A T O M I C ... S T R U C T U R E

and

The Discovery of Sub-Atomic Particles

ATOMIC THEORIES:

... Democritus (Ancient)

... Dalton (Modern)

LAW OF CONSERVATION OF MASS

... The Total Mass Entering a chemical reaction = the total mass leaving the reaction.

LAW OF DEFINITE PROPORTIONS (Dalton's Law)

... Every compound has a definite ratio of elements by mass. (Ah... Formulae!)

LAW OF MULTIPLE PROPORTIONS

... Some compounds exhibit whole number ratios of elements.

H_2O, H_2O_2, NO, N_2O, N_2O_3, N_3O_4, FeO, Fe_2O_3, Fe_3O_4

THE LAW OF GAY LUSSAC

... The combining ratios in reactions are of *small whole* numbers.

The Above Laws indicate that there are basic particles (atoms) that make up matter.

FARADAY'S DISCOVERY--

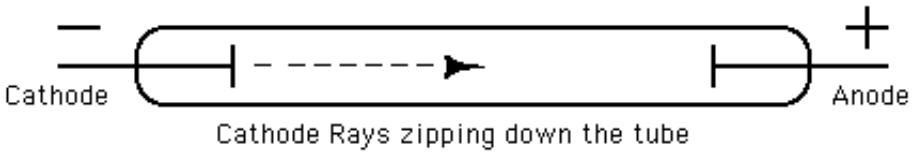
... Electricity decomposes compounds into elements. On re-forming, electricity is re-generated.

... This shows that the binding force between atoms in a compound is electrical.

THE DISCOVERY OF PARTS OF THE ATOM (Late 19^{th} and early 20^{th} century action)--

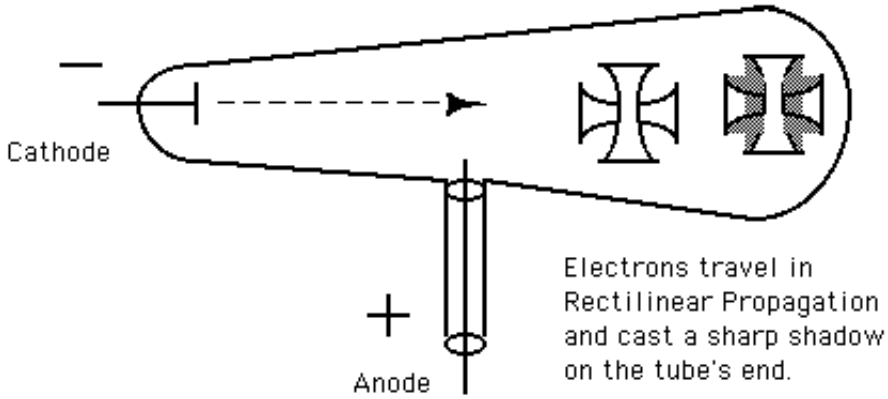
... The high voltage Induction Coil, "Sparky" gave the energy needed to probe the atom.

... Discharge Tubes-- lowering air pressure in a tube allowed the *Cathode Rays* to travel great distances (many meters).



THE DISCOVERY OF THE ELECTRON--

...The Tube of Sir William Crookes--



The Rays--

...travel from Cathode (negative) to Anode (positive). Hence they are NEGATIVE.

...are easily stopped by thin metal obstacles (the Iron Cross).

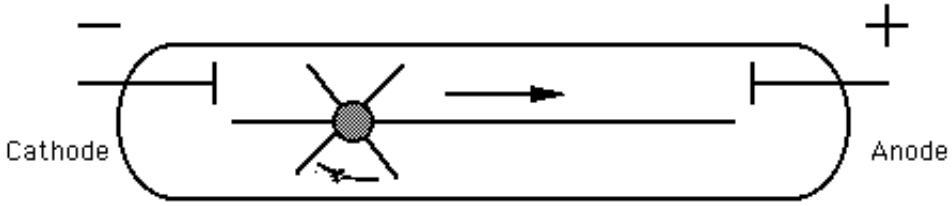
...travel in Rectilinear Propagation because the shadow of the cross is sharp.

...are attracted to positive electric charges and repelled by negative charges placed beside the tube

...are bent at right angles by magnet fields and they cause fluorescence on the glass and upon certain minerals.

THE DISCOVERY OF THE MOMENTUM OF THE RAYS--

The Paddle Wheel Tube (the tube of Jean Perrin) showed that the Cathode Rays have mass and velocity (momentum) because they push the paddles. Great fluorescent colors are demonstrated by paint on the paddles.



...The rays therefore must be *particles* and were named "*Electrons*".

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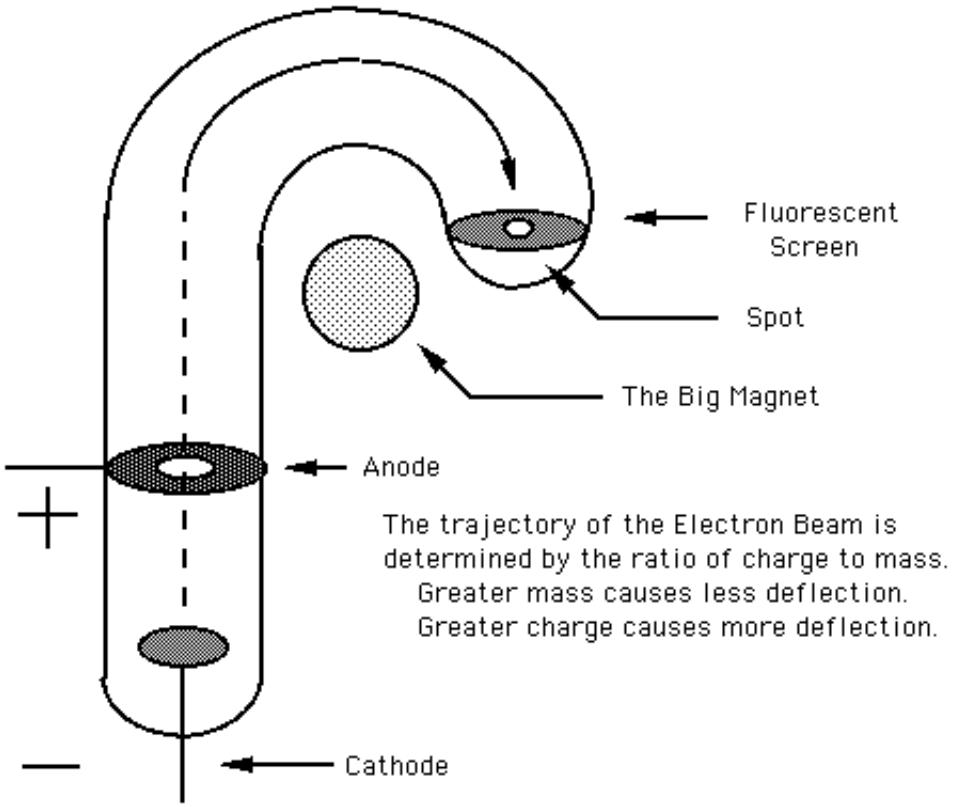
THE MEASUREMENT OF THE CHARGE TO MASS RATIO OF ELECTRONS--

... The Tube of Sir JJ Thompson--



The **candy cane-shaped tube** bent the cathode rays in a magnetic field and showed their path on a fluorescent screen. This enabled the calculation of the *Charge to Mass Ratio*. Higher charge would bend the beam more, higher mass would bend the beam less.

e/m = ratio = 1.8 X 10^{8} coulomb/gram.

THE DETERMINATION OF THE CHARGE OF THE ELECTRON--

Millikan Oil Drop Experiment to measure the actual charge on an electron. X-Rays would add or subtract electrons to the microscopic droplets. By varying the electric charge needed to balance the weight of the droplet, three biggies were discovered:

... 1. All electrons are identical.

... 2. The electron is a basic particle of electricity.

... 3. The charge of the electron:

e = 1.6 X 10^{-19} coulomb (c) of charge.

Here is the apparatus:

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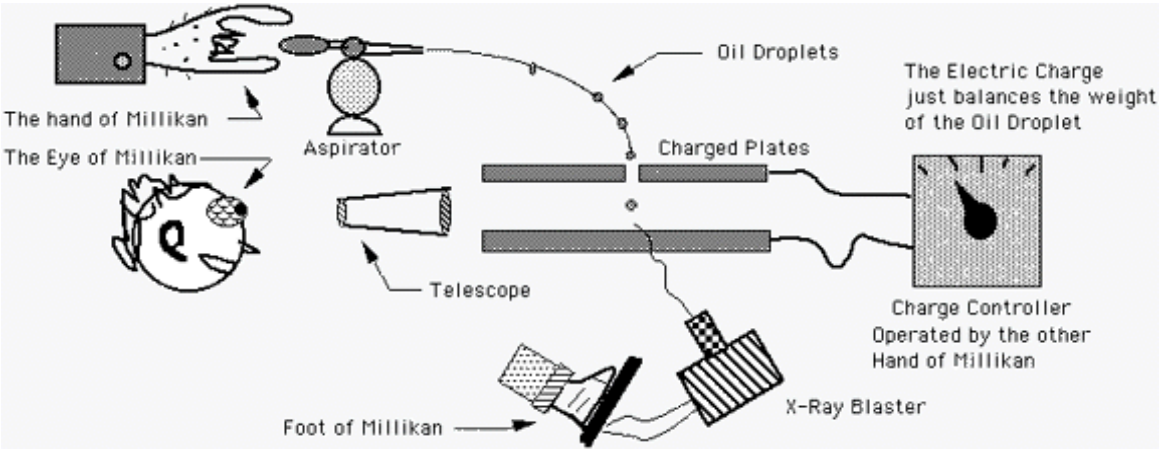

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THE CALCULATION OF THE MASS OF THE ELECTRON--

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...The Mass of the electron is determined from e/m ratio and the charge:

$$e/m = \text{ratio}$$

so

$$m = e/\text{ratio}$$

hence: $m = 1.6 \times 10^{-19} c / 1.8 \times 10^{8}\ c/g$

$m = 9.11 \times 10^{-29}$ gram/electron WOW! That's tiny!

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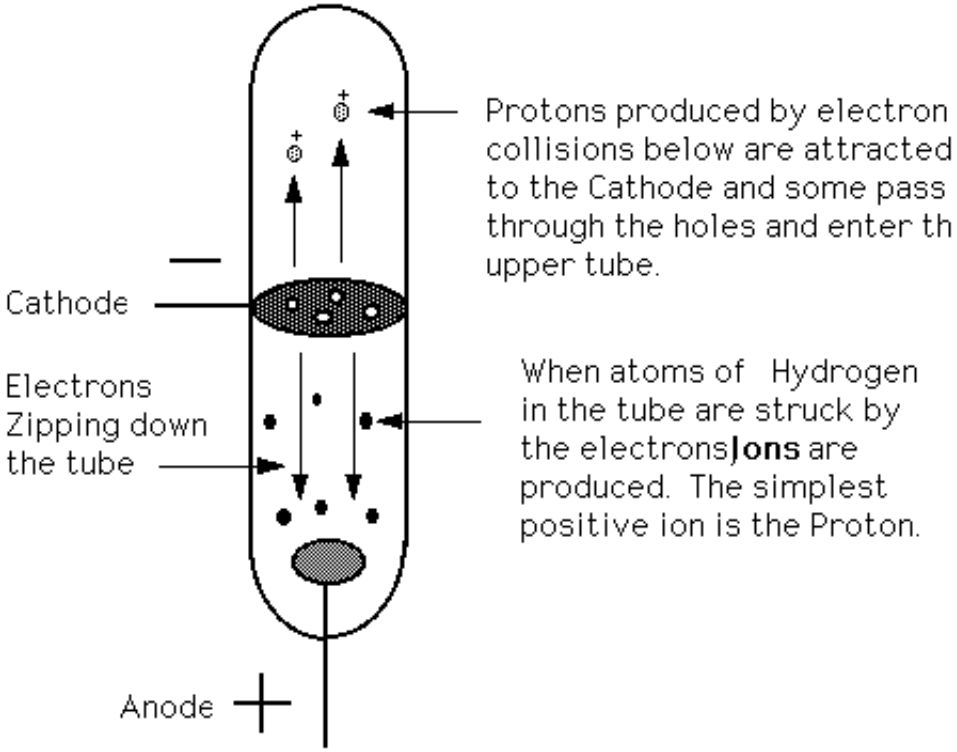
THE DISCOVERY OF IONS AND THE PROTON--

The Canal Ray Tube was built to see if there are rays from the anode. There were positive rays, but not from the anode. They were produced by the impact of electrons with atoms of gas in the tube.

... The Canal Ray Tube



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The collisions knocked electrons off the atoms creating positive IONS. The e/m ratios of the ions (in a JJ tube) depended on which gas was used. When using the simplest gas, Hydrogen, we found the simplest ion, the Hydrogen nucleus called the "PROTON".

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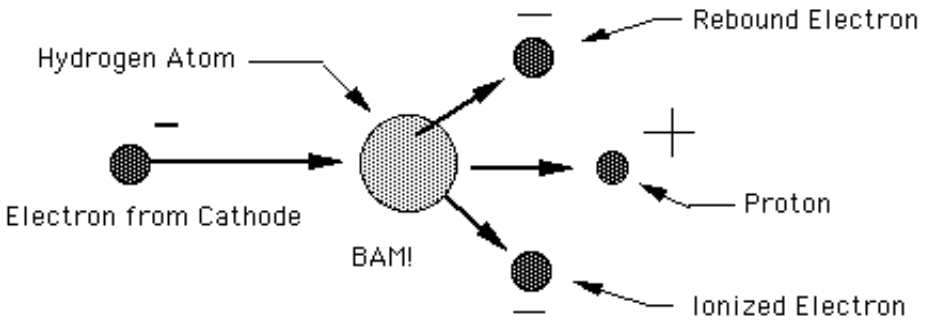

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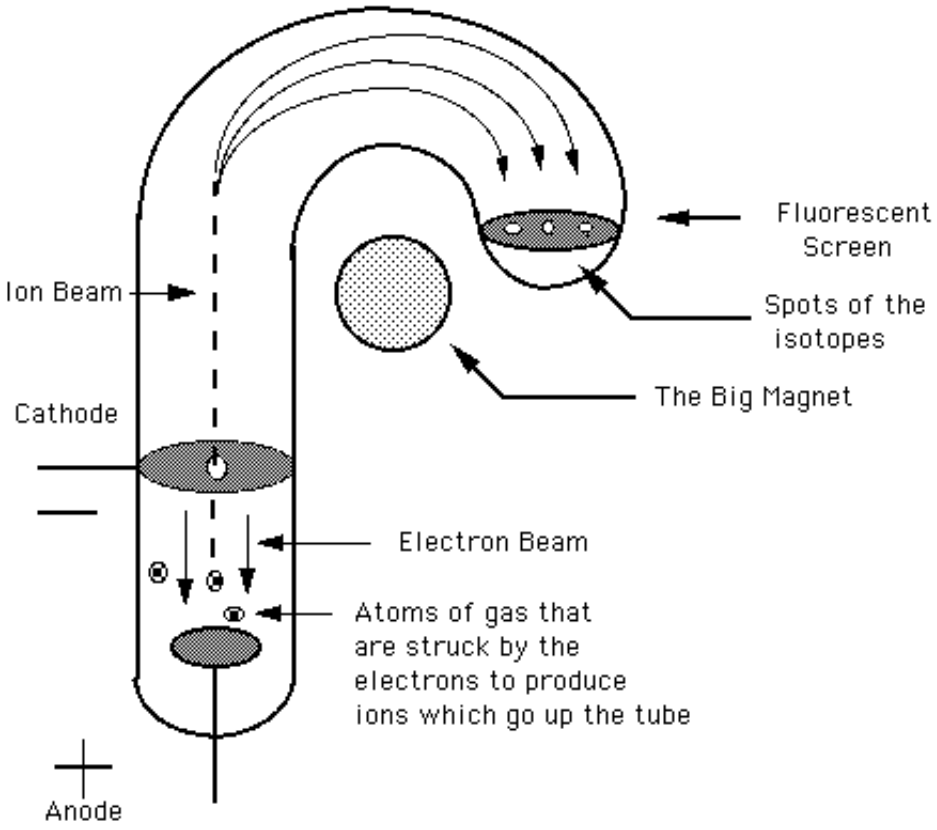
THE DISCOVERY OF ISOTOPES--
The ***Mass Spectroscope*** is a refined Sir JJ tube built for accurate measurements. When ions were sent through it, they separated into several beams according to different masses (their charges were the same). These different masses for the same element were called ***ISOTOPES*** (in the same place on the periodic table).



THE DISCOVERY OF THE NEUTRON--
To explain ***ISOTOPES*** we postulated a **NEUTRAL** particle whose mass was equal to that of the Proton. This way we could account for a change in mass without changing which element was present.

The **NEUTRON** was discovered in 1932 by Chadwick using a piece of jam jar paraffin to react with radiation.

THE DISCOVERY OF X-RAYS--
Roentgen was experimenting with discharge tubes and found fluorescent substances were glowing around in his lab including places behind barriers. Powerful! They are created when electrons strike a metal target.

X-rays are electromagnetic waves above the Ultra-Violet on the spectrum.
X-rays are used to determine:

... **The Atomic Number** (the number of protons in the nucleus. The wave length of X-rays depends on number of protons).

... **The Structure of crystals** (X-ray diffraction studies).

Discovery of *X-Rays*

Roentgen was experimenting with discharge tubes and found fluorescent substances were glowing around in his lab including places behind barriers. Powerful! They are created when electrons strike a metal target (accelerated charges ---> electromagnetic waves.

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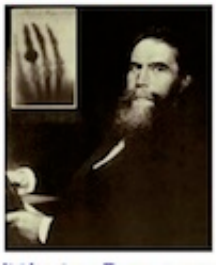
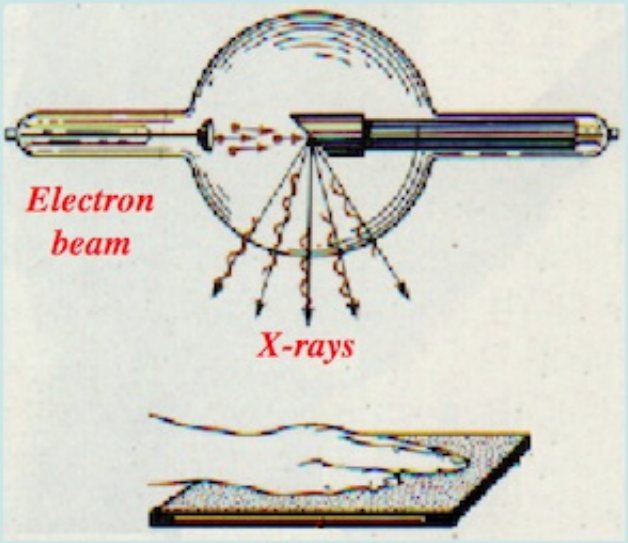


X-Ray Tube

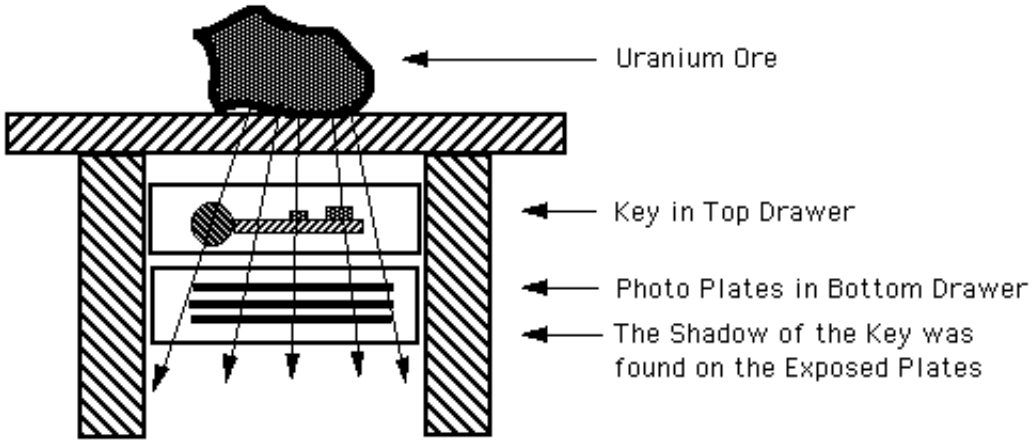
Please copy into the notes: When electrons strike a metal target, X-Rays are produced. They are Electromagnet waves.



THE DISCOVERY OF RADIOACTIVITY AND ITS THREE RAYS--

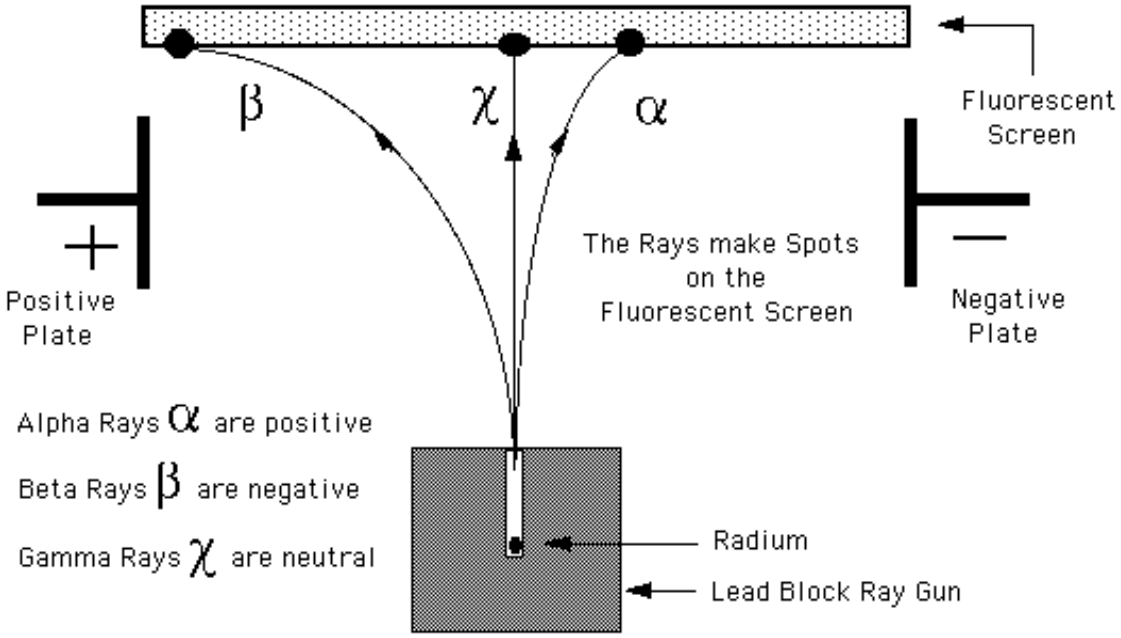
Becquerel, experimenting with fluorescent minerals, found that Uranium ore on his desktop

exposed film in the drawers below with the shadow of a key thereon.



Marie Curie analyzed Uranium ore and discovered new radioactive elements including Radium.

Lord Rutherford, using Marie's Radium, found three rays coming therefrom:



Alpha rays-- Positive Helium ions. Small deflection due to high mass.

Beta rays-- Electrons. Large deflection due to very low mass.

Gamma rays-- Electromagnetic waves of very high energy ... WOW!

Properties of Radioactivity: Cause ionization, Discharge electroscope, Cause fluorescence, Expose photographic film, Destroy livingcells, Promote nuclear reactions.

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THE SIZE OF THE ATOM--

... For Copper, weigh out 1 mole-- 63.5 g/mol.

... Make it into a cube. Ah, it's 2 cm per side.

... This cube contains 6 X 10^{23} atoms (1 mol)

... To find the number of atoms per side of the cube, take the cube root of 6 X 10^{23}. It's about 10^{8} atoms per side.

... Now divide the 2 cm per side by the 10^{8} atoms per side, and you get about 10^{-8} cm per atom.

... This is called the *Angstrom unit* (the size of an atom).

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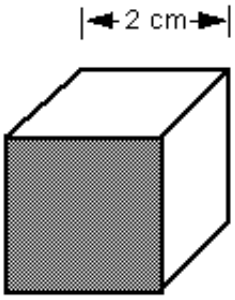

A Copper Cube of 2 cm per side contains one mole of atoms = 6.02 X 10^{23}

Rounding off Avogadro's number to 1 X 10^{24} allows us to easily extract the cube root, 1 X 10^{8} , the number of atoms along one side of the cube.

Dividing up 2 cm by 1 X 10^{8} atoms per side gives us 2 X 10^{-8} cm per atom.

THE SIZE OF THE NUCLEUS--

Lord Rutherford shoots Alpha Particles (Helium nuclei) through a thin piece of gold foil.

SHOCK! most Alphas go right on through. Hence the atom must be mostly empty space!

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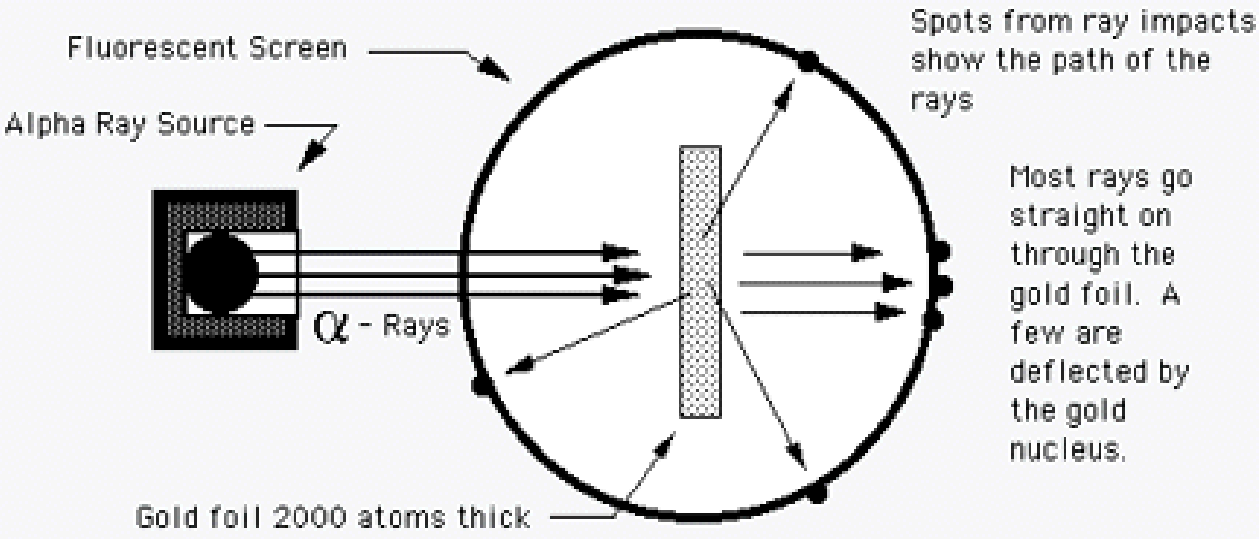

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A very few Alphas are deflected however. From the statistics of the deflection patterns, the size of the nucleus is calculated.

About 10^{-13} cm diameter!

Compared to the size of the atom (10^{-8} cm), the nucleus is "The flea in Yankee Stadium".

Comparison of Atomic vs. Nuclear Sizes

The diameter of the atom is 100,000 times that of the nucleus.

$$\frac{\text{Diameter of Atom}}{\text{Diameter of Nucleus}} = \frac{10^{-8}\ \text{cm}}{10^{-13}\ \text{cm}} = 10^{5}$$

The volume of the atom is a thousand million million times that of the nucleus!

$$\frac{\text{Volume of Atom}}{\text{Volume of Nucleus}} = \frac{\frac{4}{3}\pi R^3}{\frac{4}{3}\pi r^3} = \frac{(10^{-8})^3}{(10^{-13})^3} = \frac{10^{-24}}{10^{-39}} = 10^{15}$$

Collapsed matter: enormous gravity of super novae crush the electrons into the nucleus creating *Black Holes* whose escape velocity is greater than the speed of light.

DISCOVERY OF THE ORBITALS OF THE ELECTRONS:

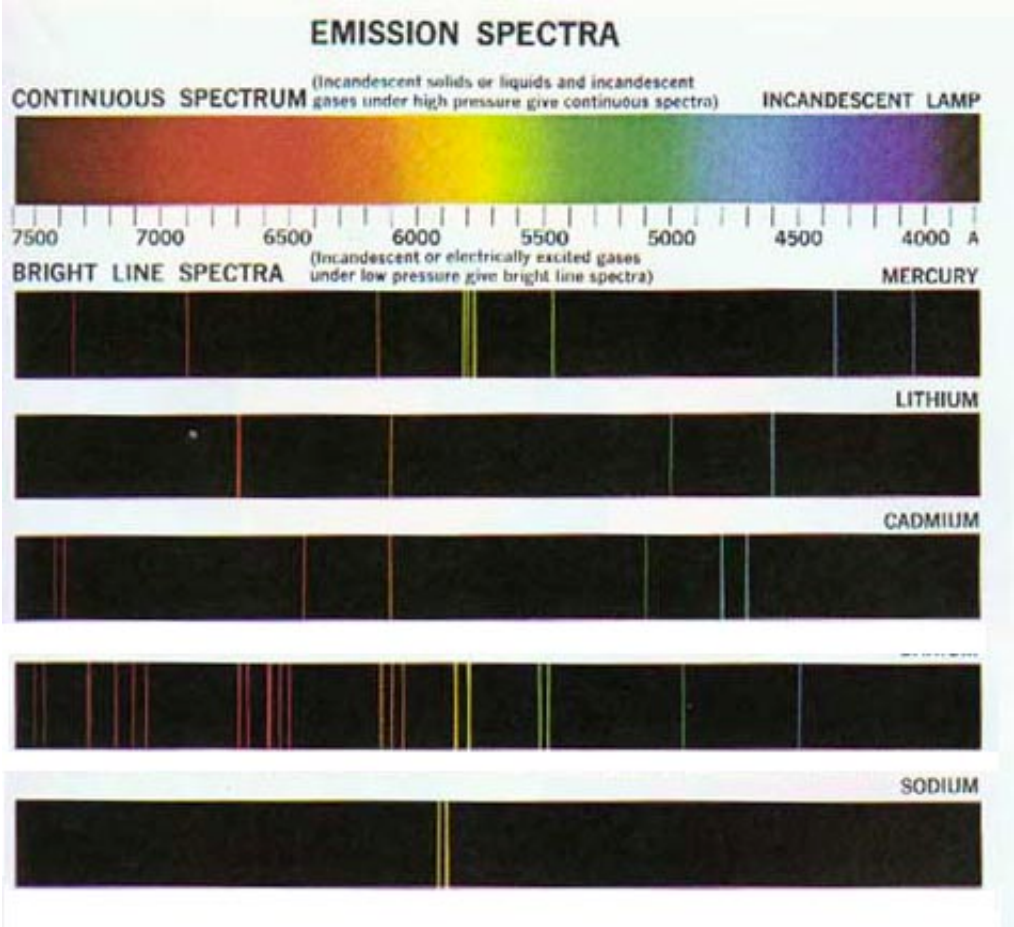
Spectroscopy--

When electrical discharge is sent through gases in a tube, and the light emittted passed through a prism, we get a spectrum of bright lines. These lines are the spectral "finger prints of the atom"

From the line spectra we learn

..... Which elements are present (like in the stars).

..... The arrangement of electrons around the nucleus, called the Electronic Configuration (the Goose Chart).



NUCLEAR PARTICLES --

Proton mass = 1 g/mol (amu) charge = +1.
Neutron mass = 1 g/mol charge = 0.
Electron mass = 1/2000 g/mol charge = -1
Isotopes have a different number of neutrons.
p + n = mass
Atomic Weight is the average of the isotopes' masses.

NUCLEAR REACTIONS--

Top numbers are the mass numbers (protons + neutrons).

Bottom numbers are the charge numbers (atomic numbers).

The sum of the numbers on the right must equal the sum of the numbers on the left.

.

$$_2He^4 + _4Be^9 \rightarrow _6C^{12} + _0n^1$$

.

$$_0n^1 + _{92}U^{238} \rightarrow _{93}Np^{239} + _{-1}e^0$$

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NUCLEAR FISSION & THE CHAIN REACTION--

Transmutation-- Changing an element into a different element. Let's make a new element!

$_0n^1 + _{92}U^{238} \rightarrow _{93}Np^{239} + _{-1}e^0$ Oooooh… a new element!

Nuclear Fission-- The breaking up of an isotope into smaller elements.

$_{92}U^{235} + _0n^1 \rightarrow _{56}Ba^{141} + _{36}Kr^{92} + 3\ _0n^1$ + ENERGY!!

Oh, oh… $_{92}U^{235}$ fissions! And the three new neutrons are available to continue a chain reaction!

NUCLEAR BOMB-- Needs a Critical Mass to sustain a chain reaction.
The Critical Mass (about 50 kilograms) is the minimum amount of $_{92}U^{235}$ needed to sustain a chain reaction. Remember that the neutrons must hit the nucleus of the atom (the flea in Yankee Stadium) to cause another fission. So to make the bomb one merely needs to accumulate the critical mass and it's




Fundamental Particles & Parameters of the Standard Model

Leptons

Type (flavor)	Mass (GeV)	Charge
Electron neutrino	10^{-9}	0
Electron	.0005	-1
Muon neutrino	.0003	0
Muon	.1057	-1
Tau neutrino	.0003	0
Tau	1.7771	-1

Quarks

Type (flavor)	Mass (GeV)	Charge
Up	.005	2/3
Down	.008	-1/3
Charm	1.5	2/3
Strange	.16	-1/3
Top	176	2/3
Bottom	4.25	-1/3

See the *Lectures Page* for the *PowerPoint* action on the above and much more.