Atomic Structure

The first formal idea of atoms is from Democritus

Matter could not be infinitely divisible

The structure of matter was of concern to:

- Metallurgists
- Alchemists

Alchemist

If you are going to turn lead into gold, you need to know what lead and gold are made of

CHRONOLOGY

470 -380 B.C.: DEMOCRITUS, Greek philosopher best known for his atomic theory, that all matter consisted of tiny particles, so small that nothing smaller was conceivable. Hence indivisible.

1770's and 80's: Lavoisier, French chemist, carries out his experiments that help to establish concept of atomic weights.

1803: John Dalton, English chemist, who brings together the ideas of Democritus and Lavoisier, with the first quantitative atomic theory. All matter is composed of atoms. Atoms of elements differ from each other only in mass. First to prepare a table of atomic weights.

1869: Mendeleev, Russian chemist, who arranged the elements in a Periodic Table based on atomic weight and chemical properties.

What is the smallest particle of matter?

Matter is made out of Quarks and Leptons

Bulk Material

Molecules

Atoms

Electrons, Protons, Neutrons

A Lepton
(fundemental particle)

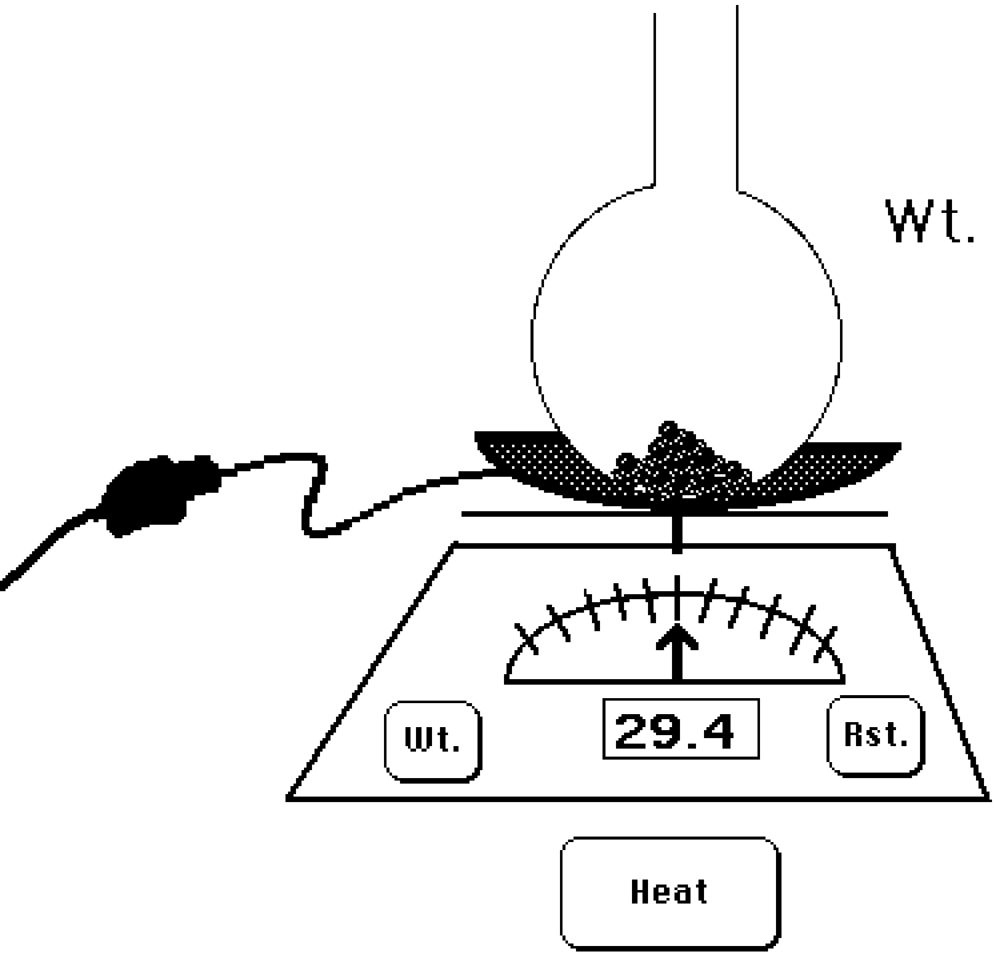
Quarks

Antoine Lavoisier performed a classic experiment. He took the red oxide of mercury which we now call mercuric oxide and heated it. The results were striking: a gas was given off and the red mercuric oxide was transformed into the silver liquid metal mercury.

$$HgO \xrightleftharpoons{\Delta} Hg + O$$

He weighed the mercuric oxide he started with and the mercury he produced.

$$\text{Wt. HgO} - \text{Wt. Hg} = \text{Wt. O}$$



Wt. HgO	Wt. Hg
31.8	29.4

$$\text{Wt. HgO} - \text{Wt. Hg} = \text{Wt. O}$$

2.35

$$\frac{\text{Wt. Hg}}{\text{Wt. O}} = 12.5$$

$$HgO \underset{}{\overset{\Delta}{\rightleftarrows}} Hg + O$$

Weigh HgO at start **Weigh Hg at end**

Wt. HgO – Wt. Hg = Wt. O

The ratio of Hg:O is the same no matter how much HgO you start with:

$$13.5g\ HgO \overset{\Delta}{\rightleftarrows} 12.5g\ Hg + 1g\ O$$

Hg:O = 12.5

$$50g\ HgO \overset{\Delta}{\rightleftarrows} 43.6g\ Hg + 3.7g\ O$$

Hg:O = 12.5

When atoms combine to form a particular compound, they always combine in the same ratio by weight.

–John Dalton

Dalton

This leads to the idea that atoms themselves have weight

You cannot weigh an individual atom but you can get the ratios of their weights from the combining ratios:

$$13.5\text{g HgO} \underset{}{\overset{\Delta}{\rightleftharpoons}} 12.5\text{g Hg} + 1\text{g O}$$

$$\text{Hg:O} = 12.5$$

$$13.5g\ HgO \underset{}{\overset{\Delta}{\rightleftharpoons}} 12.5g\ Hg + 1g\ O$$

$$Hg:O = 12.5$$

What is the percent O in HgO?

$$\%O = \frac{1}{1 + 12.5} = .074 = 7.4\%$$

Today we do it differently:

$$\%O = \frac{16}{16 + 200.6} = .074 = 7.4\%$$

What is the percent H in Water?

Later it was found that H_2O had 11% H and 89% O

Hence the ratio of the wt of O to that of 2H was 89:11

Thus the ratio of the wt of O to that of 1H was 89:5.5 or 16:1

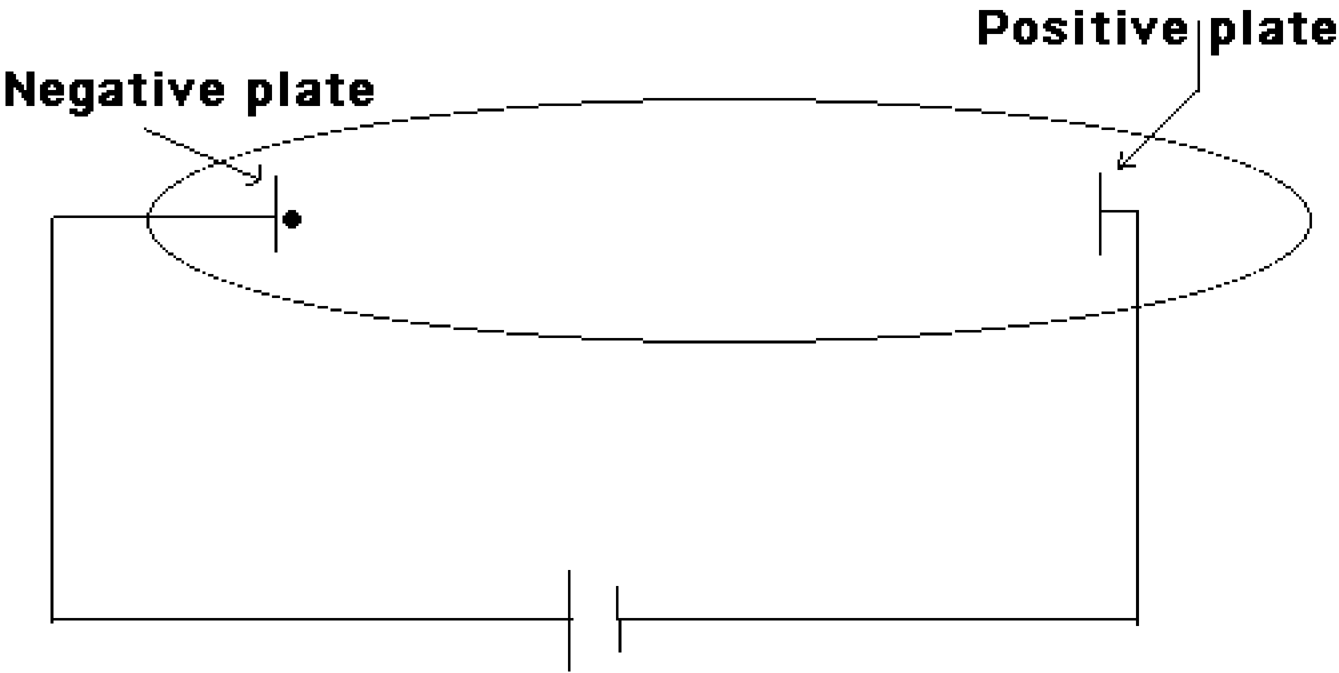
Since H was the lightest element which could be found, it is assigned an atomic wt of 1

In this way, the ratio of the weights of the atoms of the various elements could be determined

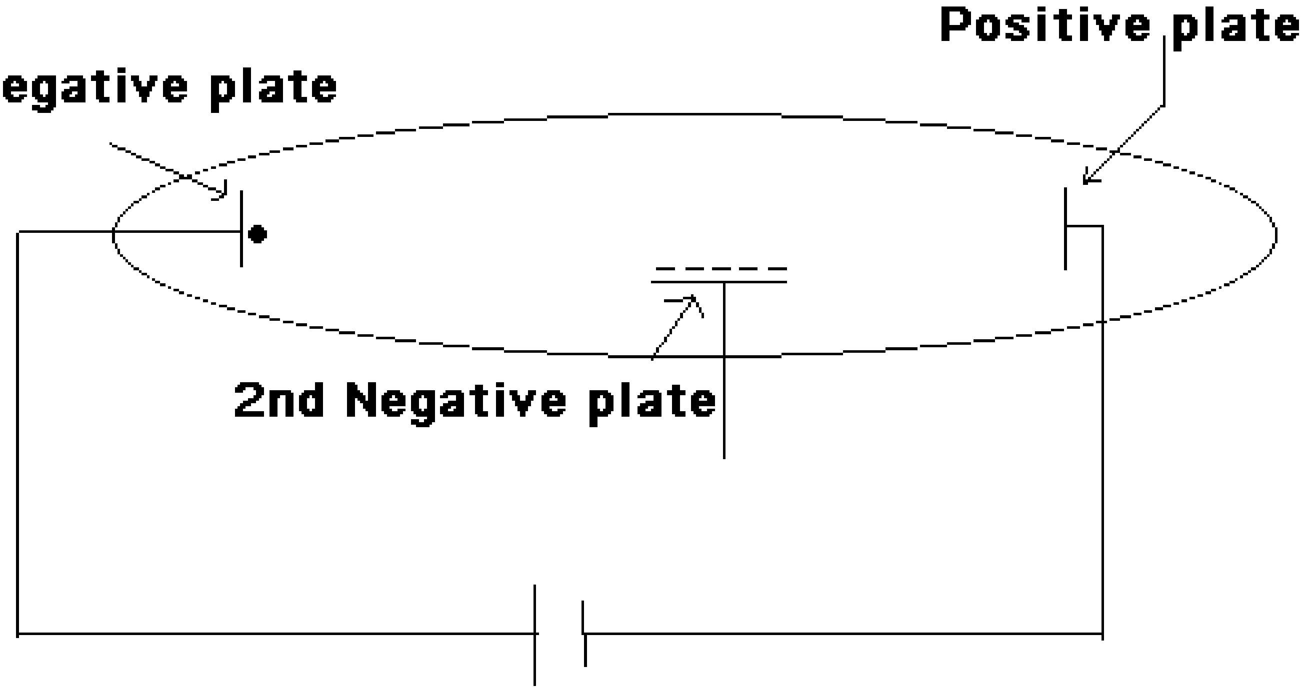
This method only determines relative weights and one atom must be assigned an arbitrary weight

Today this is carbon with atomic weight = 12

The Cathode Ray tube demonstrates that atoms are not Indivisible

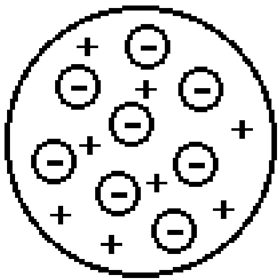


J. J. Thomson put in a second negative plate and observed that it repelled the cathode rays

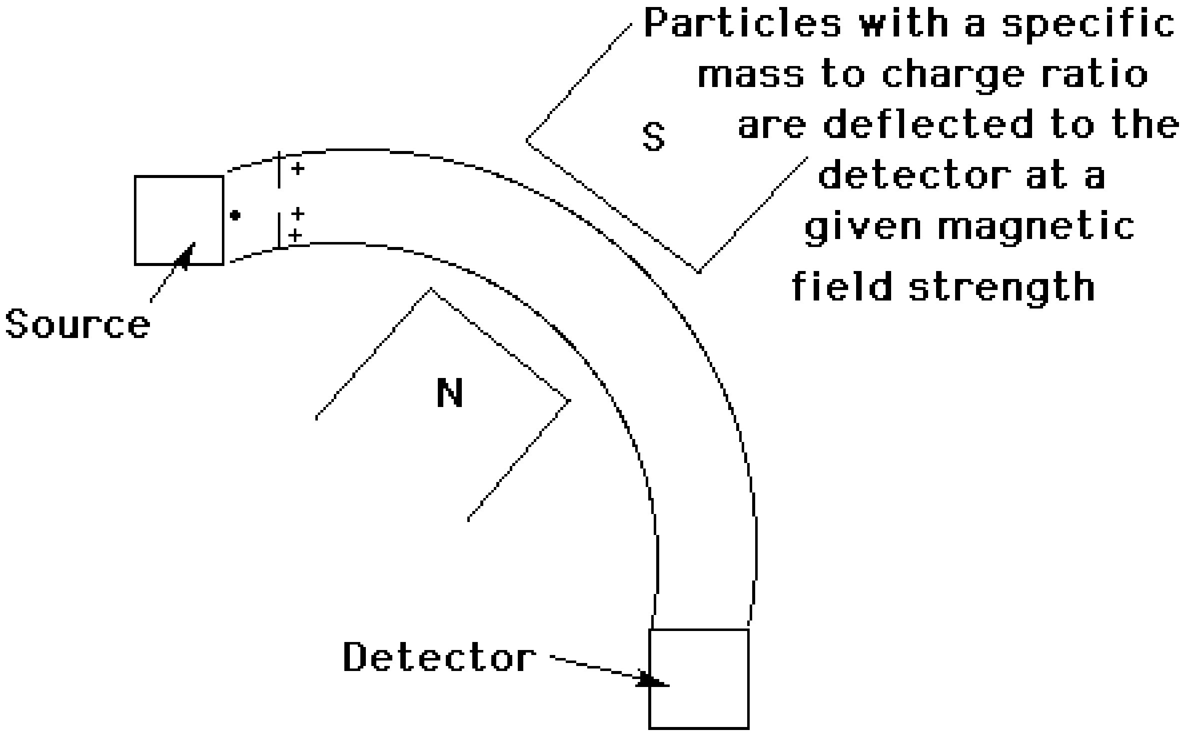


Thomson drew a new model of the atom to account for the presence of electrons. It is referred to as the "plum pudding" model, for in the absence of any indication of how electrons might be arranged in atoms, Thomson simply represented them as negatively charged "plums" in a positively charged "dough," to account for the fact that ordinary atoms have no net charge.

J. J. Thompson

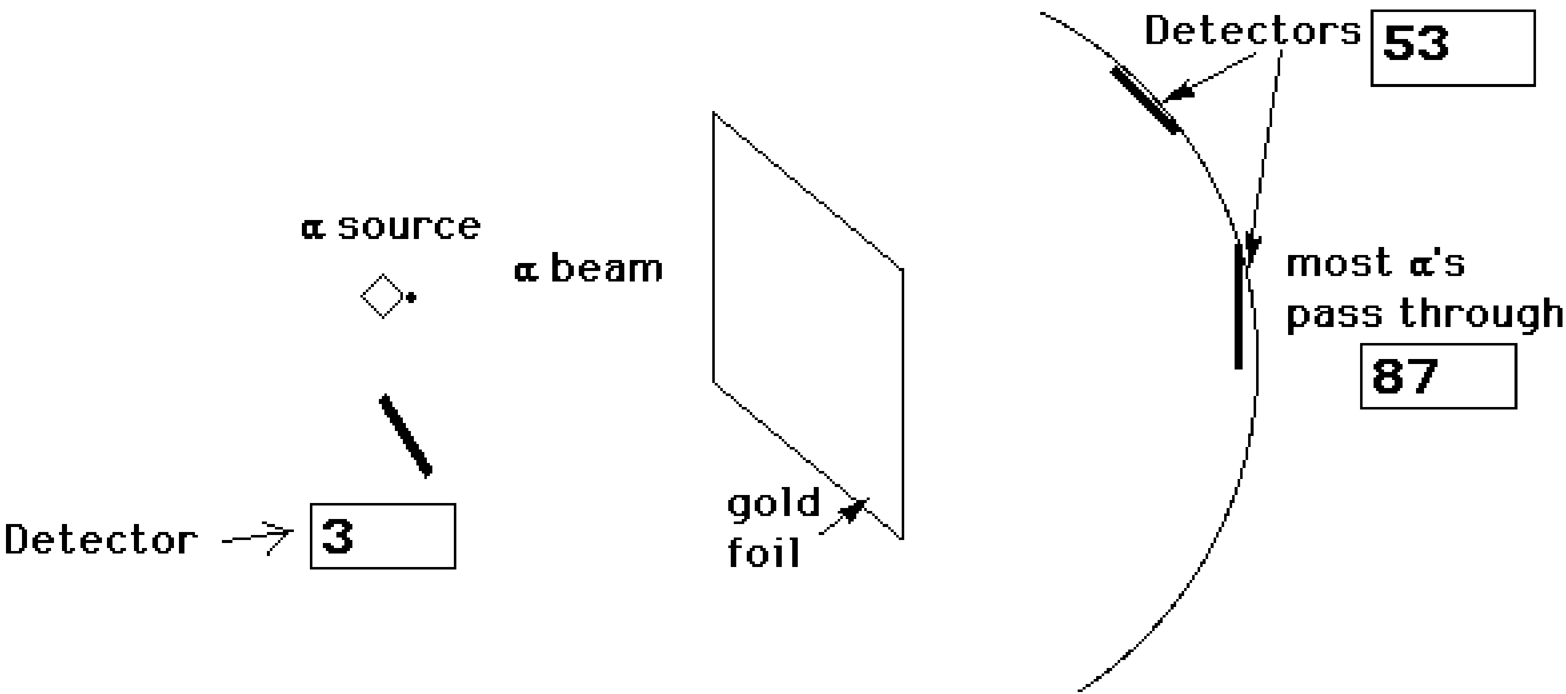


Mass to charge ratio measured by Frederick Aston using a simple Mass spectrometer



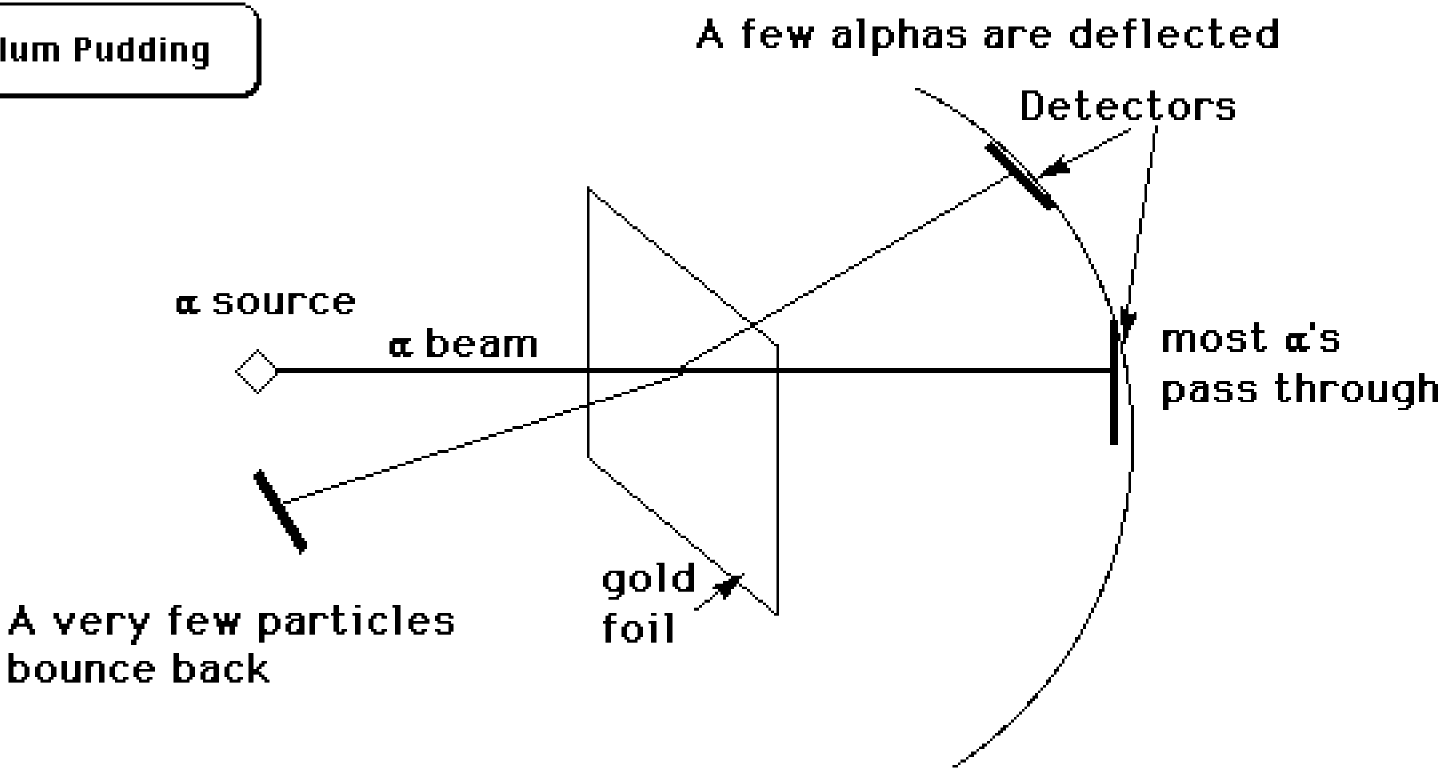
Ernest Rutherford shoots a beam of alpha particles with + charges at a thin sheet of gold foil

Rutherford

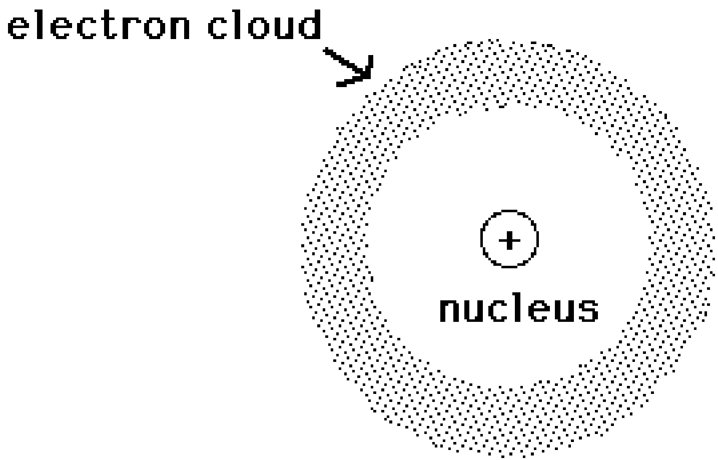


This experiment demonstrates that atoms are mostly empty space with a positively charged center

Plum Pudding



The model Rutherford drew to account for all three events is what is known as the "nuclear model." The electrons orbit the nucleus in a swarm, or cloud, somewhat as planets orbit the sun.



The problem with this model is that orbiting charges should lose energy rapidly, according to Maxwell's laws of electro-magnetism.

Subatomic particles:

- Electron – charge
- Proton + charge
- Neutron no charge

Calculate the charge on an atom;

Charge = number of protons – number electrons

Protons	Electrons	Neutrons	Charge
6	6	6	0
6	5	6	+1
8	10	8	–2

The last two are ions

Isotopes – Same number of protons (same atomic No.) but different number of neutrons (different atomic wt.) ○

Some carbon isotopes:

Carbon	**6 protons**	**6 neutrons**	**(99%)**	$^{12}_{6}C$
	6 protons	**7 neutrons**	**(1%)**	$^{13}_{6}C$
	6 protons	**8 neutrons**	**(very small %)**	$^{14}_{6}C$
	6 protons	**5 neutrons**	**(very small %)**	$^{11}_{6}C$

Isotopes - Same number of protons (same atomic No.) but different number of neutrons (different atomic wt.)

Uranium	92 p	146 n	$^{238}_{92}U$
	92 p	143 n	$^{235}_{92}U$

Calculating an element's actual atomic mass: Neon

^{20}Ne 90.92%

^{21}Ne 0.257%

^{22}Ne 8.82%

(0.9092x20)+(0.00257x21)+(0.882x22)

||

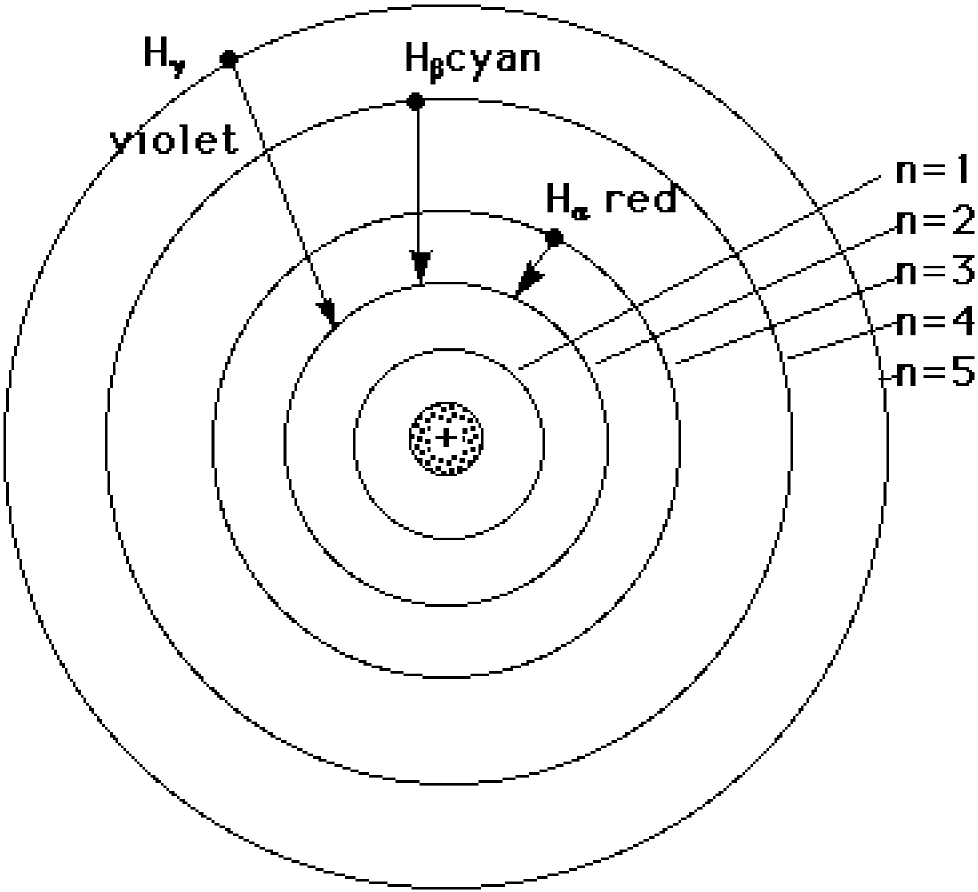
20.18 AMU

"When it comes to atoms, language can only be used as in poetry. The poet too, is not nearly so concerned with describing facts as with creating images."

Bohr&Heisenberg Niels Bohr to Werner Heisenberg

Niels Bohr proposed that electrons could have only specific "allowed" amounts of energy, and that kept them in specific "allowed" orbits. If they lost or gained energy, they would change orbits, and the amounts they could lose or gain had to correspond exactly to the difference in energy requirements of two allowed orbits. That meant that an electron going from a higher to a lower energy orbit (i. e., falling toward the nucleus) would have to radiate light of a specific wavelength.

Bohr's model for hydrogen, showing the transitions that account for the three bright colored lines of the spectrum, looked like this:



Bohr Atom

Spectrum of Atom

But, atoms are not tiny solar systems