Physics 100 - February 28, 2007

- Exam 1 is graded

  Solutions and grade distribution are on the web

  Mean was 71 → Great job!

  Will return papers to you at end of class

- Project groups

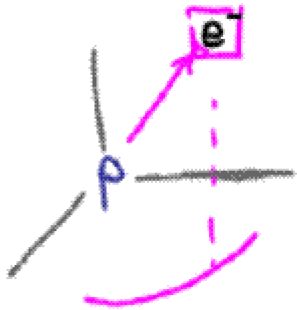
  You need to meet and think about what you want to do w/ your topic

  ... Then make a "group" Appt w/ Me.

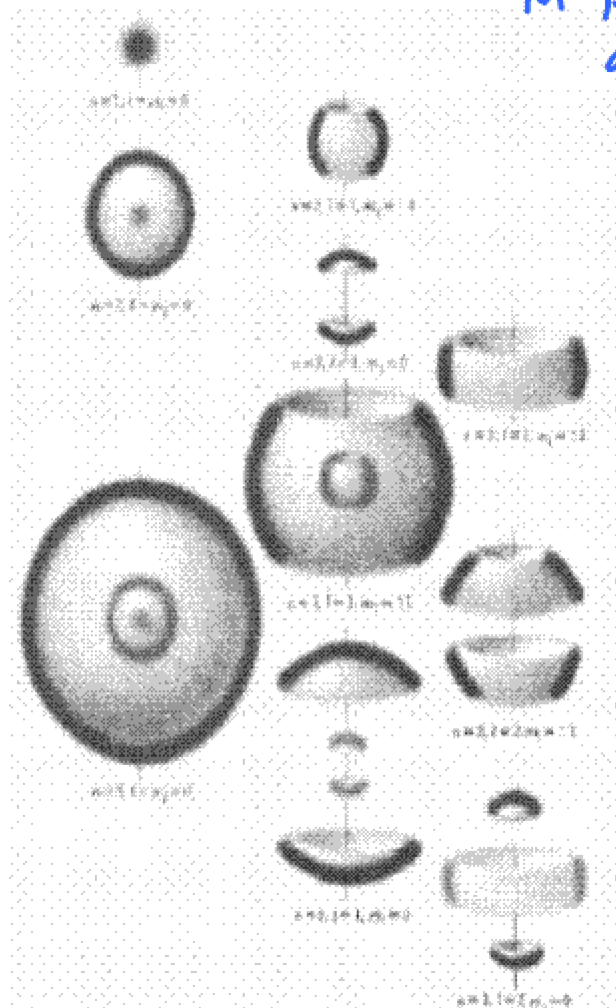
QM treatment of H atom

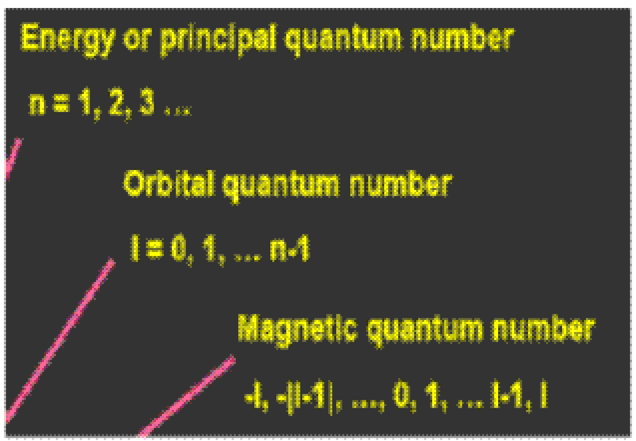
wave mechanics

Spherical Symmetry



Shapes of allowed electron states in Hydrogen atom



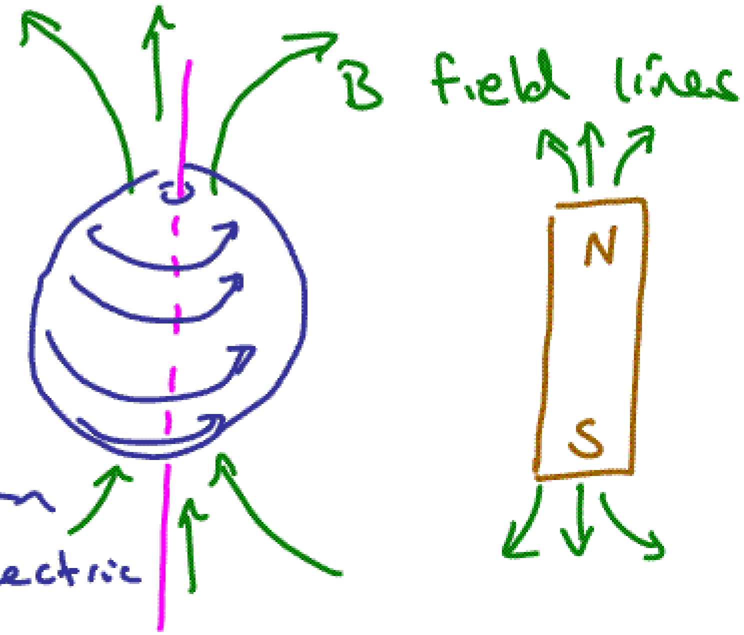


Similar to Bohr – discrete states

But orbits are not circular

* Look at Falstad's Applet on Lecturelinks page

Spin



Imagine that the electron is a uniform ball of electric charge that "spins"

It would be like a little current loop

current loops create magnetic fields that look like Magnetic fields coming from a bar magnet

Particles w/ spin have "magnetic moments" and look like tiny little bar magnets

This was discovered in 1922 by Stern + Gerlach

Spin is quantized

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

Integer Spin 0, 1, 2 .... ⇒ Boson

$\frac{1}{2}$-integer Spin $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$ .... ⇒ Fermion

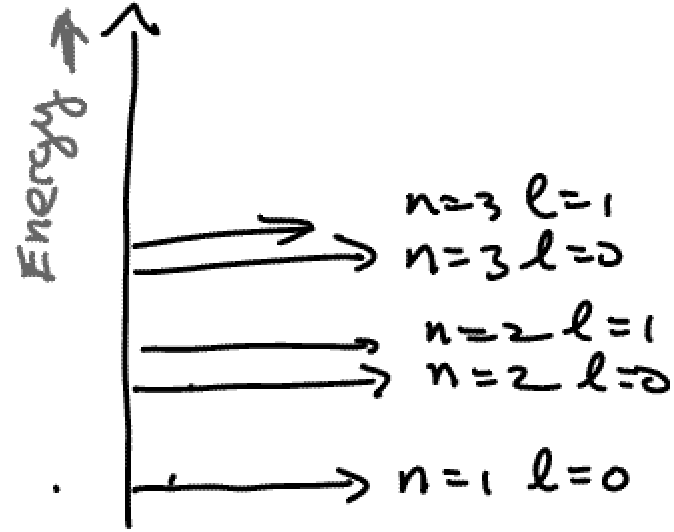
It's like you can only have bar magnets with certain discrete strengths

2 identical Fermions → cannot occupy the same quantum state

2 identical Bosons → can occupy the same quantum state

Schrödinger's eqn gives allowed energy states for e^- in atom

They vary in energy like so →



n = energy quantum number
l = orbital angular momentum quantum number

→ These characterize the state ... determine the orbital

Z ↓	ATOM ↓	n=1, l=0	n=2, l=0	n=2, l=1			n=3, l=0
1	H	↑	_	_	_	_	_
2	He	↑↓	_	_	_	_	_
3	Li	↑↓	↑	_	_	_	_
4	Be	↑↓	↑↓	_	_	_	_
5	B	↑↓	↑↓	↑	_	_	_
⋮							
11	Na	↑↓	↑↓	↑↓	↑↓	↑↓	↑

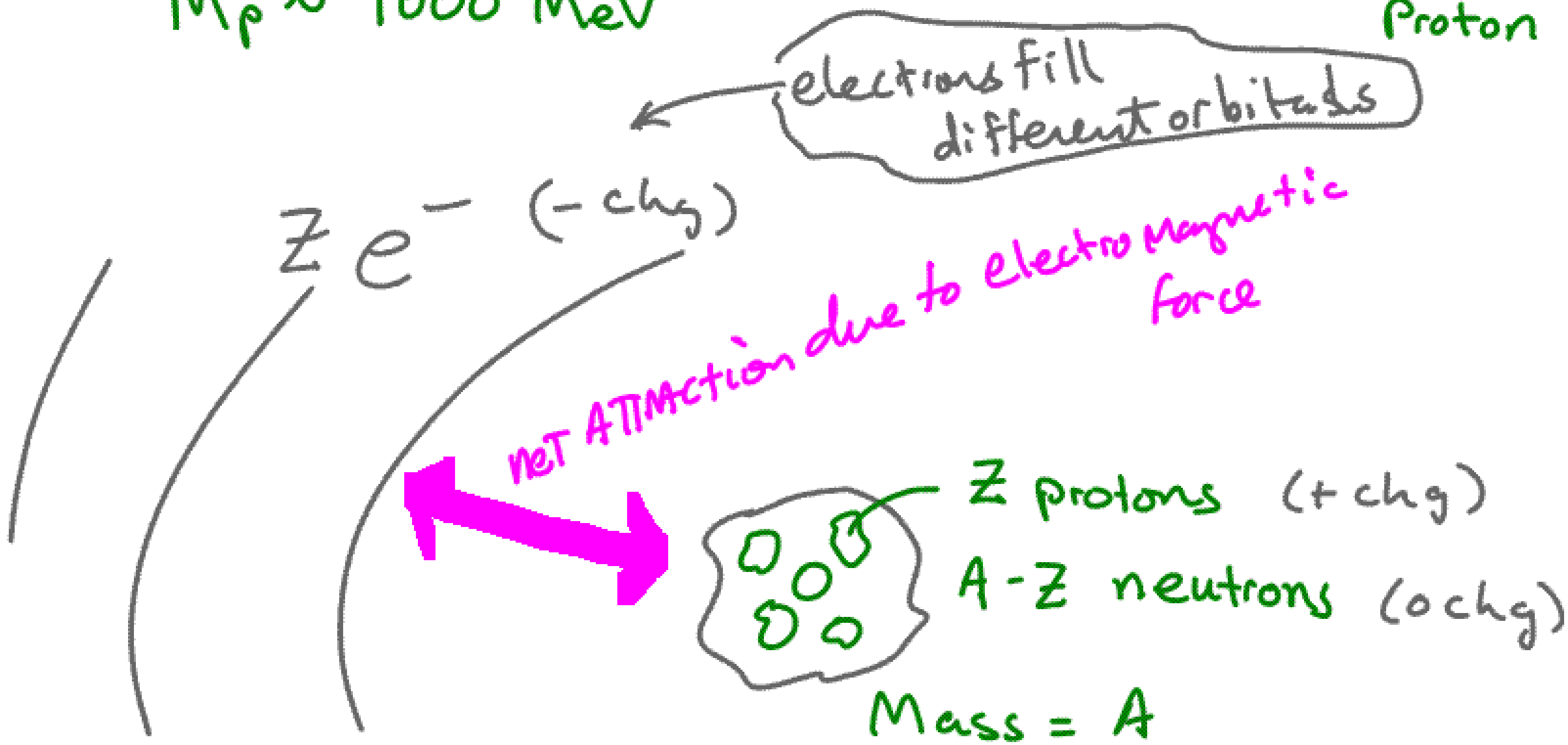
Electrons fill levels lowest energy to highest

They do NOT all crowd into lowest level because they are <u>Fermions</u>

$M_e = .5\ MeV/c^2$

$M_p \sim 1000\ MeV$

Mass of 1 A = Mass of Proton



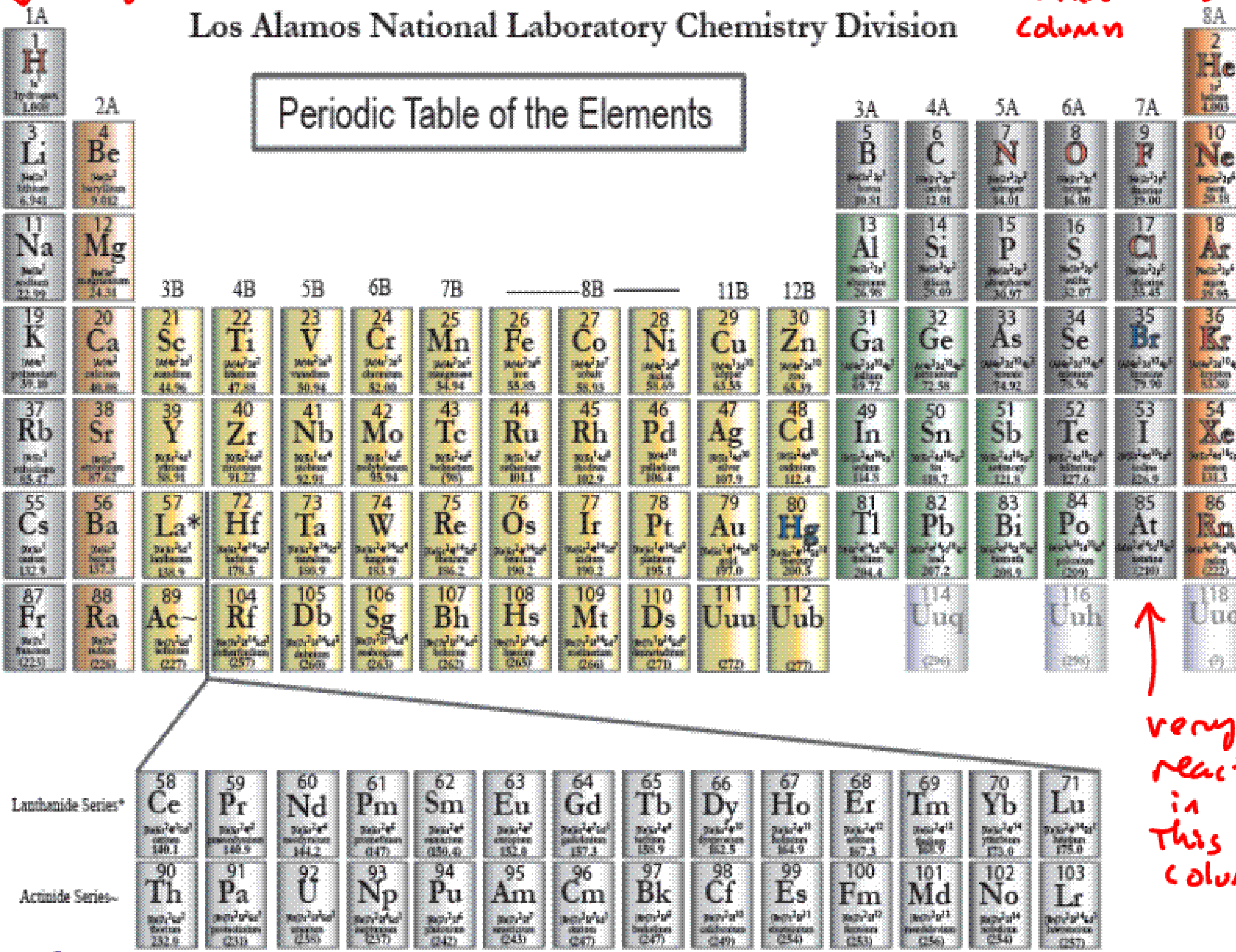
The Atom

The way in which the orbitals are filled means there is Periodicity in ATomic characteristics as Z increases very reactive in this column

very inert in this column

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

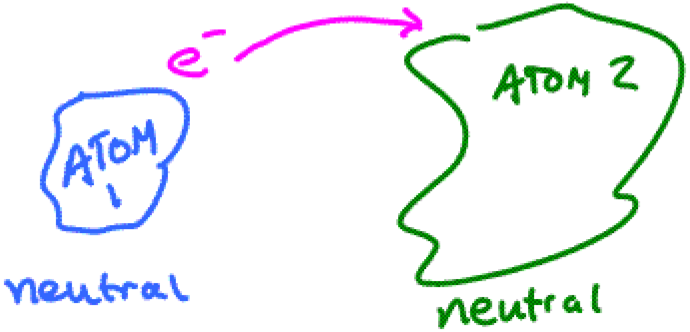


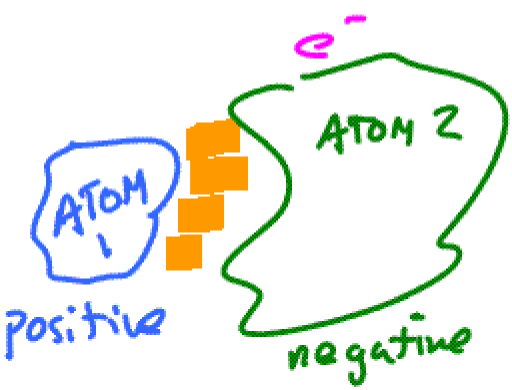
very reactive in this column

element names in blue are liquids at room temperature
element names in red are gases at room temperature
element names in black are solids at room temperature

Chemical Bonds

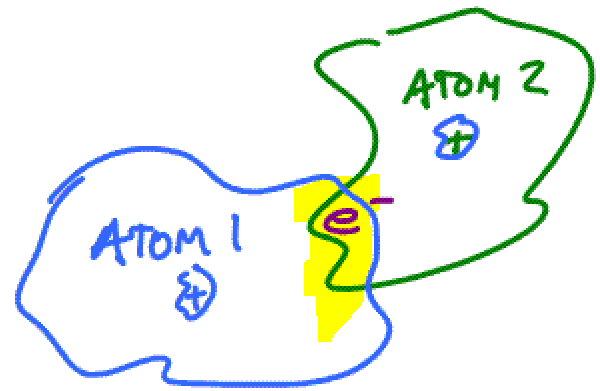
Due to way electrons are distributed in the available quantum levels —— Sometimes energetically favorable for one atom to give another an electron . . . or share electrons





chemical "bond" from electric ATTRACTION

→ ionic Bond



ATOMS share an electron

creates higher density of negative charge between the two positive nuclei

→ Covalent chemical Bond

Quantum Mechanics and Uncertainty

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

1927 **Copenhagen Interpretation**

Born
Heisenberg
Bohr

$\psi(x)$ is not real → Tool for calc.

$\psi^2(x)$ is well-defined → probability

description is probabilistic

complementarity → Expt can show particle characteristic -or- wave characteristics

BUT NOT BOTH

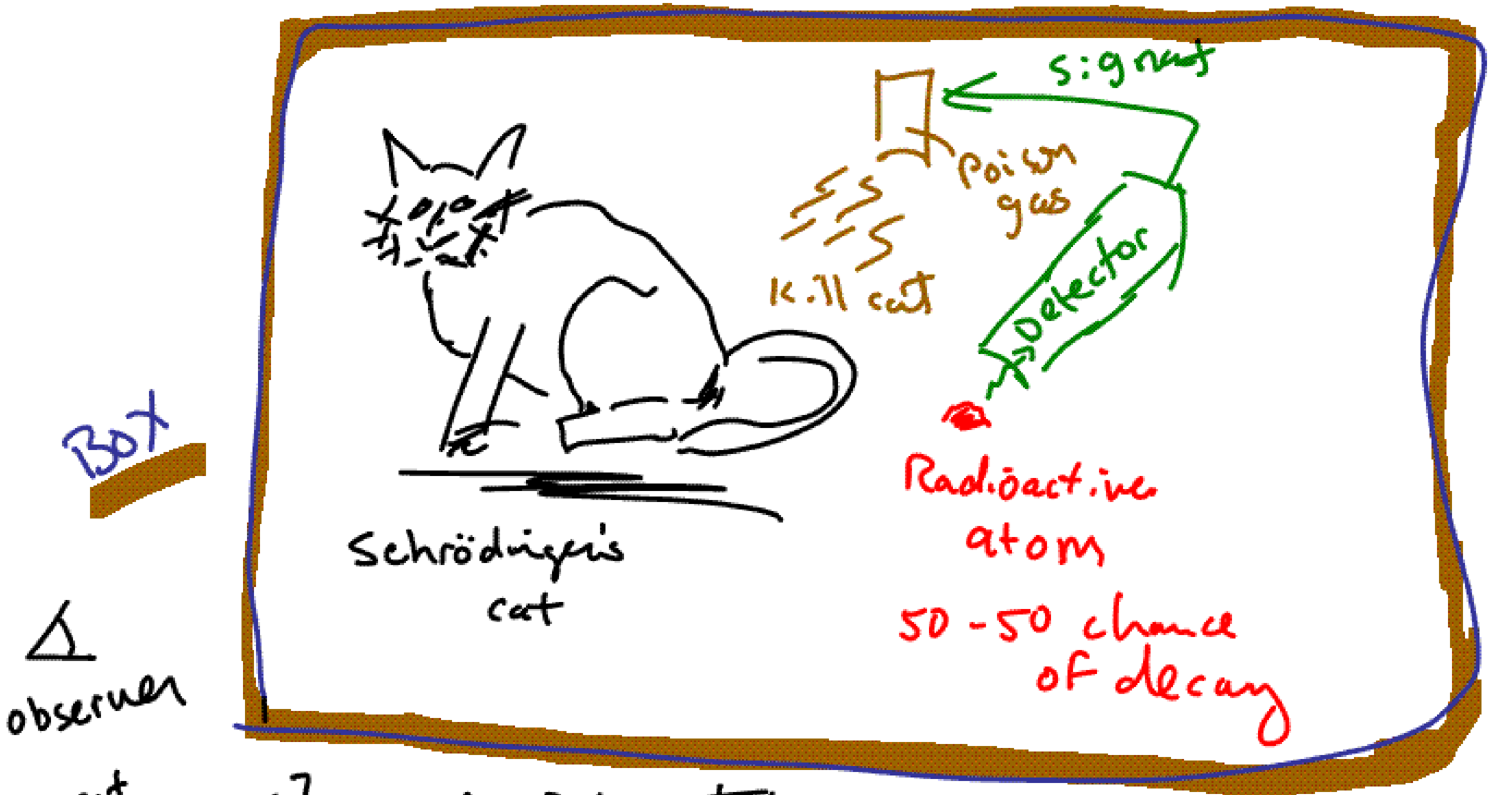
Max Born German (1882 - 1970)

1954 Nobel Prize in physics

"For his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction"

$\psi_{(x)}$ wave function

$\psi^2_{(x)}$ ~ probability of finding particle in region of space



Is cat Dead or Alive?

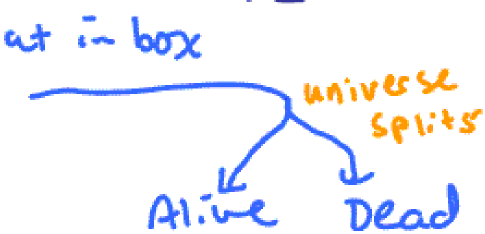
Cop. Interpretation says

$$\text{Cat} = \frac{1}{2}\left(|\text{Dead}\rangle + |\text{alive}\rangle \right)$$

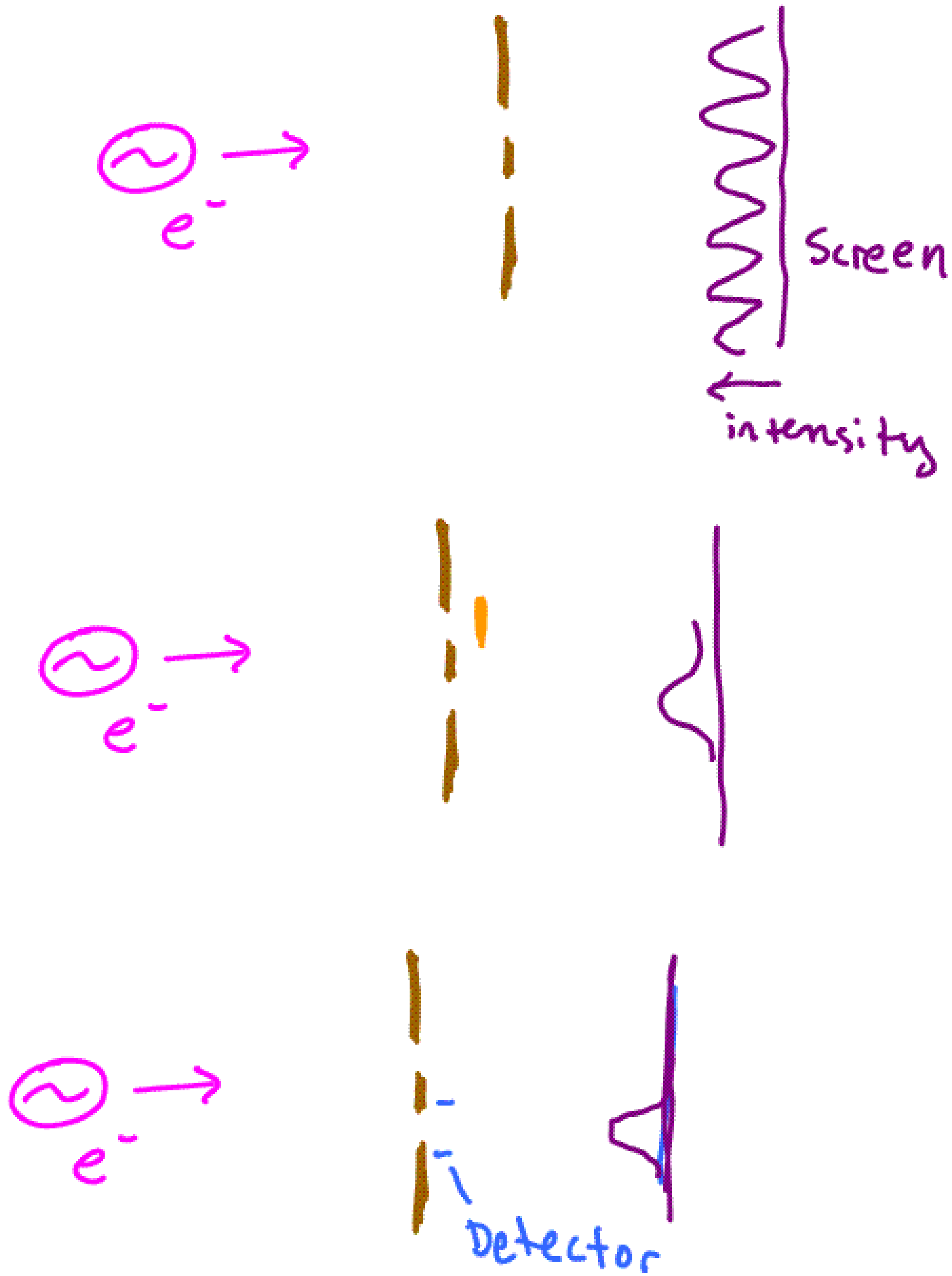
Many Worlds view of quantum Mechanics

Hugh Everett
1957

relative STATE formalism



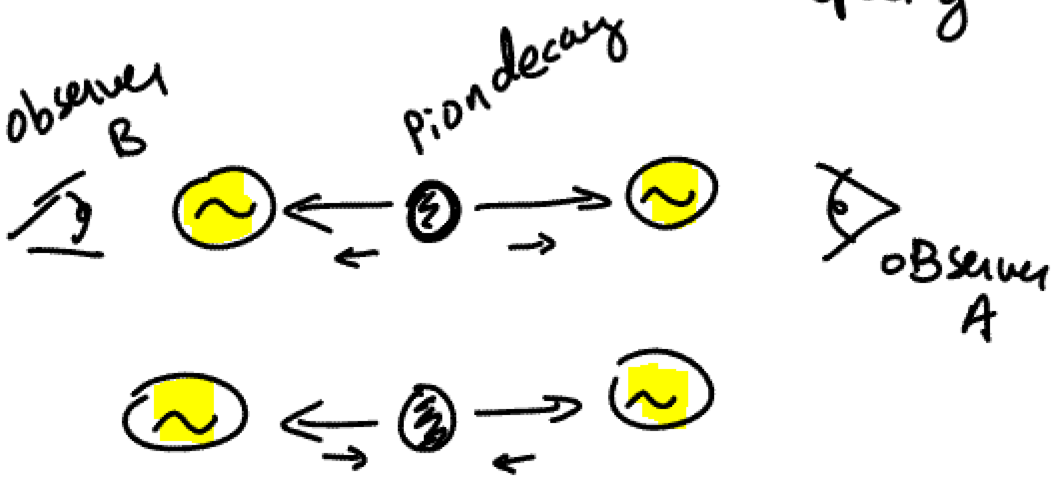
one where cat is dead
" " " " alive



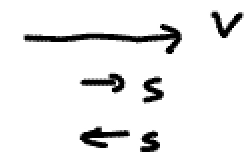
Observation of electron causes Collapse of Wavefunction and interference Pattern Disappears

EPR Paradox — Einstein, Podolsky, Rosen
1935

"spooky Action at a distance"



photon spin = 1



Two photons are produced at once — They are correlated.

If one has spin one way the other has spin the other way.

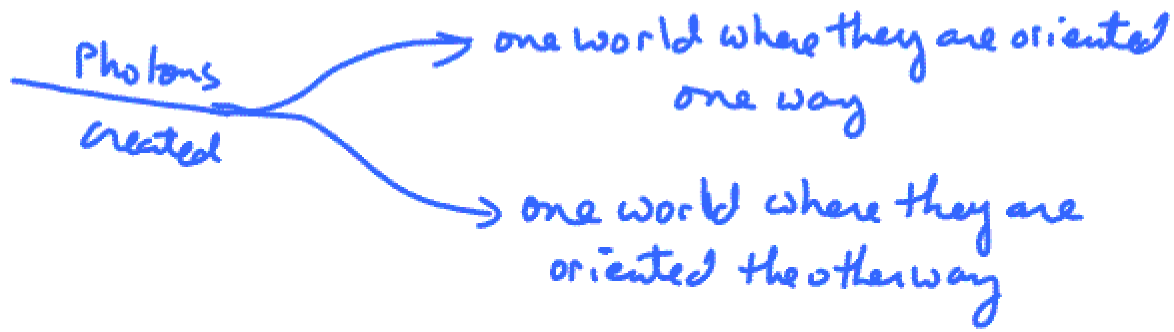
They are in an entangled quantum STATE

When observer A observes the spin of photon — The wavefunction collapses and the spin of the photon observer B will observe is determined.

But collapse instantaneous and observers A + B far apart
Does this mean information conveys faster than speed of light?

Copenhagen Interpretation → $\psi(x)$ Not real
Things sort of only become when observation made

Many Worlds



QUANTUM cryptography

Entangled photons

QUANTUM STATE

Len Mandel (1928 – 2001) university of Rochester Physicist

observed "entangled" photons

Heisenberg's Uncertainty principle

$$\Delta x \, \Delta p \leq \frac{h}{2\pi} \sim 10^{-34}$$

uncertainty in position

uncertainty in momentum (mv)

CANNOT know both the position and momentum with arbitrarily good precision

A different form of Heis. unc. princ.

$$\Delta E \, \Delta t \leq \frac{h}{2\pi}$$

unc. in energy

time over which it exists

CAN Break conservation of energy — so long as you do it over a short enough time.

Tremendous implications

It's a Harry Potter universe