Atomic Theory

Why do we believe that all matter is made of atoms?

1. Law of definite composition: Compounds (like H_2O) contain the *same* elements in the *same* proportions by mass regardless of the size of the sample or the source of the compound.

Atomic Theory Cont.

2. Law of conservation of mass: In a closed system mass is not created or destroyed (even when atoms change what they are combined with).
3. Law of multiple proportions: The mass ratio for different compounds made of the same elements can be expressed in small whole numbers. Example: CO and CO_2. Ratio of oxygen in CO to oxygen in CO_2 is 1:2.

Atomic Theory Cont.

John Dalton – in 1808 came up with a theory:

- Elements are made of tiny particles (atoms)
- All atoms of a given element are identical
- Atoms of a given element are different than those of another element

Atomic Theory Cont.

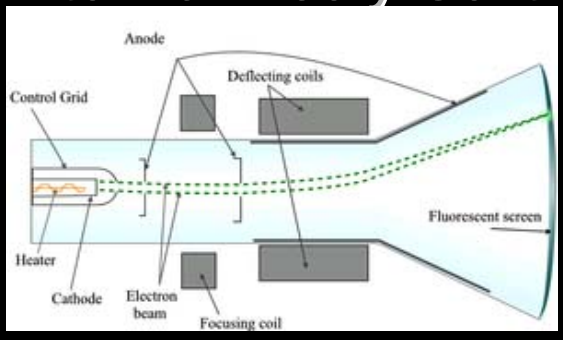
- Atoms combine to form compounds. A given compound always has the same relative numbers and types of atoms
- Atoms cannot be created or destroyed. Chemical reactions change how they are grouped.

Atomic Theory Cont.

J.J. Thomson – in the late 1890's showed that atoms can emit tiny negatively charged particles

- Used a cathode ray tube (CRT) to show that these tiny particles were deflected by a negatively charged electrical field.

Atomic Theory Cont.



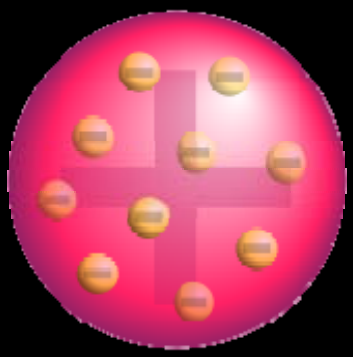
- Used a magnetic field to calculate the m/e (mass/electrical charge) ratio and found that it was over a thousand times smaller than that of a hydrogen ion…so either the electron is much smaller or has much greater charge…which do you think is the case? (image from http://www.wikipedia.org)

Atomic Theory Cont.

William Thomson, AKA: Lord Kelvin – Came up with the “plum pudding” model of the atom.

- Reasoned that the atom could be thought of as a “pudding” of positive charge with negatively charged “plums” scattered throughout

Atomic Theory Cont.



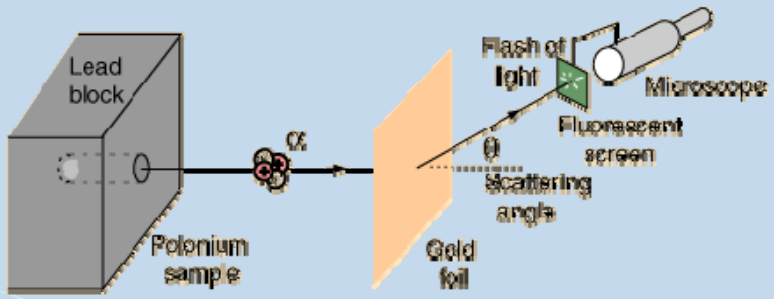
Plum pudding model. (http://www.wikipedia.org)

Atomic Theory Cont.

Ernest Rutherford – in 1910 proved the existence of the proton with his famous alpha gun and gold foil experiment.

- See page 56 in your book for a diagram
- An alpha particle is a Helium nucleus, or He^{+2}
- Alpha particles were shot at a thin gold foil. If the plum pudding model were true, the alpha particles would just crash straight through the foil

Atomic Theory Cont.



- Animation link: http://micro.magnet.fsu.edu/electromag/java/rutherford/

Atomic Theory Cont.

- The results of the experiment were quite different – most of the particles went straight through or only suffered a slight deflection. HOWEVER – some of the alpha particles were deflected at great angles, and some even bounced back in the direction they came from.
- Rutherford stated, “It was as incredible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you.”

Atomic Theory Cont.

- This led to the realization that atoms are mostly made up of space (between the nucleus and electrons) and that they have a positively charged nucleus (that would deflect a positively charged alpha particle)

Atomic Theory Cont.

Bohr Model (1913) – Niels Bohr (Denmark

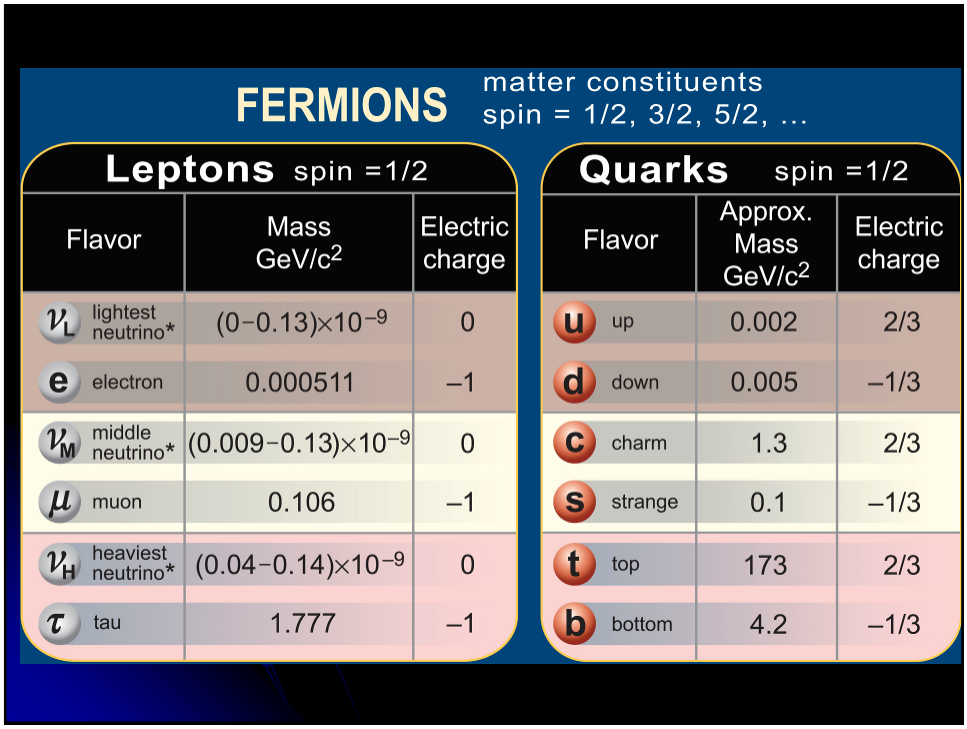
- Electrons occupy discrete energy levels
- Electrons cannot reside between these levels

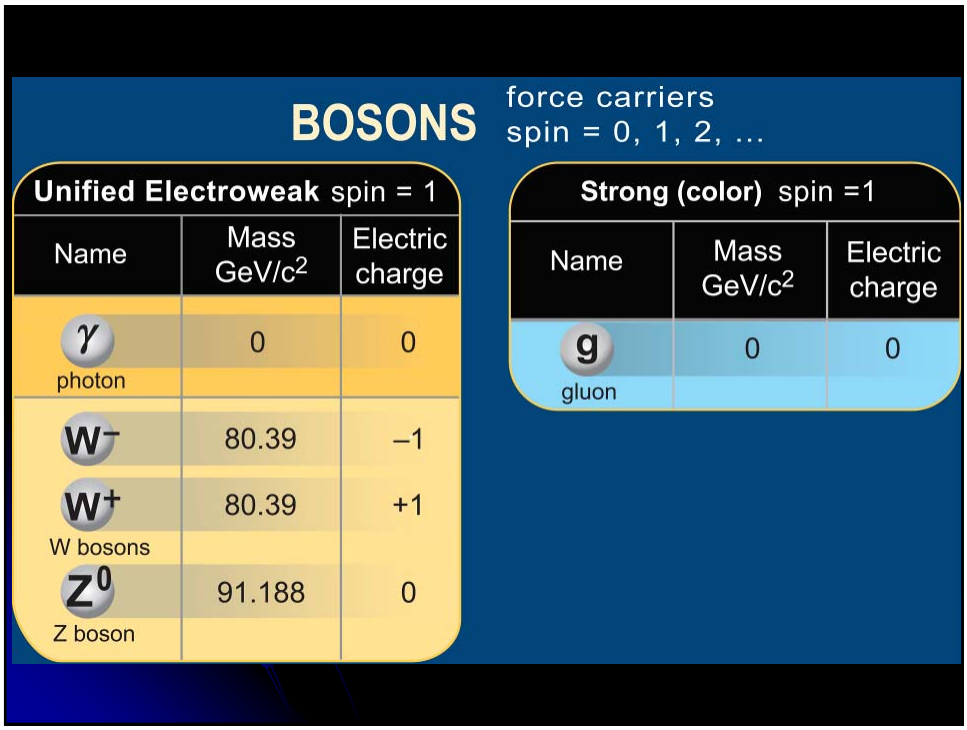
Schroedinger (1926) – Modern "quantum theory"

- A mathematical theory of orbits

Subatomic Particles

- In the next few slides we'll look at what makes up protons and neutron.
- The fundamental particles that we are most interested in:
  - Electrons
  - Photons
  - Quarks (how do you make a proton or neutron?)
  - You can ignore the other stuff until AP Physics next year!
  - Upcoming charts/images are from http://particleadventure.org


FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, …
Leptons spin =1/2
Flavor
Mass GeV/c2
Electric charge
νL lightest neutrino*
(0–0.13)×10–9
0
e electron
0.000511
–1
νM middle neutrino*
(0.009–0.13)×10–9
0
μ muon
0.106
–1
νH heaviest neutrino*
(0.04–0.14)×10–9
0
τ tau
1.777
–1
Quarks spin =1/2
Flavor
Approx. Mass GeV/c2
Electric charge
u up
0.002
2/3
d down
0.005
–1/3
c charm
1.3
2/3
s strange
0.1
–1/3
t top
173
2/3
b bottom
4.2
–1/3


BOSONS
force carriers
spin = 0, 1, 2, …
Unified Electroweak spin = 1
Name
Mass GeV/c2
Electric charge
γ photon
0
0
W–
80.39
–1
W+
80.39
+1
W bosons
Z0
91.188
0
Z boson
Strong (color) spin =1
Name
Mass GeV/c2
Electric charge
g gluon
0
0

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$

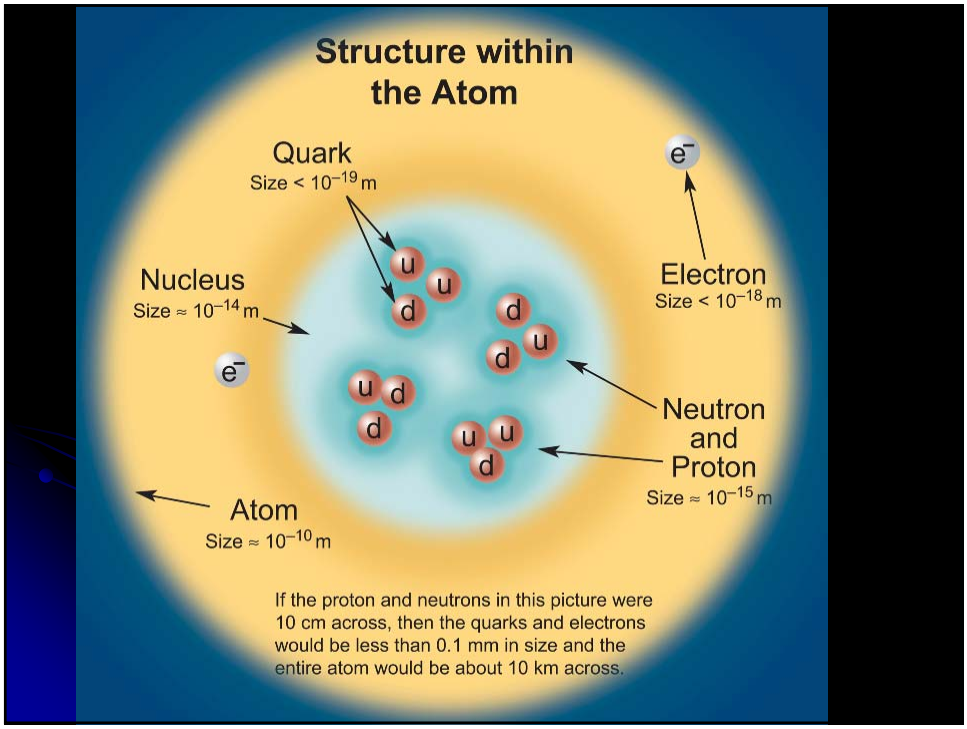
Baryons are fermionic hadrons.
These are a few of the many types of baryons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	**uud**	1	0.938	1/2
$\bar{\mathbf{p}}$	antiproton	$\bar{\mathbf{u}}\bar{\mathbf{u}}\bar{\mathbf{d}}$	–1	0.938	1/2
n	neutron	**udd**	0	0.940	1/2
Λ	lambda	**uds**	0	1.116	1/2
Ω^-	omega	**sss**	–1	1.672	3/2

Mesons $q\bar{q}$

Mesons are bosonic hadrons
These are a few of the many types of mesons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$\mathbf{u\bar{d}}$	+1	0.140	0
$\mathbf{K^-}$	kaon	$\mathbf{s\bar{u}}$	–1	0.494	0
ρ^+	rho	$\mathbf{u\bar{d}}$	+1	0.776	1
B^0	B-zero	$\mathbf{d\bar{b}}$	0	5.279	0
η_c	eta-c	$\mathbf{c\bar{c}}$	0	2.980	0



Atomic Structure

- Atomic Number: # of protons.
  Example: $_{3}Li$
- Mass Number: # of protons + # of neutrons
  Example: ^{7}Li
- Proton: Symbol = $^{1}_{1}p$ (+) Has an atomic # of 1 and an atomic mass of 1
- Neutron: Symbol = $^{1}_{0}n$ (neutral) Has an atomic # of 0 and an atomic mass of 1
- Electron: Symbol = $^{0}_{-1}e^{-}$ (e^{-}) Has atomic # of –1 and mass of zero*

Atomic Structure

- Mass of a proton = 1.67265×10^{-24} g
- Mass of a neutron = 1.67495×10^{-24} g
- Mass of an electron = 9.10953×10^{-28} g

- Notice that the mass of a proton is not quite identical to that of a neutron, but for most of our purposes we can consider them equal.
- Especially in larger atoms this difference will cause mass numbers to not be whole numbers.

Forces in the Atom

So what holds an atom together?

- The nucleus (p & n) has an overall positive charge and holds the negatively charged electrons with **electromagnetic force**

What holds the nucleus together?

- The nucleus contains protons (+) and neutrons (neutral).
- Why would positive and neutral things want to stick to each other?
- The **Strong Nuclear Force** holds them together
- The Strong Nuclear Force only occurs between particles that are extremely close together
- It is created between the nucleons by the exchange of particles called **mesons**
- I know – pretty wild!