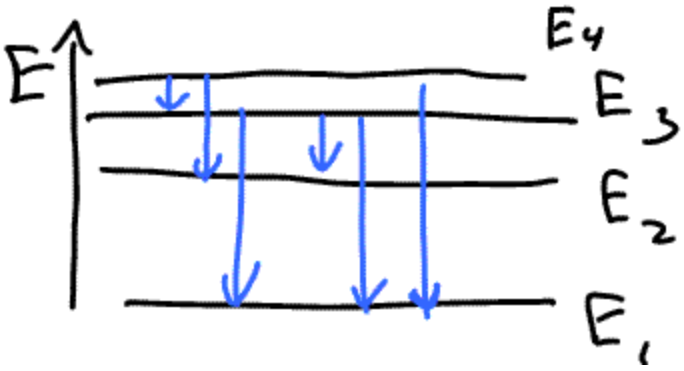
Different Atoms → different discrete frequency pattern

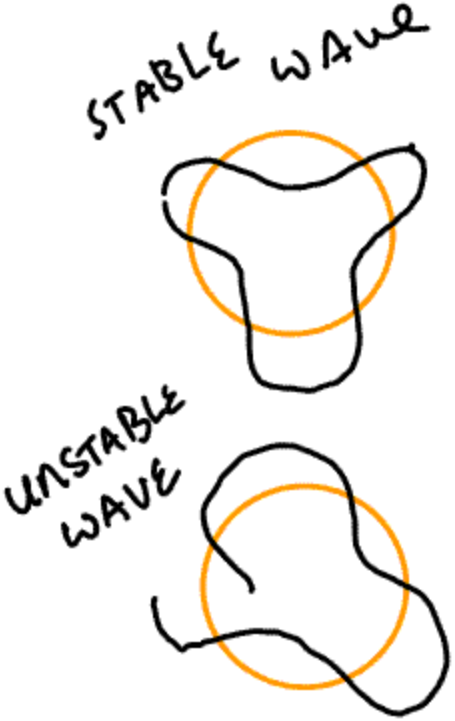


Atomic Fingerprinting

STANDING wave on STRING

Question: if I have 4 energy levels how many spectral lines do I have?
→ 6 (see below)





STANDING electron wave in Bohr Model

Werner Karl Heisenberg

(1901 - 1976)

Nobel Prize in physics - 1932

for "the creation of quantum Mechanics"

(Max Born, Pascual Jordan - co-workers)

Erwin Rudolf Josef Alexander Schrödinger

(1887 - 1961) Austria

1933 Nobel Prize in physics

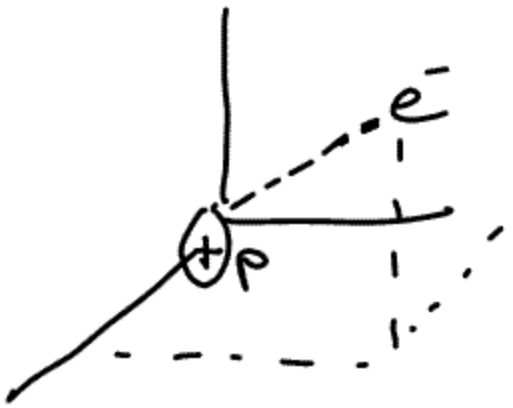
1926 - Paper on wave Mechanics of Matter

Annalen der Physik

"for discovery of new and productive forms of atomic theory"

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + V\psi(x) = E\psi(x)$$ Schrödinger's Equation

Just so you've seen it



Physicists put wave e^- in

Spherically symmetric physical situation

into Schrödinger's equation and solve

What comes out of this?

→ Particular Allowed spatial STATES (of existence)

→ Each associated with a particular energy

→ These are known as "Quantum States"

What is a quantum STATE ?

Spot density corresponds to probability of finding e^- at that point in space

one quantum STATE centered on nucleus

$n=1$

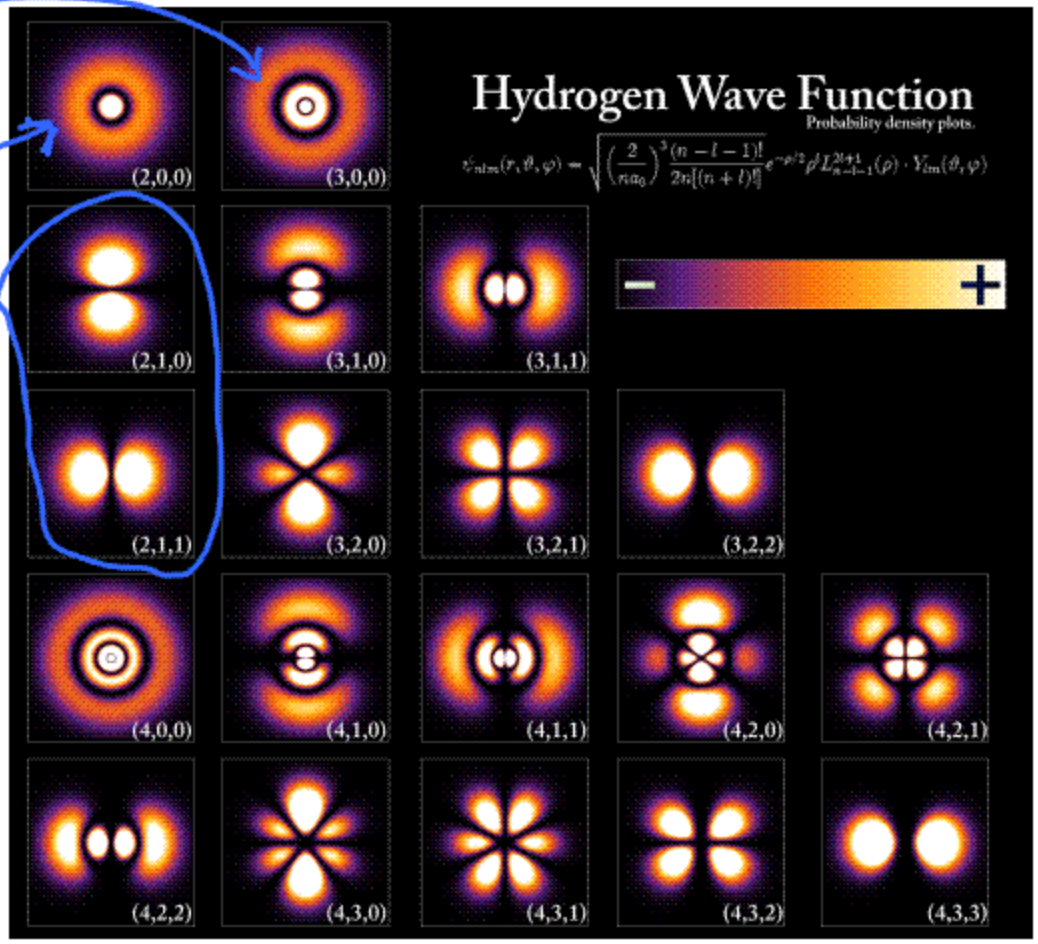
a different quantum STATE centered on nucleus 1 same

$n=2$

Better Pictures on next page

imagine ski resort with discrete condos that can be occupied.

Only discrete energies and spatial STATES allowed for the electron to occupy → orbital



Higher energy

low energy

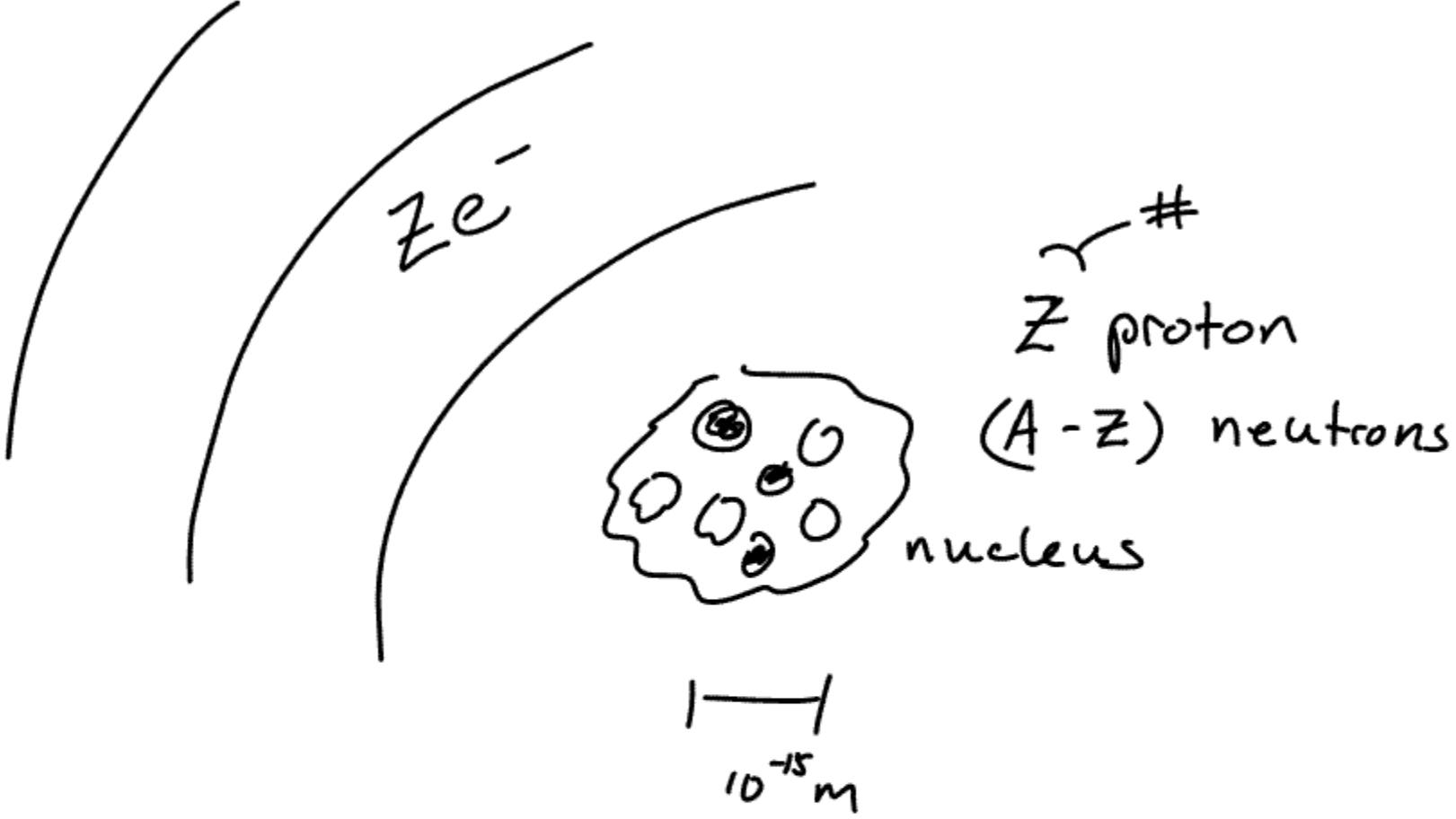
"degenerate" + slightly higher energy

figure from http://en.wikipedia.org/wiki/File:Hydrogen_Density_Plots.png

Analogy of condos in a ski village to allowed quantum STATES in an atom.

discrete places to reside.

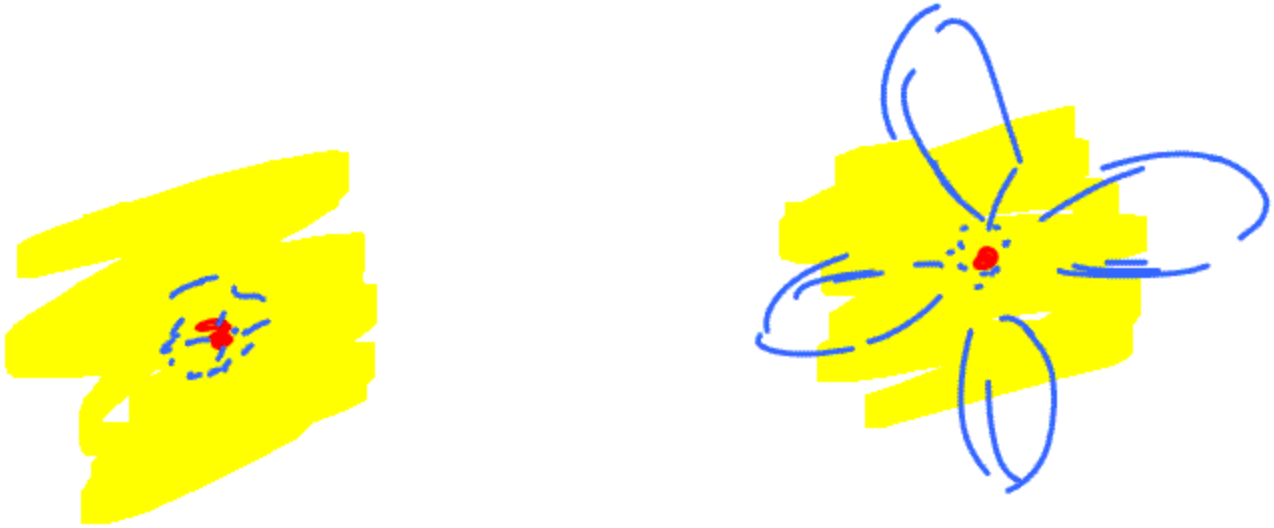
different energies to reach those places.



A ≡ Atomic Mass

Hydrogen has Z = 1
Helium has Z = 2
Lithium has Z = 3
⋮
up to slightly over 100

} Known as elements



as Z increases → # electrons increase

↑

protons in nucleus

How do these electrons populate the available orbitals?

To Answer this we need to investigate

Particle Promiscuity

Stern-Gerlach experiment — 1922

→ Discovery that electrons have Spin

Spin

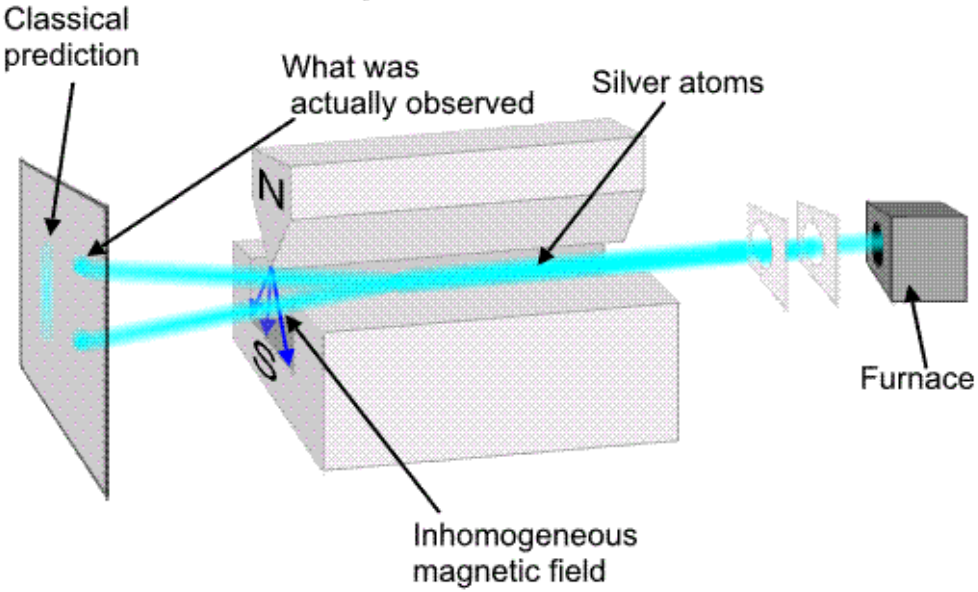


Diagram from Wikipedia

Otto Stern

-wikipedia

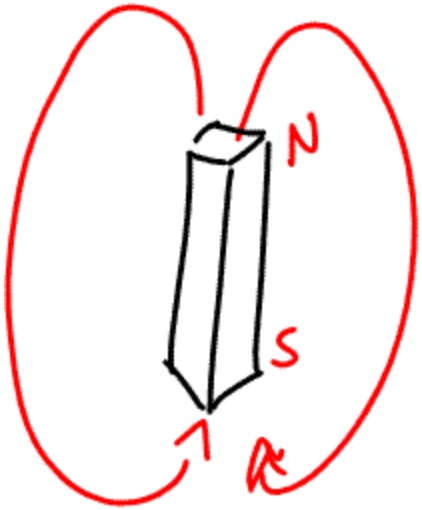
"If this nonsense from Bohr will prove to be right we will quit physics."
(Stern vowed in 1913)

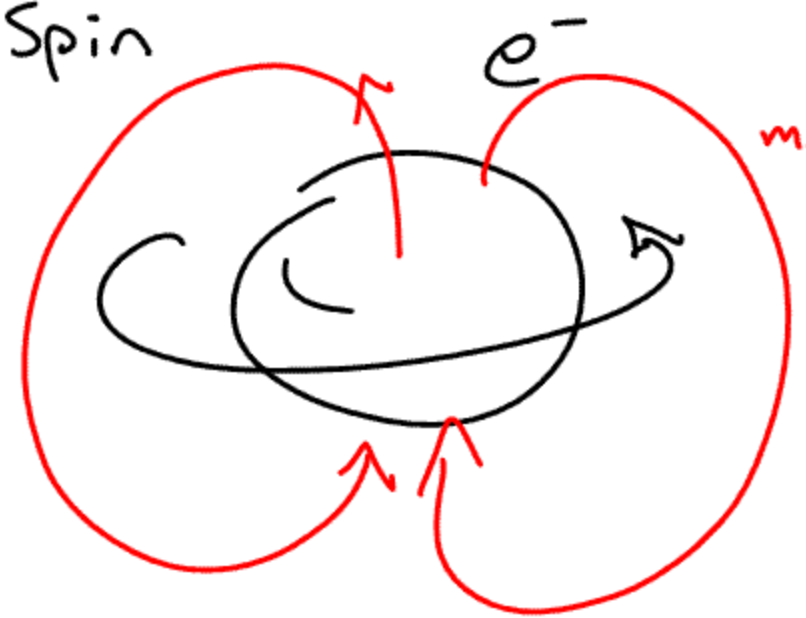
as quoted in Phys. Today Dec 03

Walther Gerlach

from phys Today article (Dec. 03)

Intrinsic Spin





magnetic field looks like a bar magnet

Spin is quantized → only discrete values allowed

$0, \frac{1}{2}, 1, \frac{3}{2}, 2 \ldots$

relative spin (or magnetic field strength)

Particles have little magnetic fields like bar magnets

Think of as spinning charge distribution

integer spin $0, 1, 2 \cdots$ **Bosons**

half integer $\frac{1}{2}, \frac{3}{2}, \frac{5}{2} \cdots$ **Fermions**

Particle Promiscuity

MANY per quantum STATE Allowed

only 1 per quantum STATE allowed

electrons are fermions

This governs how multiple electrons fill available quantum orbitals

How different # of electrons populate the orbitals

Sodium (Na) has 11 electrons

Chlorine (Cl) has 17 electrons

Chemical characteristics of an atom depends on the arrangements of the electrons in the orbitals

chemical reactions — rearrangements / swaps / shares of electrons in orbitals about interacting atoms