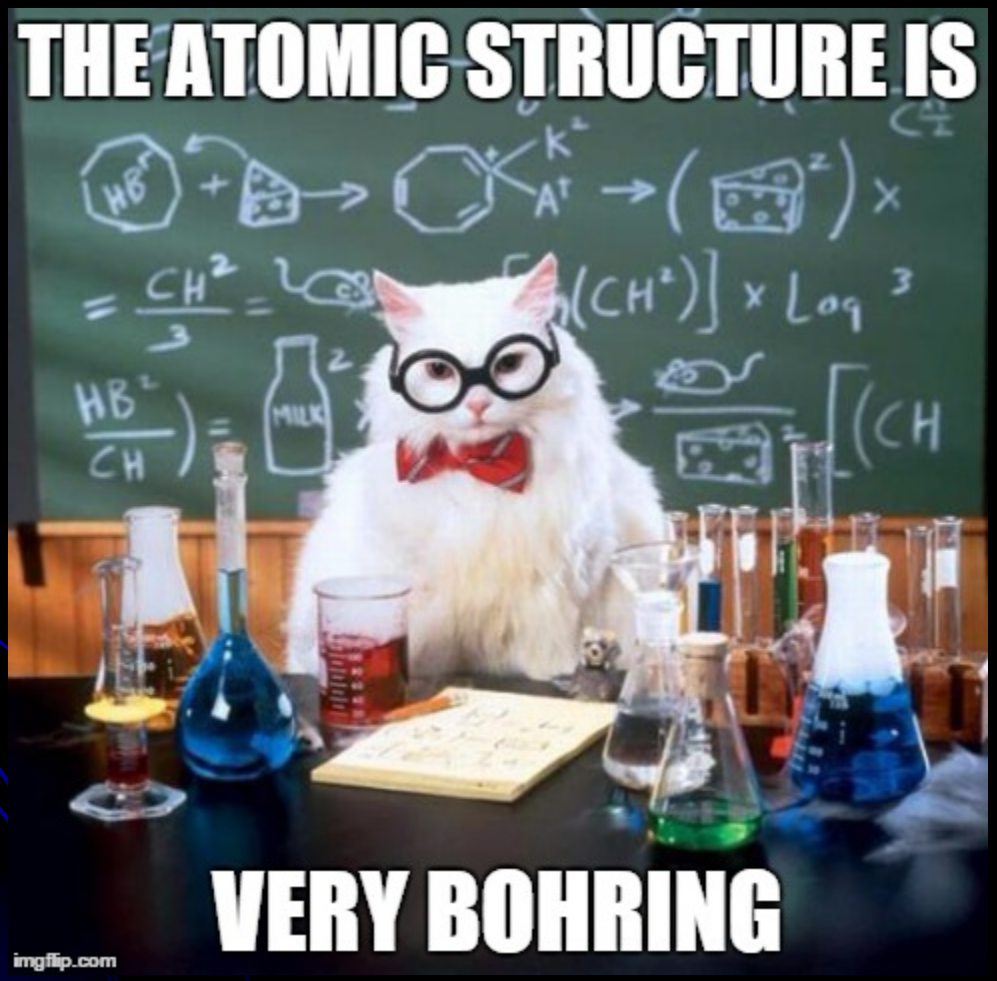
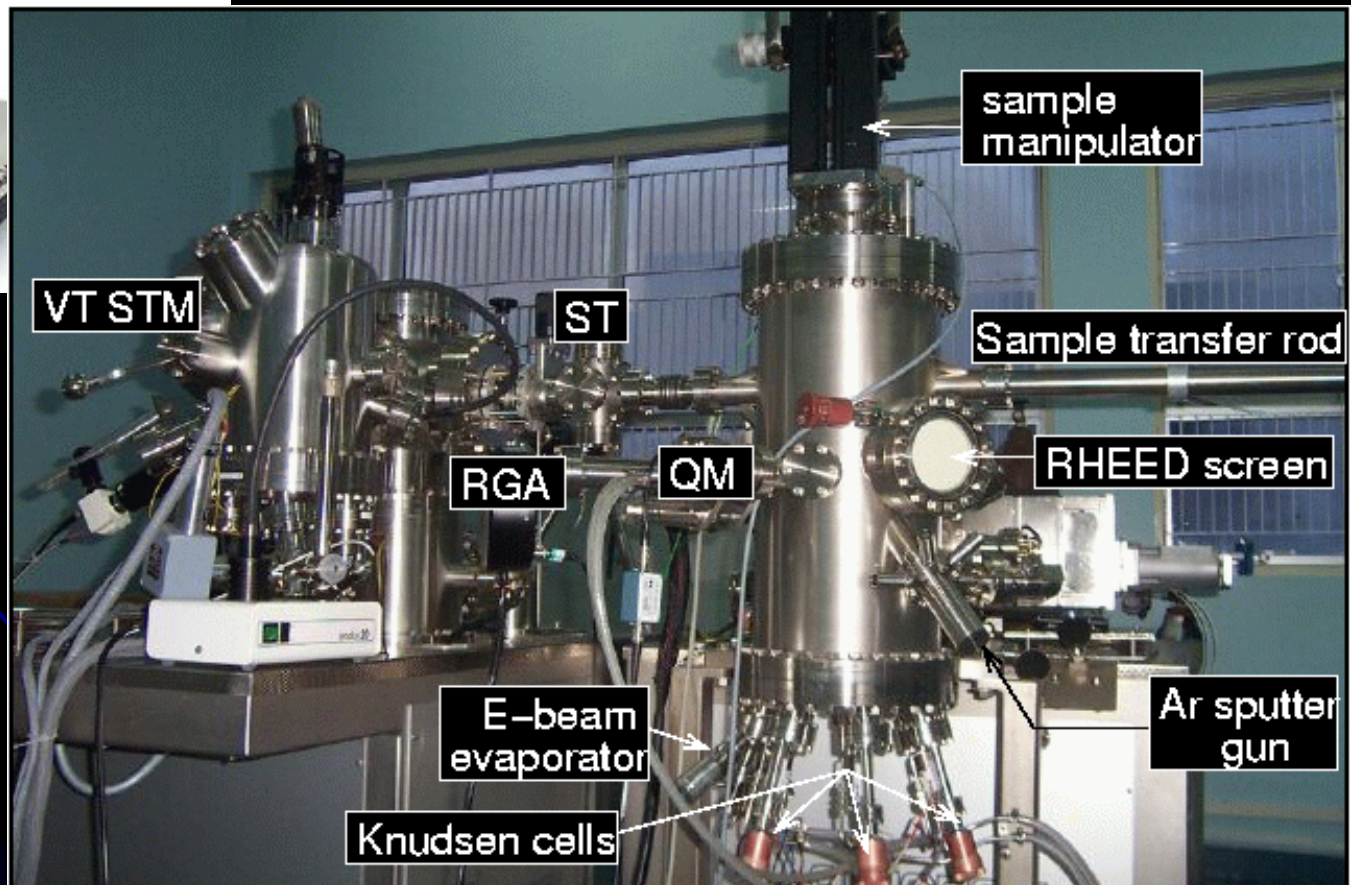
What is today's objective?



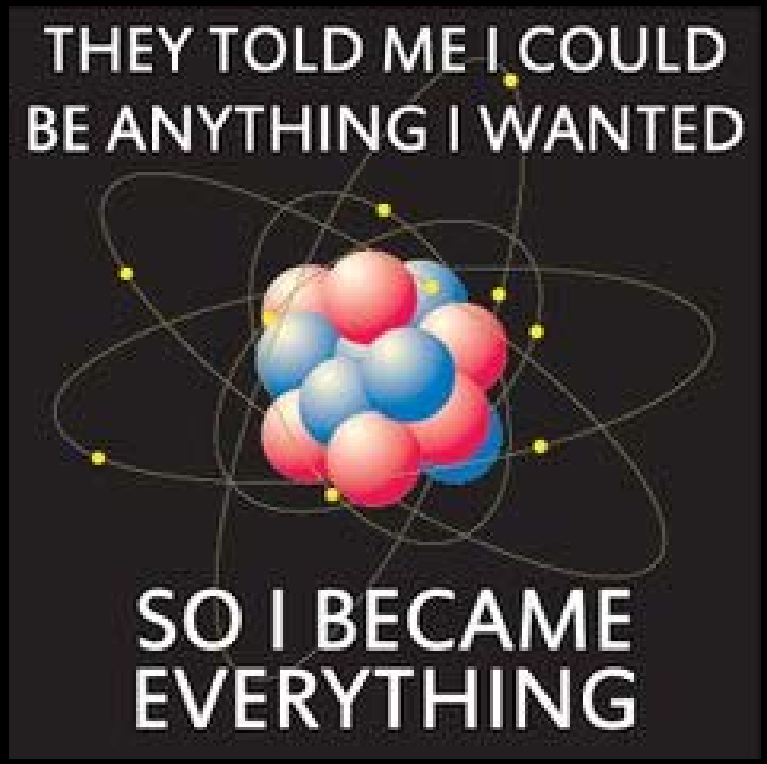
Sizing up the Atom 

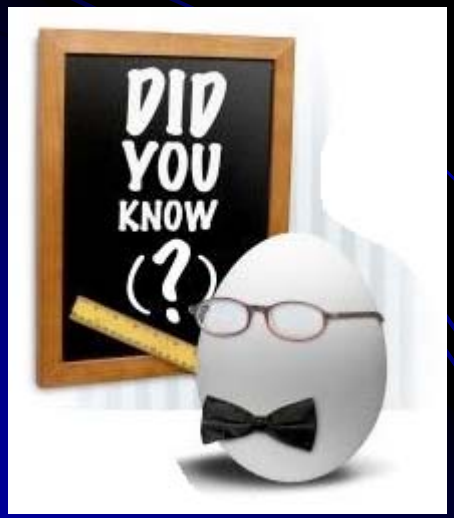
- **Elements** are able to be subdivided into smaller and smaller particles – these are the ***atoms***, and they still have properties of that element
  - If you could line up 100,000,000 copper atoms in a single file, they would be approximately *1 cm long*
  - Despite their small size, individual atoms **are** observable with instruments such as *scanning tunneling (electron) microscopes*

VS

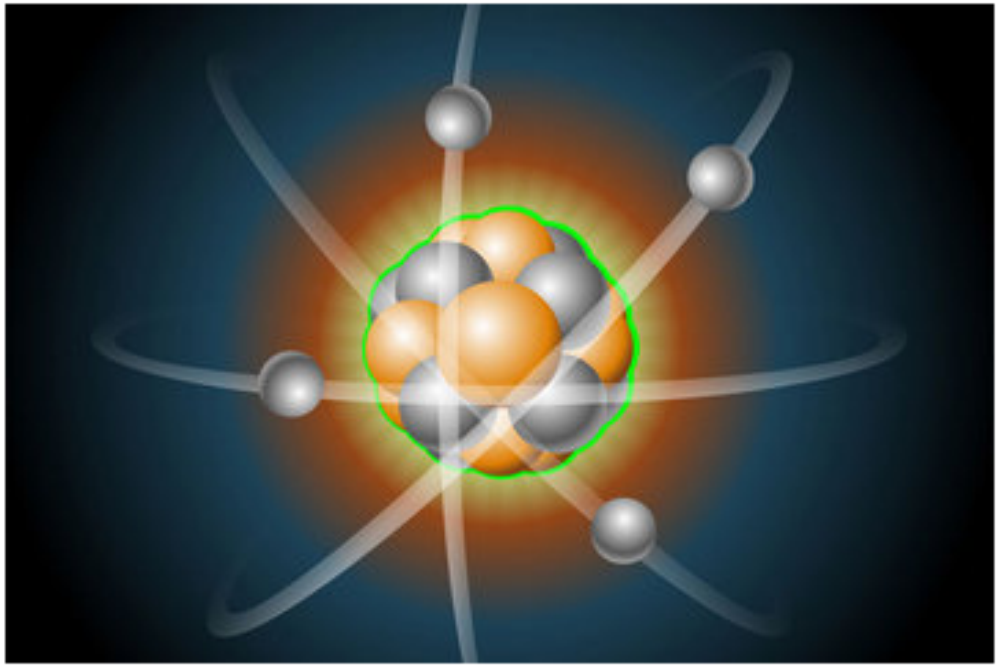

sample manipulator
VT STM
ST
Sample transfer rod
RGA
QM
RHEED screen
E-beam evaporator
Ar sputter gun
Knudsen cells

Atom - smallest particle making up elements





One teaspoon of water has 3 times as many atoms as the Atlantic Ocean has teaspoons of water!



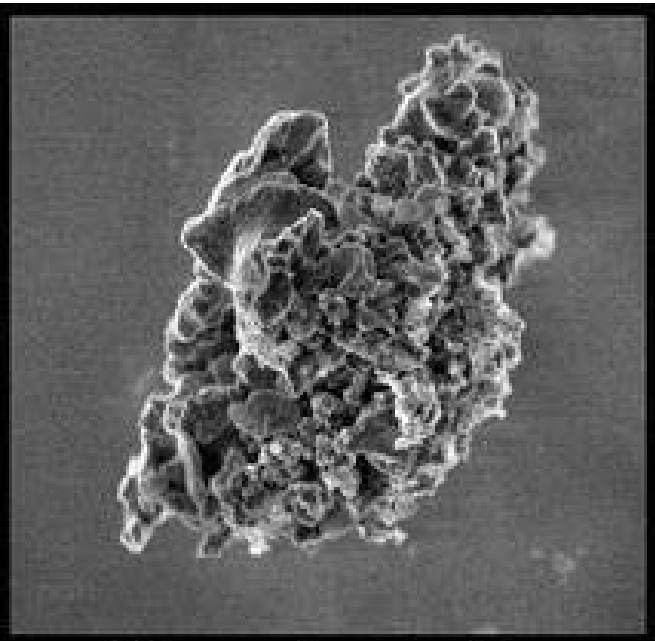
Researchers have found the proton is smaller than thought. The proton is one of the ingredients (along with neutrons and electrons) of the atoms that make up our bodies and the world around us.
CREDIT: aurin | Shutterstock
View full size image

How many protons can dance on the head of a pin? The answer is nowhere near as straightforward as one may think — and it might offer new insights into one of the most well-tested theories in physics.

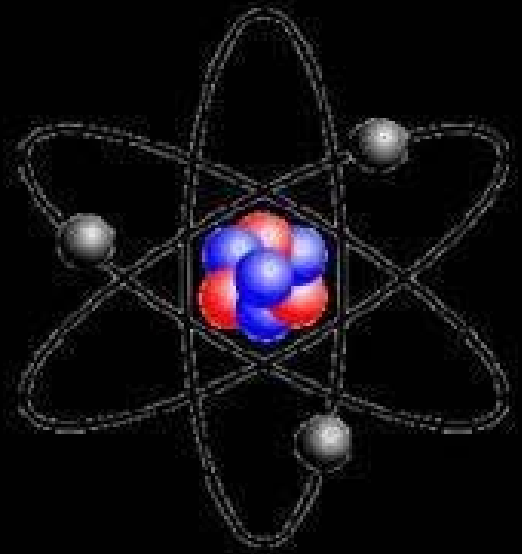
An international team of scientists recently tried to find out the actual size of a proton, one of the ingredients (along with neutrons and electrons) of the atoms that make up our bodies and the world around us.

Reporting this week in the journal Science, the researchers found that the particle's radius is 0.84087 femtometers. A femtometer is a millionth of a billionth of a meter, or so small that the wavelength of gamma radiation is 100 times longer. The new measurement is about 4 percentsmaller than the currently accepted radius of 0.8768 femtometers, and that small difference presents a puzzle.

A speck of dust



is halfway between the size of

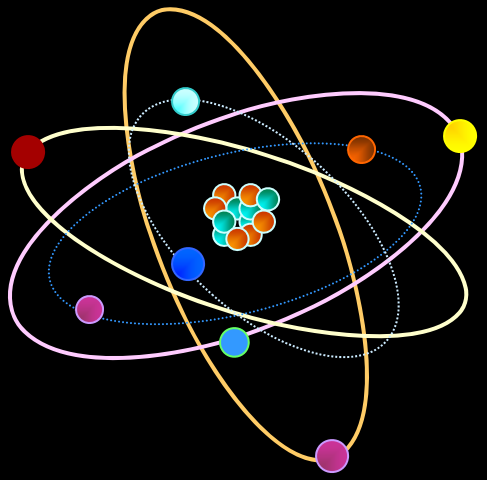


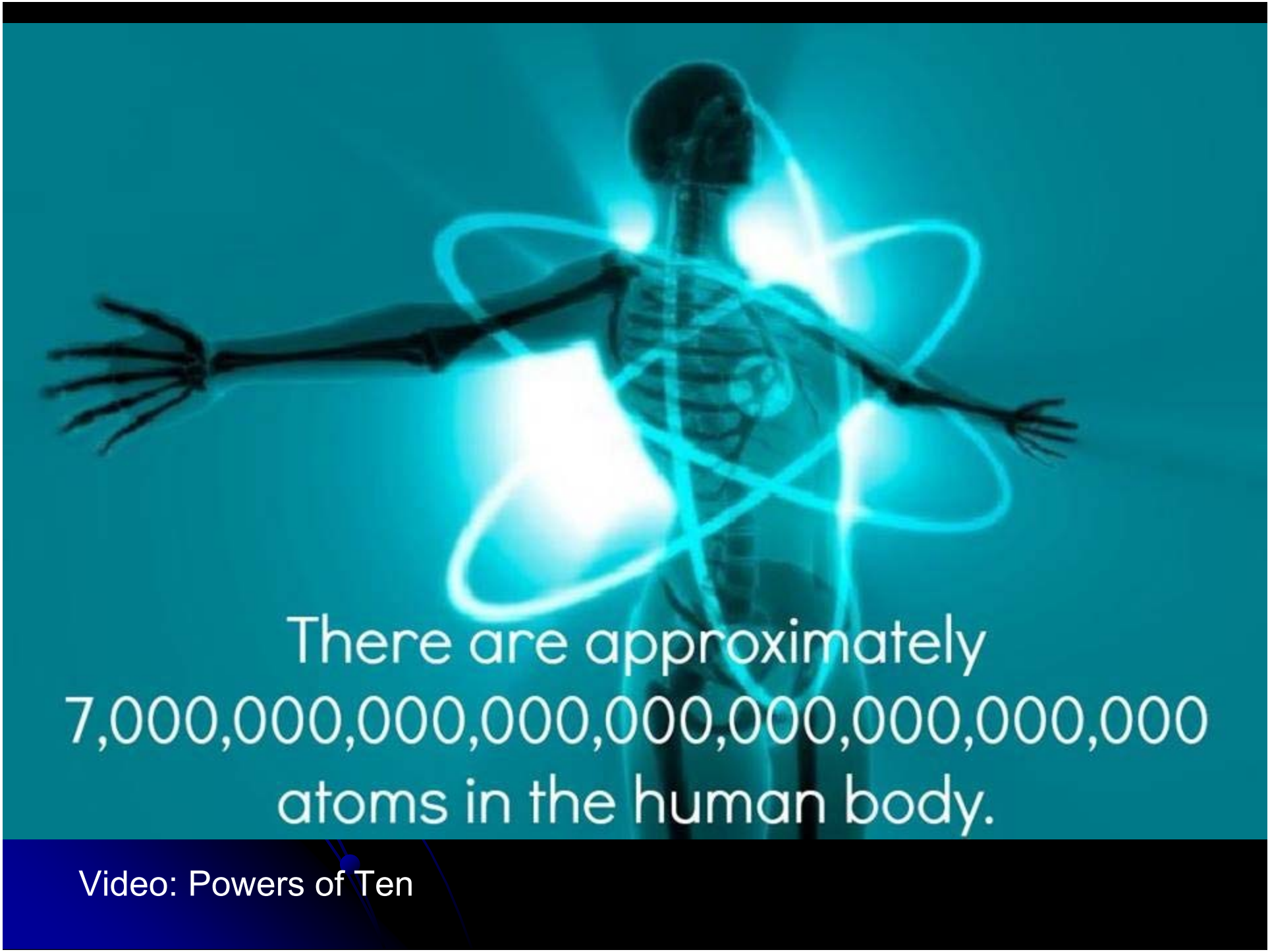
this

and this.

Development of The Atomic Theory

This explosion of technology occurred once we had a better understanding of the atom and how it behaves!

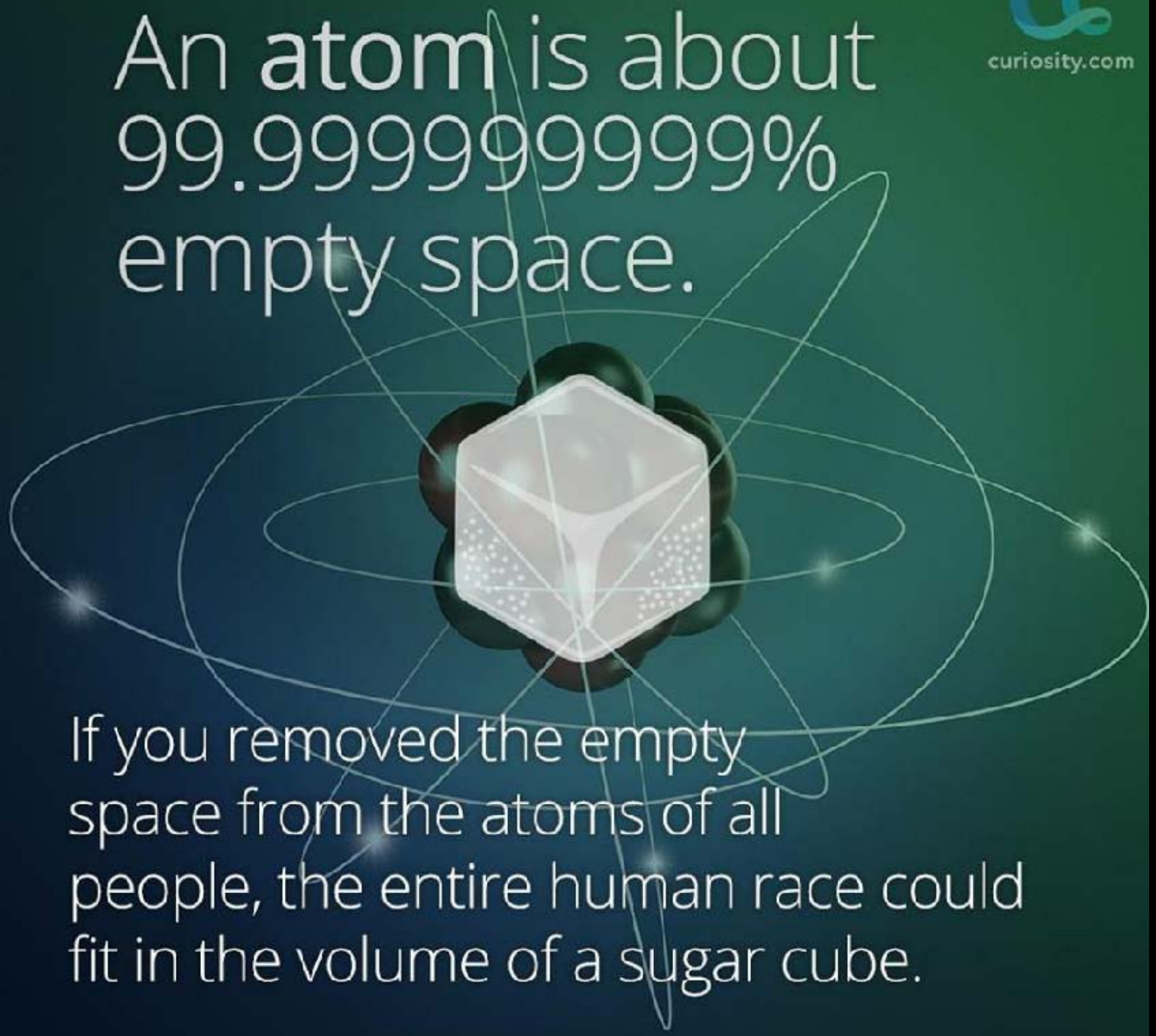




Video: Powers of Ten

curiosity.com

An **atom** is about 99.999999999% empty space.

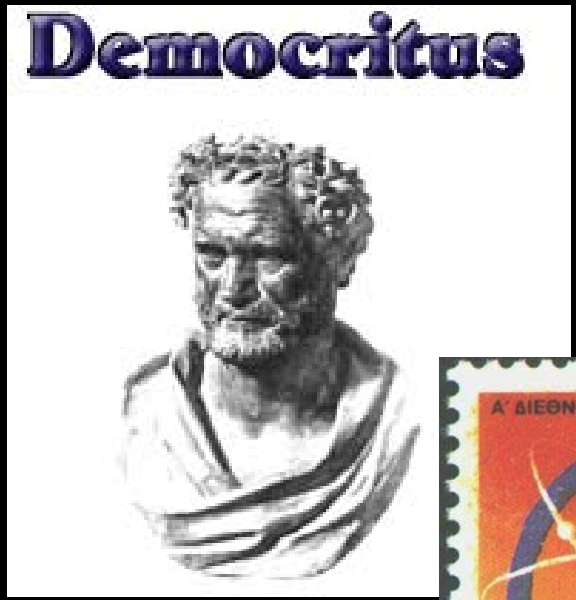


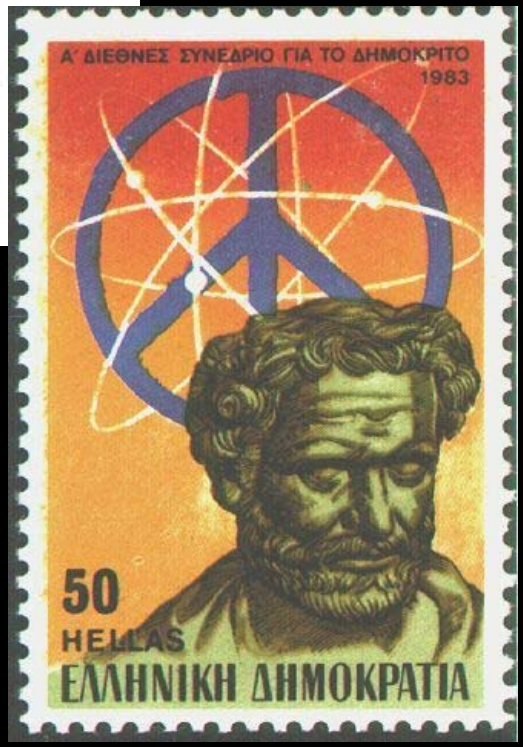
If you removed the empty space from the atoms of all people, the entire human race could fit in the volume of a sugar cube.

Where did it all begin?

The word "**atom**" comes from the Greek word ***"atomos"*** which means ***indivisible***.

The idea that all matter is made up of atoms was first proposed by the Greek philosopher **Democritus** in the 5th century B.C.





Then came the idea of "The 4 Basic Elements"
Earth, Air, Fire, & Water

After that came Alchemy.

The change to "real" Chemistry didn't occur until the first true element was discovered! (1774)

The first element discovered was

Oxygen

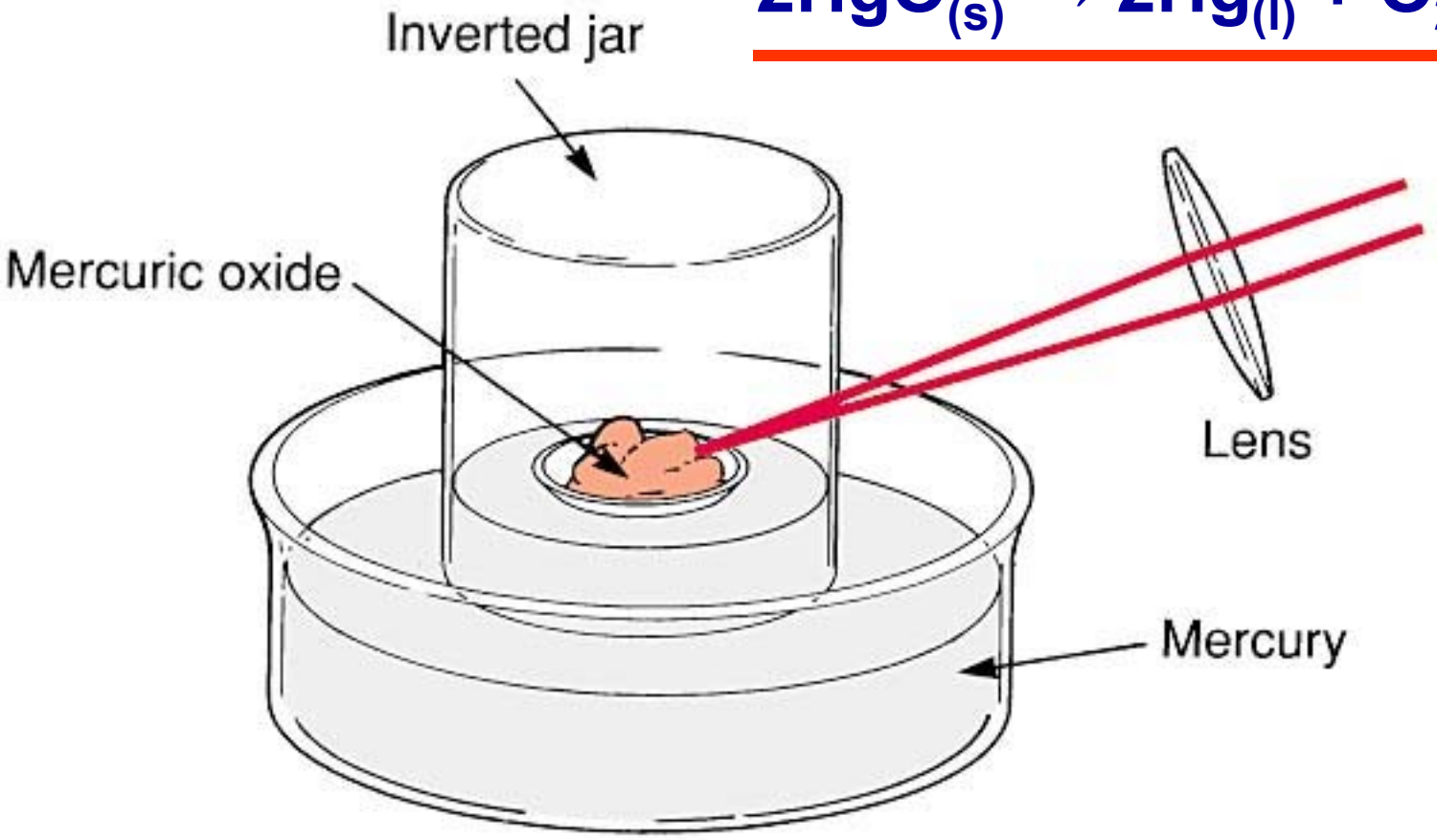
The discovery of oxygen is attributed to 3 scientists (working independently)

- Karl Scheele (1771) (German)
  - first to prepare and describe oxygen
- Joseph Priestley (1774) (British)
  - isolated oxygen gas from mercuric oxide.
  - observed accelerated burning
- Antoine Lavoisier (1784) (French)
  - made accurate measurements and interpreted Priestley's results

Carl Wilhelm Scheele.

Carl Wilhelm Scheele beat Priestley to the discovery but published afterwards.

$$2HgO_{(s)} \rightarrow 2Hg_{(l)} + O_{2\ (g)}$$

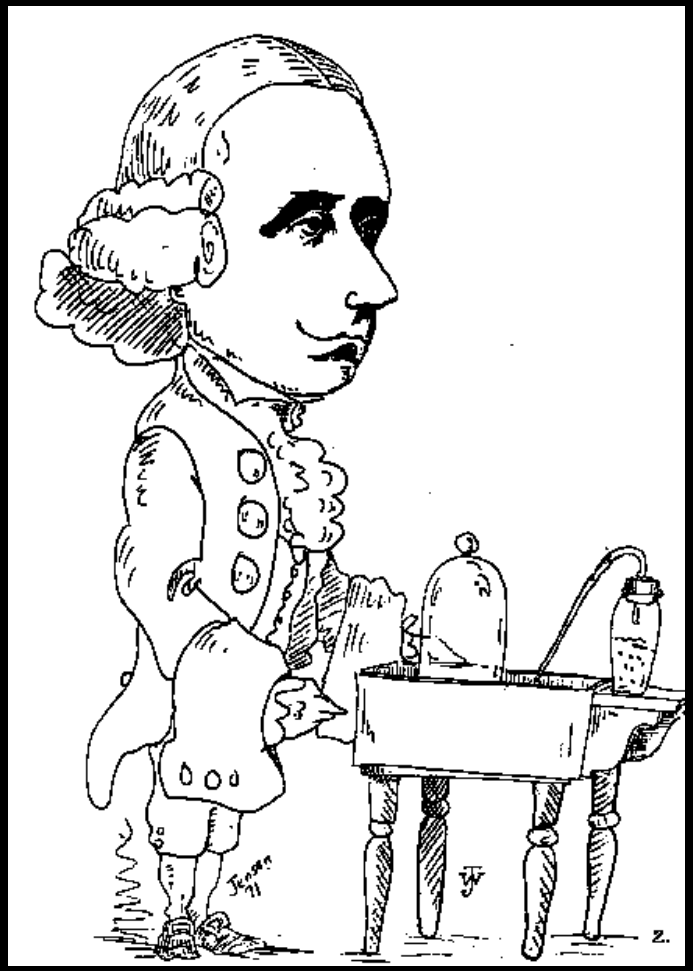


Priestley produced a gas (oxygen) by using sunlight to heat mercuric oxide kept in a closed container. The oxygen forced some of the mercury out of the jar as it was produced, increasing the volume about five times.

Priestley Medal

Source: Roald Hoffman, Cornell University

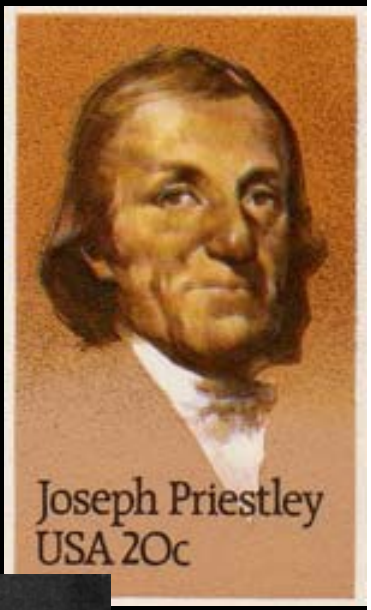
Priestley gets the main credit for discovering oxygen!

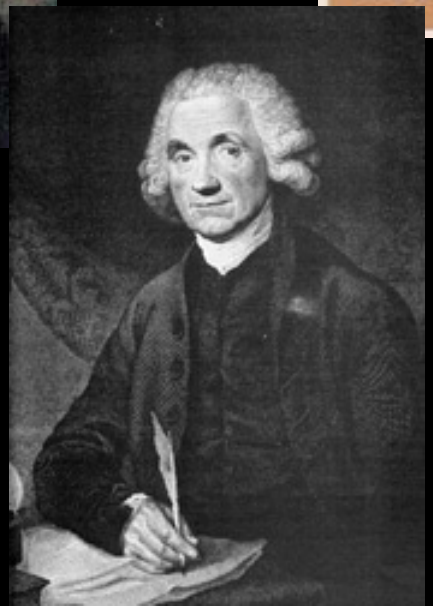


Priestley's Scientific Contributions

DISCOVERY OF 8 GASES

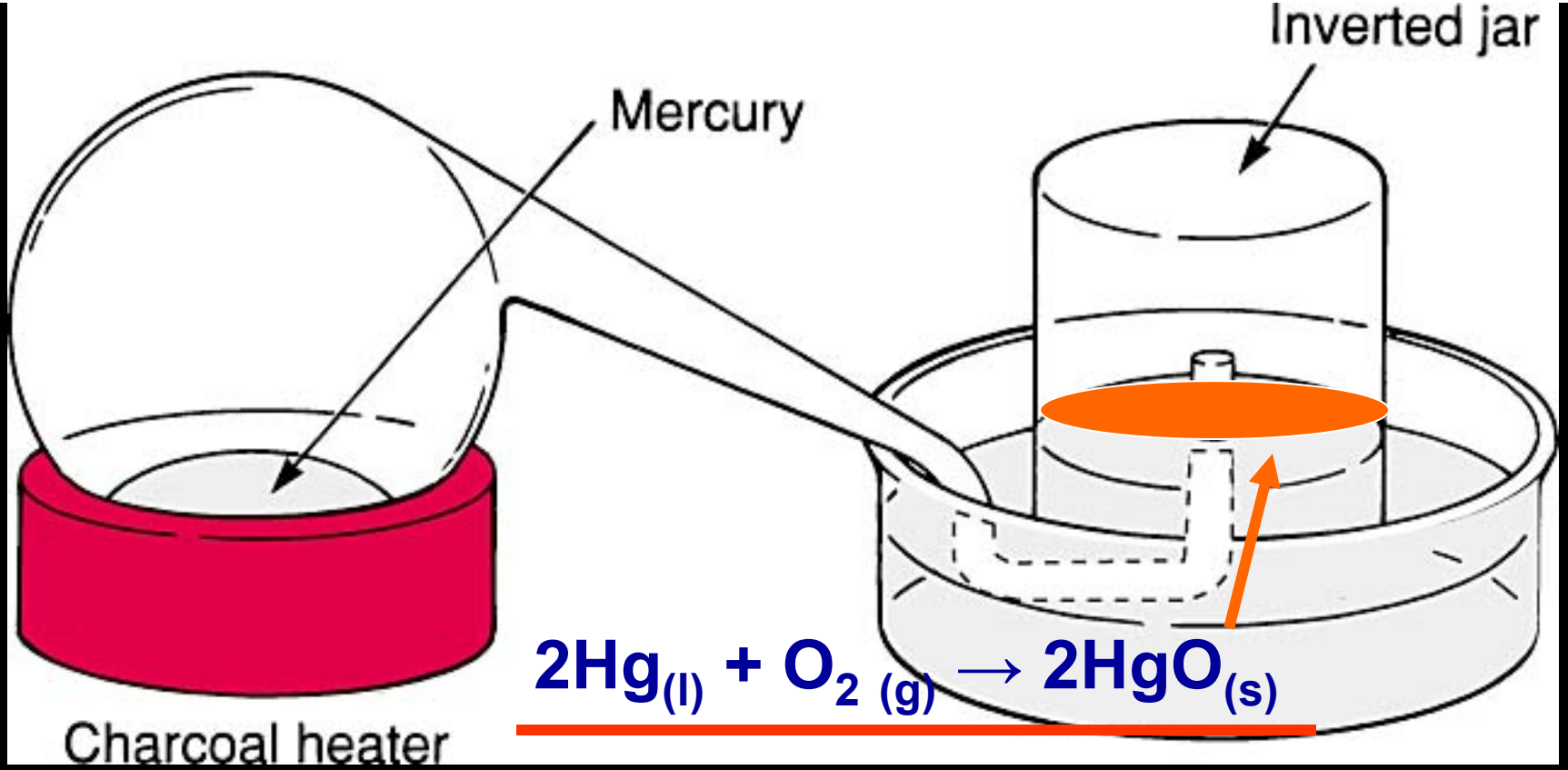
- Oxygen
- Nitrogen
- Carbon Dioxide
- Carbon Monoxide
- Sulfur Dioxide
- Nitrous Oxide
- Nitric Oxide
- Hydrogen Chloride





Priestley: Additional Scientific Contributions

- Discovered the interconnection between photosynthesis and respiration
- Discovered carbonated water
- Discovered that India rubber removed graphite pencil marks - the first rubber eraser



Lavoisier heated a measured amount of mercury to form the red mercuric oxide. He measured the amount of oxygen removed from the jar and the amount of red oxide formed. When the reaction was reversed, he found the original amounts of mercury and oxygen.

Lavoisier: the Founder of Modern Chemistry

Antoine-Laurent Lavoisier

- Lavoisier continued the investigations of Priestly
- Quantitative experiments led to:

  Law of Conservation of Matter

- He systematized the language of chemistry, its nomenclature and rhetoric.

did you know?

did-you-kno.tumblr.com

Antoine Lavoisier, 18th century French chemist, as a final experiment told his college that he would try to blink as long as possible after being beheaded. Some sources say he continued to blink for 30 seconds.

Where do I sign up for this experiment

Properties of Oxygen

P
P
P
P
P
C
C

- Colorless
- Odorless
- Tasteless
- Gas at room temperature
- Slightly soluble in water
- Inflammable (does NOT burn)
- Only part of air that supports combustion

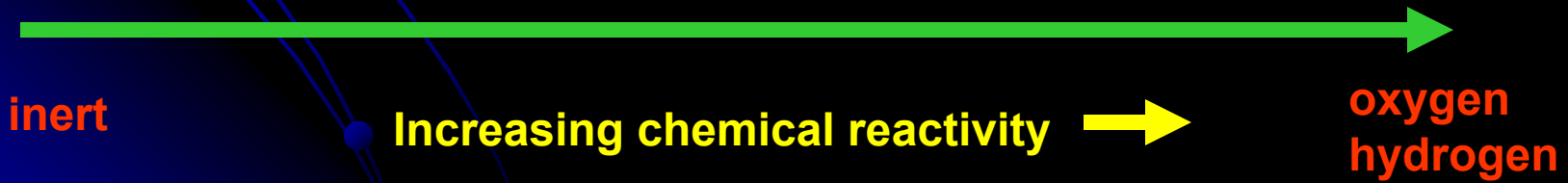
Physical Property or Chemical Property?

Sometimes, when they tried to react substances together, nothing happened!

Substances that DO NOT react are **inert**

They found that *most* materials will react to form new substances. These elements are said to be **chemically active** (**reactive**)

Oxygen is very reactive, so is hydrogen which we will look at next!



The Discovery of Hydrogen

(1731 – 1810)

- Henry Cavendish (1766)
- Reacted various metals with acids producing a salt and hydrogen gas
- Acid + metal → hydrogen gas + salt
- Zinc + sulfuric acid → Hydrogen + zinc sulfate

Word Equation

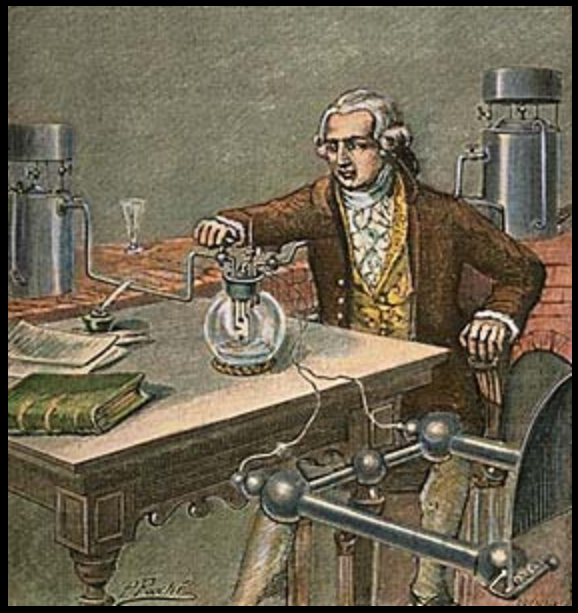
- $Zn_{(s)} + H_2SO_{4(aq)} \rightarrow H_{2\ (g)} + ZnSO_{4\ (aq)}$

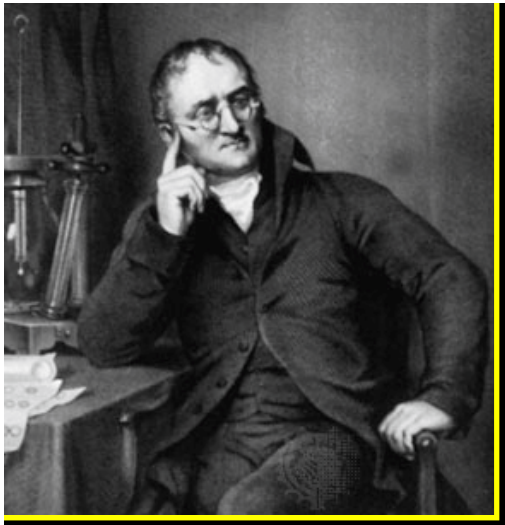
Chemical equation

- While testing the properties of Hydrogen he found that water is a **compound**

Antoine Lavoisier

- Named Priestly's newly discovered gas - "oxygen" - meaning "acid former"
- Named Cavendish's new gas "hydrogen" - meaning "water former"





Dalton's Atomic Theory

John Dalton (1766-1844)

While his theory was ***not*** completely correct, it revolutionized how chemists ***looked*** at matter and brought about chemistry as we know it today (instead of alchemy)

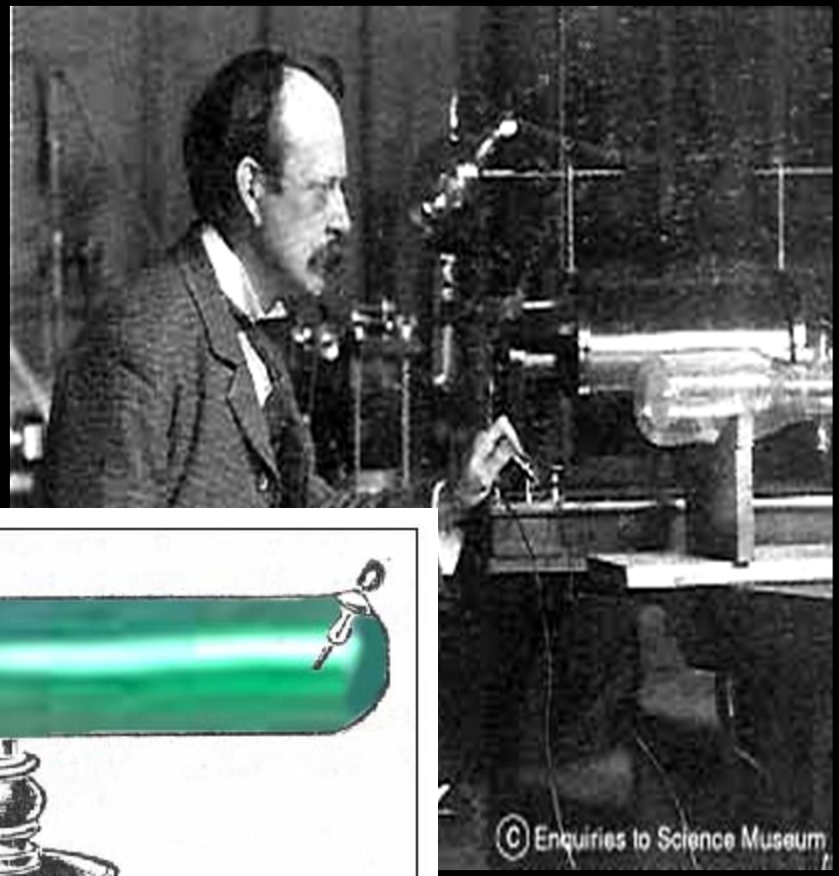
So, it's an important landmark in the history of science.

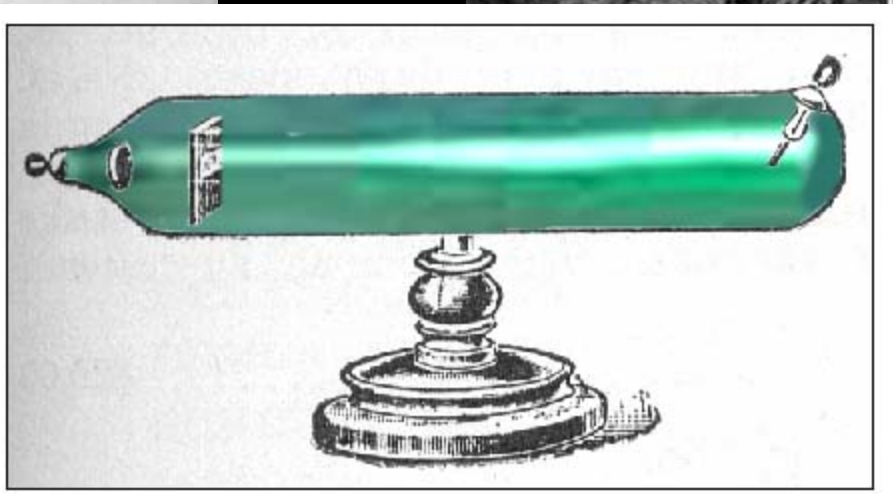
Dalton's Atomic Theory

(experiment based!)

1) All elements are composed of tiny indivisible particles called atoms
2) Atoms of the same element are identical. Atoms of any one element are different from those of any other element.
3) Atoms of different elements combine in simple whole-number ratios to form chemical compounds
4) In chemical reactions, atoms are combined, separated, or rearranged – **but never changed into atoms of another element.**

In 1897, J.J. Thomson used a *cathode ray tube* to study gases.





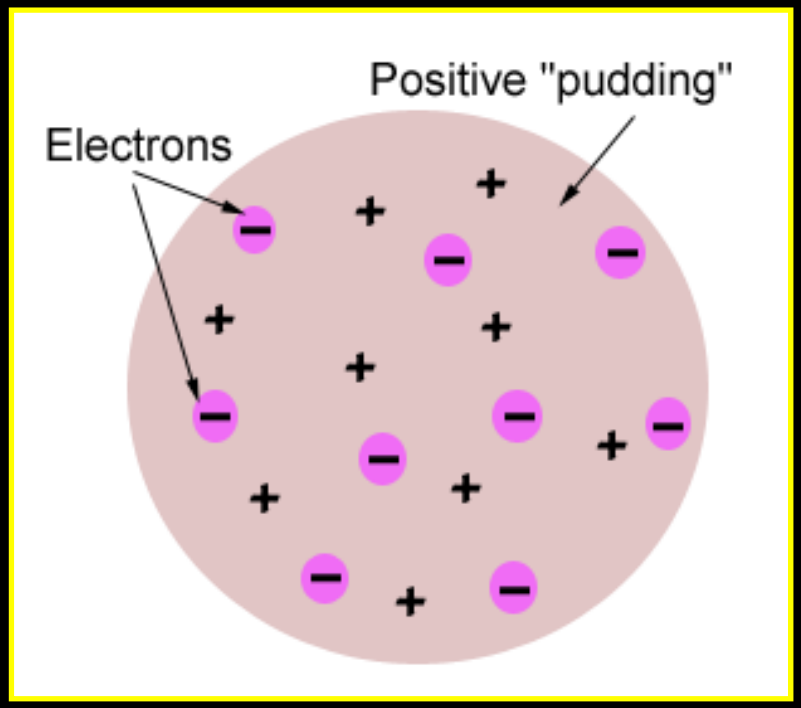
Conclusions from the Study of the Electron:

a) Cathode rays have identical properties regardless of the element used to produce them. Therefore, **all elements must contain identically charged electrons.**

b) **Atoms are neutral**, so there must be a **positive substance** in the atom to balance the negative charge of the electrons

c) **Electrons have so little mass** that atoms must contain other particles that account for most of their mass

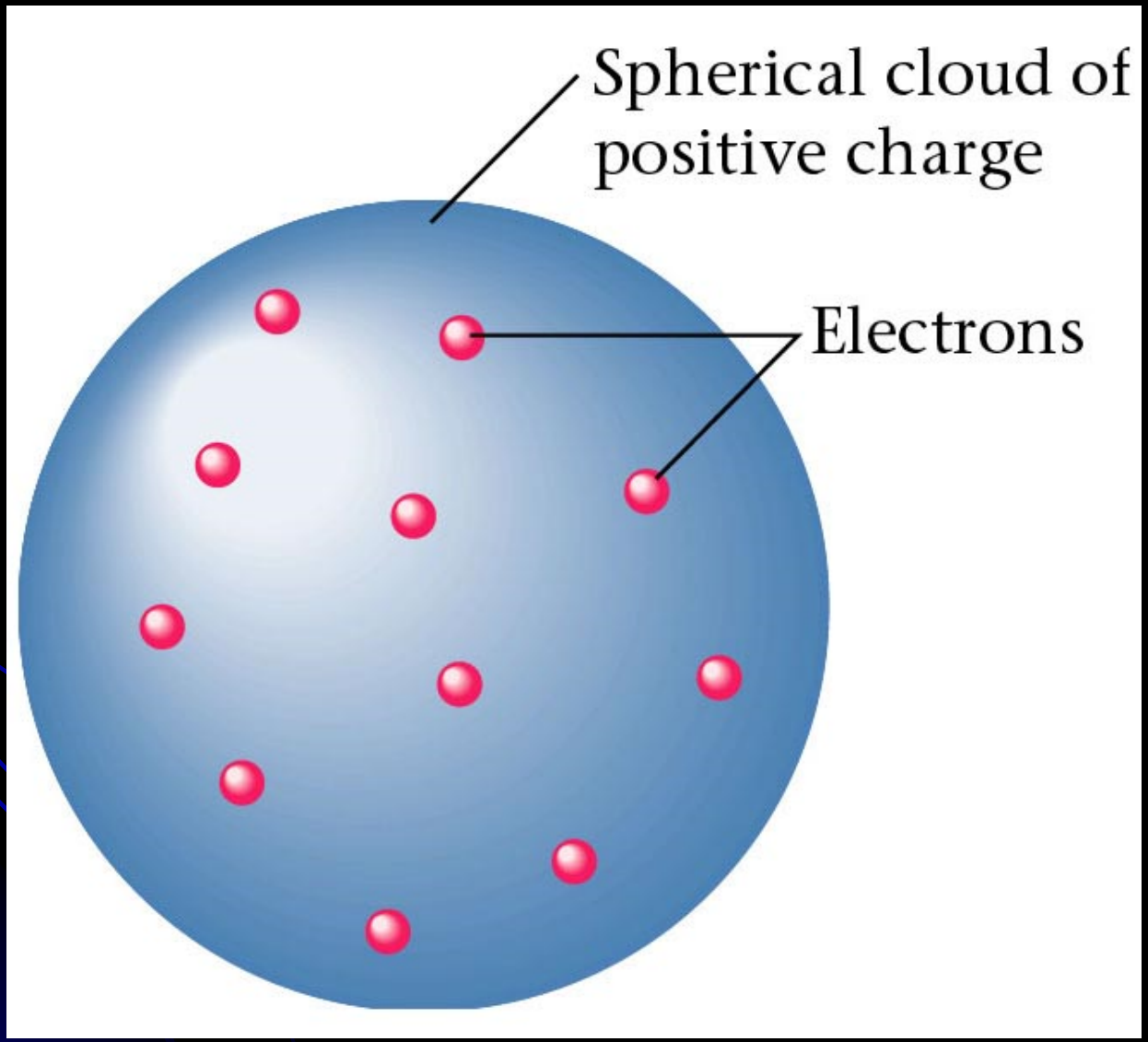
Thomson's Atomic Model



Thomson believed that the electrons were like plums embedded in a positively charged "pudding," thus it was called the "**plum pudding**" model.


THAT MOMENT WHEN YOU..
REALIZE J.J THOMSON DIDNT MAKE PUDDING
memegenerator.net

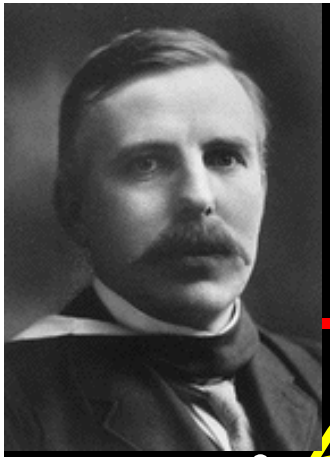
Plum-Pudding Model



Zumdahl, Zumdahl, DeCoste, World of Chemistry 2002, page 56

Ernest Rutherford (1871-1937)
The Nobel Prize in Chemistry 1908

Studied under J. J. Thomson



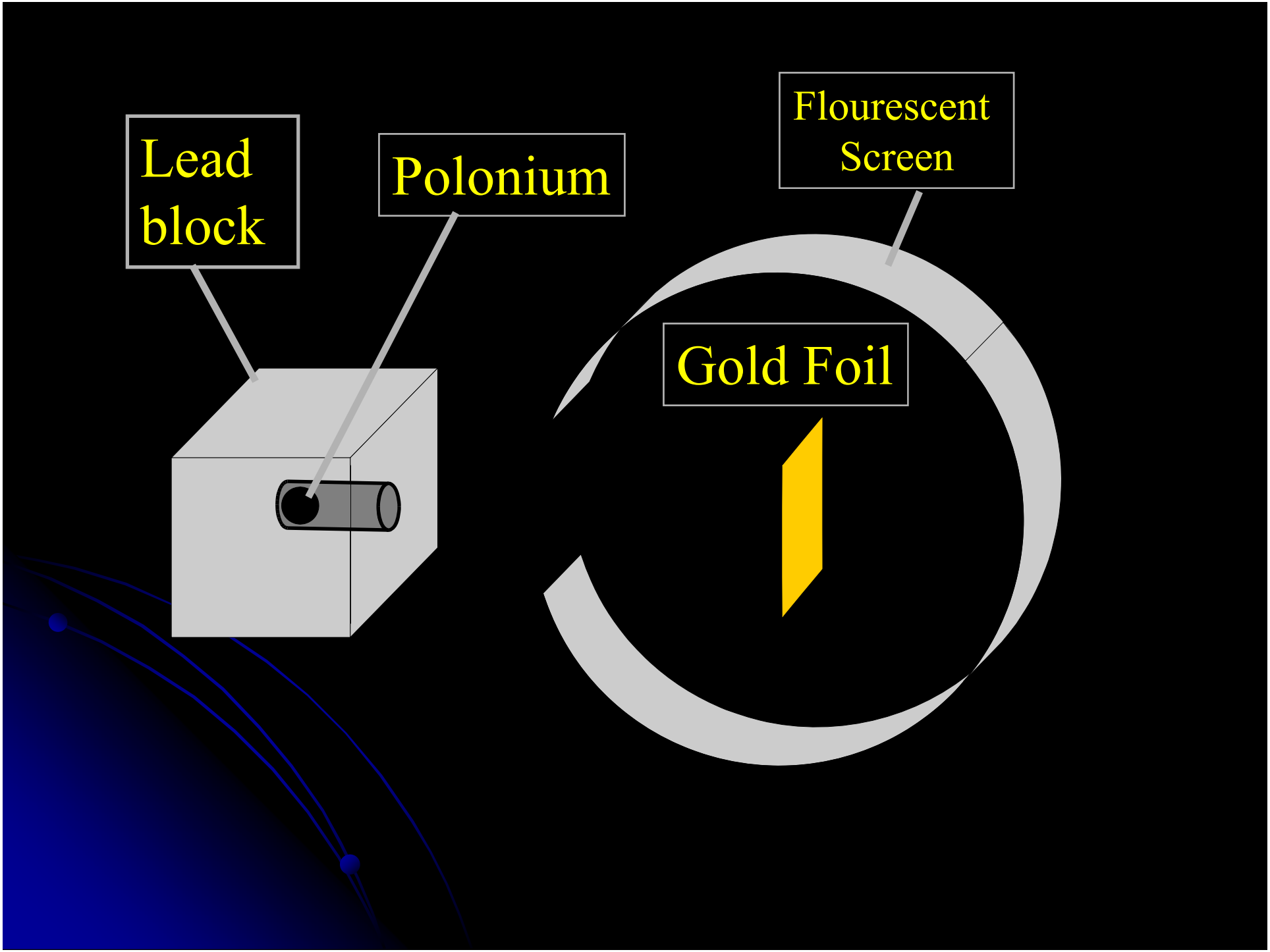
3 Types of Radiation

discovered by Ernest Rutherford

- Alpha (α) – a positively charged helium nucleus $^{4}_{2}\mathrm{He}^{+2}$ $^{4}_{2}He$
- Beta (β) – fast-moving electrons $^{0}_{-1}e$
- Gamma (γ) – like high-energy x-rays $^{0}_{0}\gamma$

Ernest Rutherford's Gold Foil Experiment - 1911

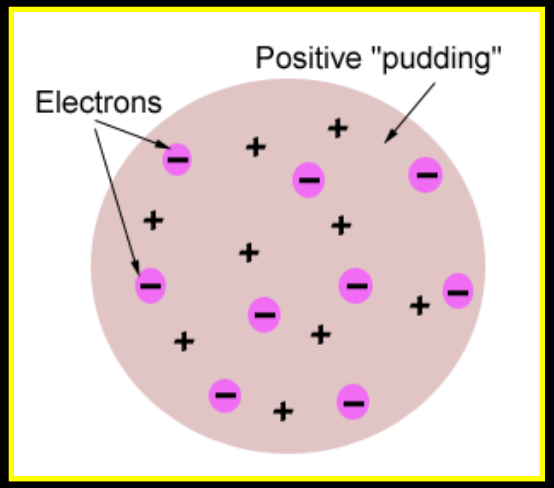
- Shot alpha particles at a thin sheet of gold foil
- Particles that hit on a detecting screen (film) were recorded


Lead block
Polonium
Flourescent Screen
Gold Foil

He Expected:

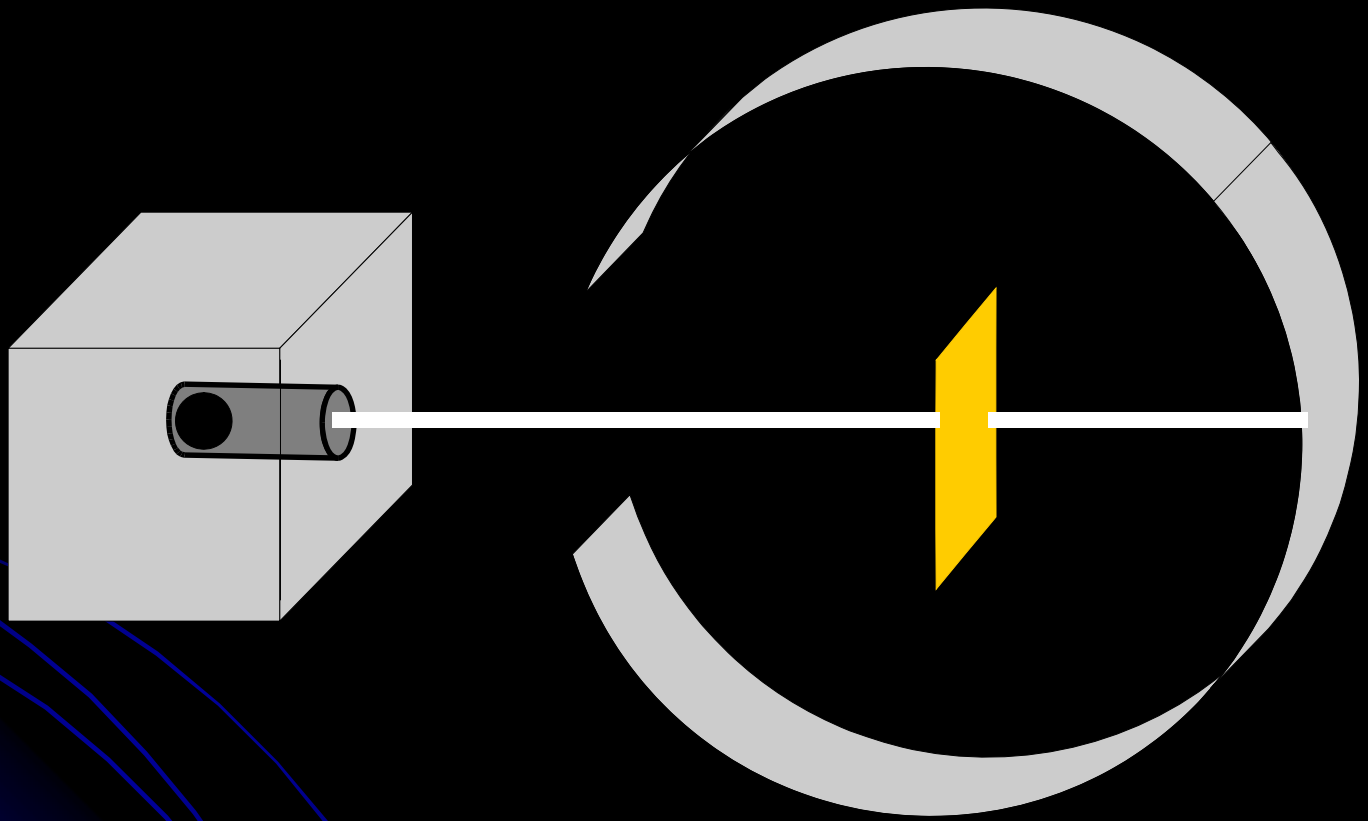
- The alpha particles to pass through the foil without changing direction very much.

  Because…

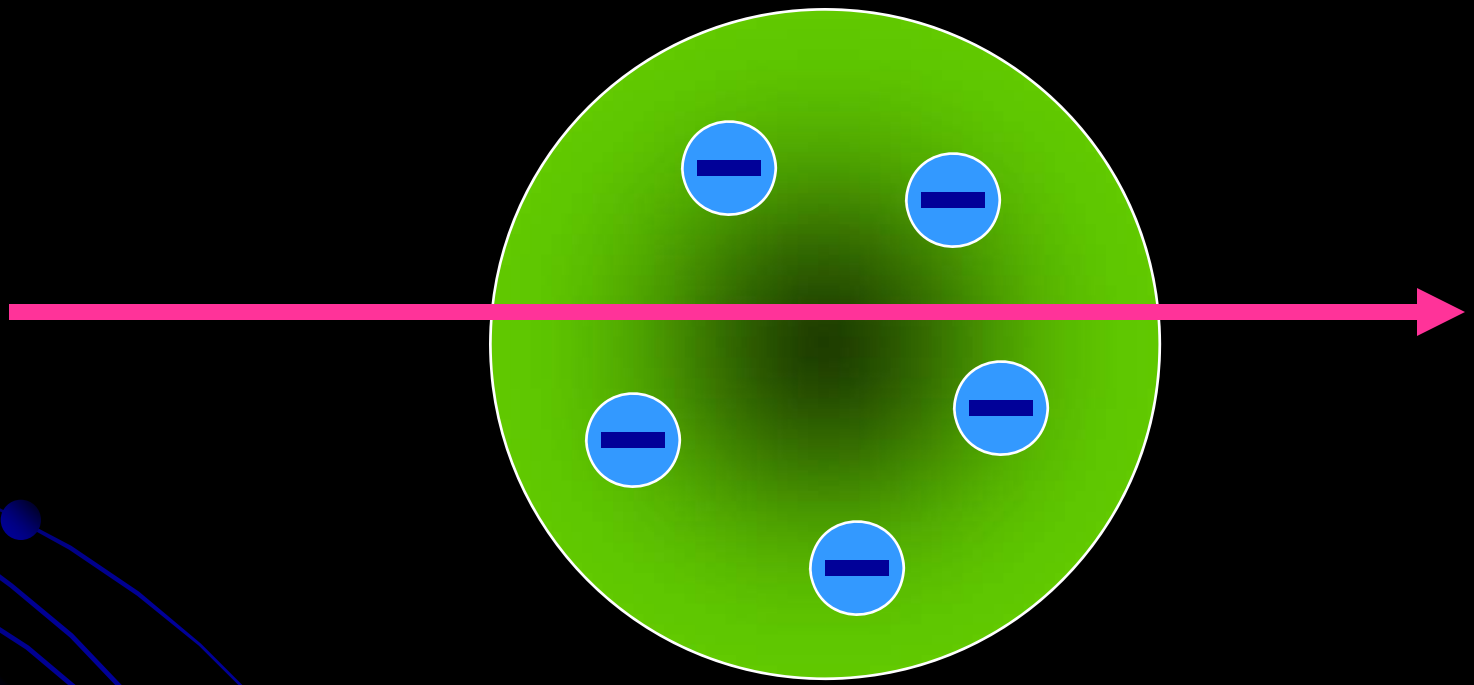


- The positive charges were spread out evenly (according to Thomson's atomic theory). Alone they were not enough to stop the alpha particles.

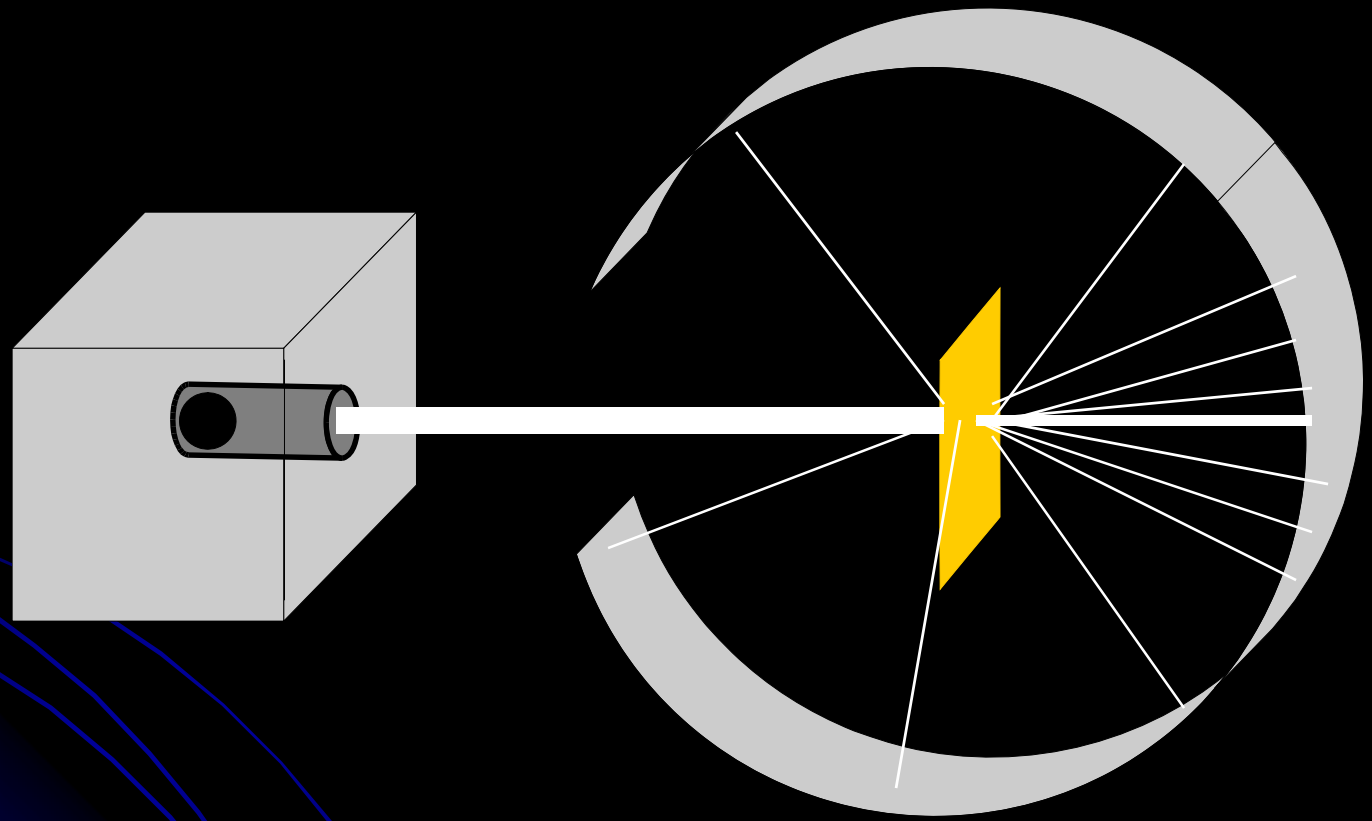
What he expected



Again, because he thought the mass was evenly distributed in the atom

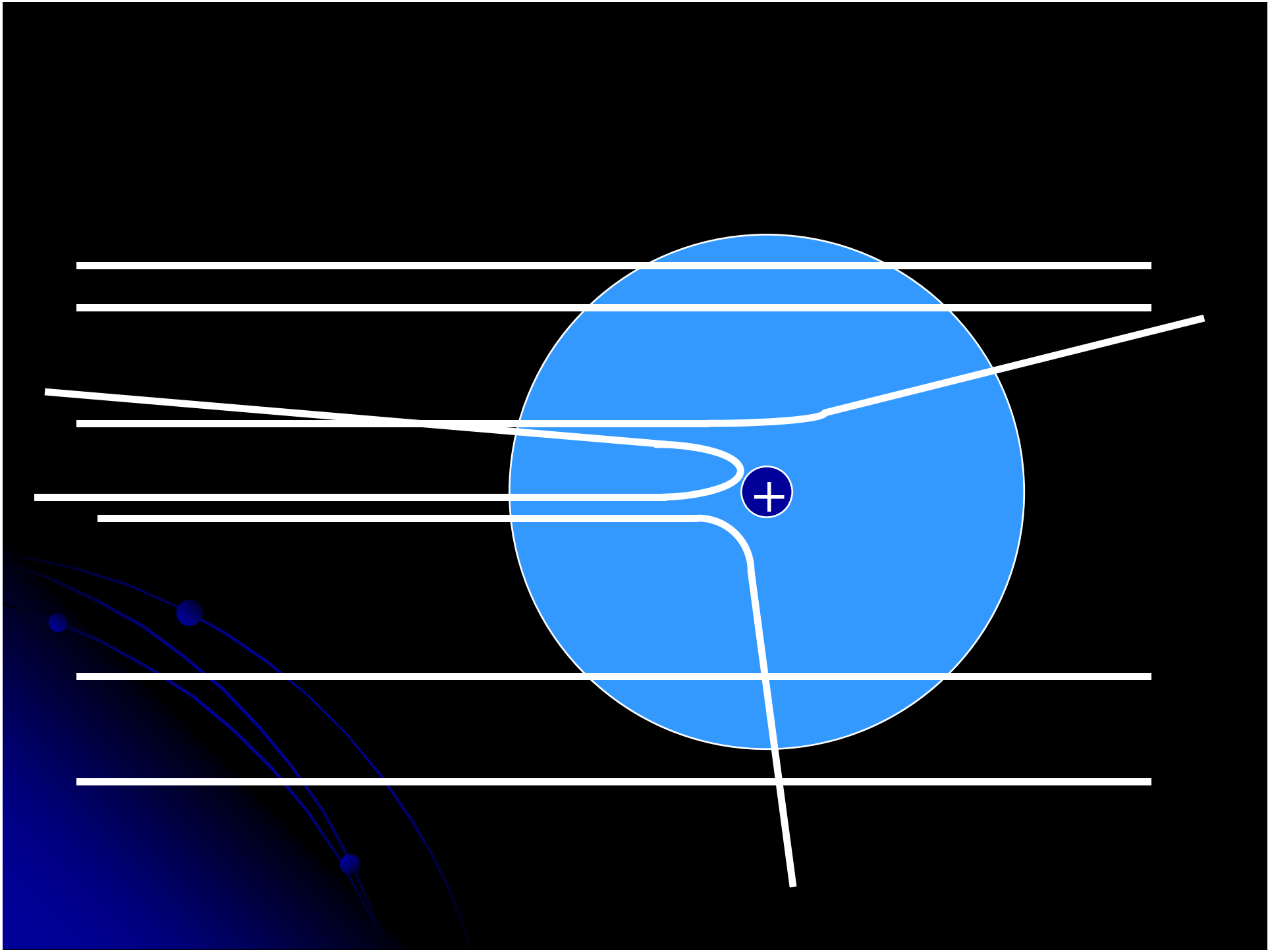


What he got



Rutherford's Observations

- Most of the particles went straight through the foil (what he expected)
- A few particles were slightly deflected
- Still fewer actually bounced back towards the source!
  - Astonishing!!!
- Rutherford said it was like firing a Howitzer shell at a piece of tissue paper & having it bounce back & hit you!



Rutherford's Conclusions

- Since most of the particles went through the foil - atoms are mostly empty space
- Because a few + particles were deflected they must have come close to a positively charged core
- Since a very few particles were deflected straight back, the positively-charged core must be very dense
-
- This small dense positive area is the nucleus

The Rutherford Atomic Model

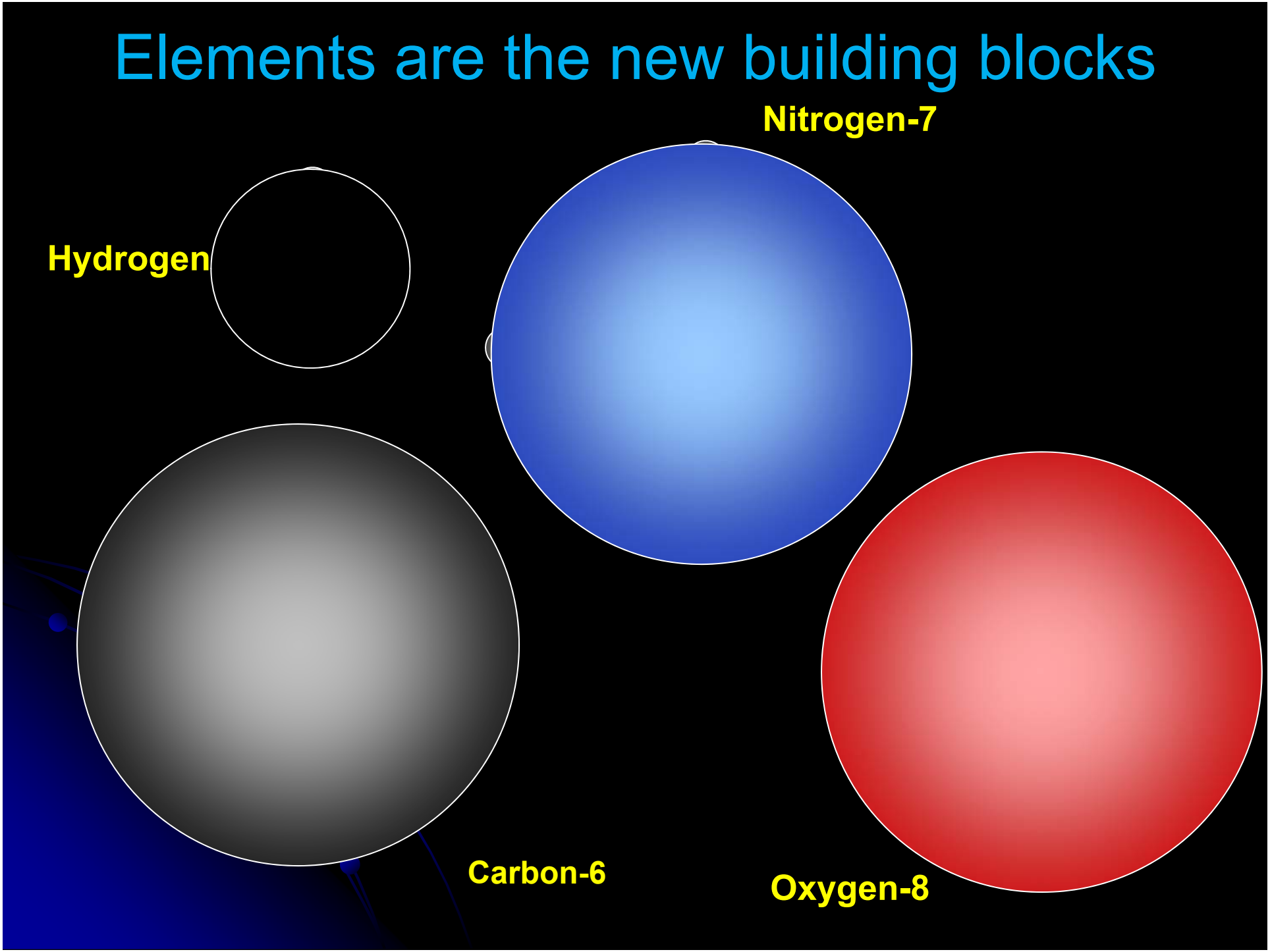
Based on his experimental evidence:

- The atom is mostly empty space
- All the positive charge, and almost all the mass is concentrated in a small area in the center. He called this a "nucleus"
- The electrons are distributed around the nucleus, and occupy most of the volume
- His model was called a "nuclear model"

Subatomic Particles

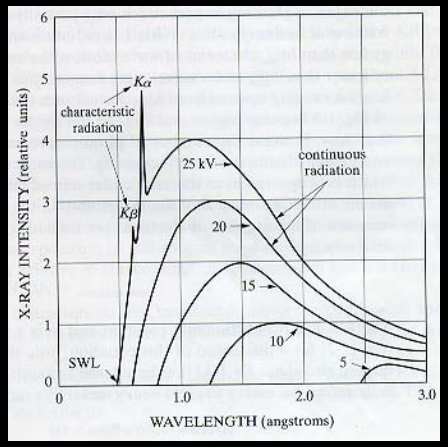
Particle	Charge	Mass (g)	Location
Electron (e^-)	-1	9.11×10^{-28}g (virtually 0)	outside nucleus
Proton (p^+) (H^+)	+1	1 amu (1.7×10^{-24}g)	in nucleus
Neutron (n^o)	0	1 amu (1.67×10^{-24}g)	in nucleus

Elements are the new building blocks



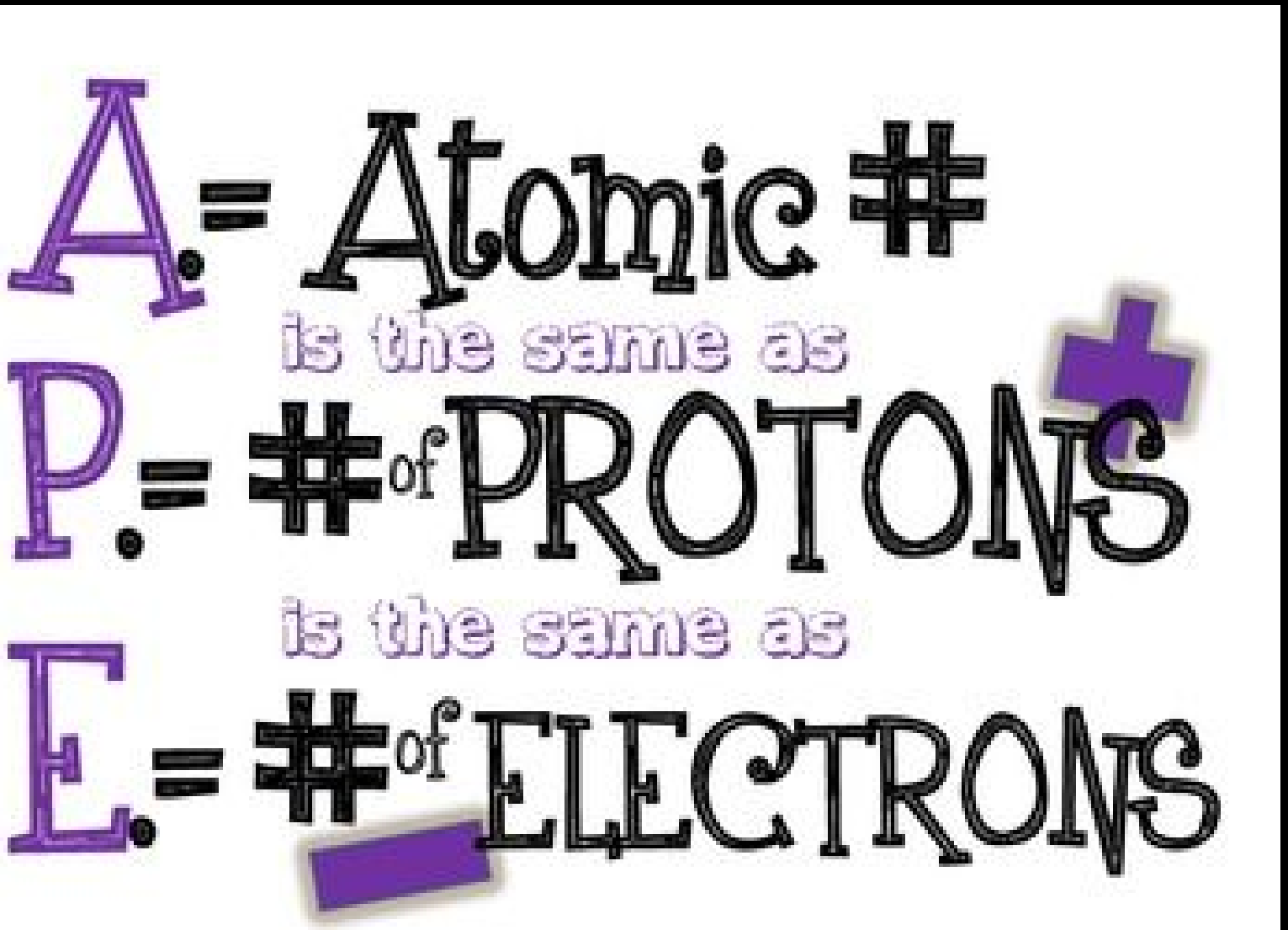
Atomic Number

Henry Moseley – used x-ray spectra & came up with the idea of the Atomic Number



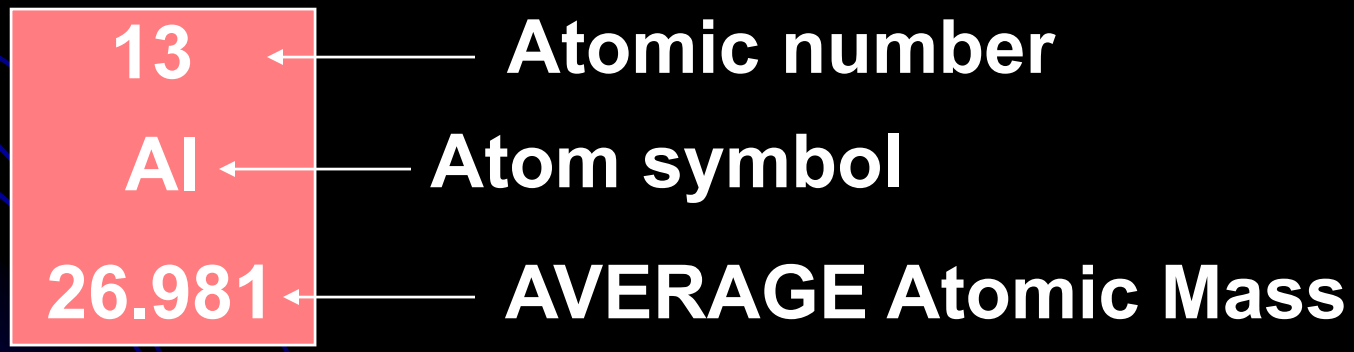
- Elements are different because they contain different numbers of **PROTONS**
- The "**atomic number**" of an element is the number of protons in the nucleus
- Since all atoms are neutral: the

  # protons in an atom = # electrons


A.= Atomic #
is the same as
P.= #of PROTONS
is the same as
E.= #of ELECTRONS

Atomic Number, Z

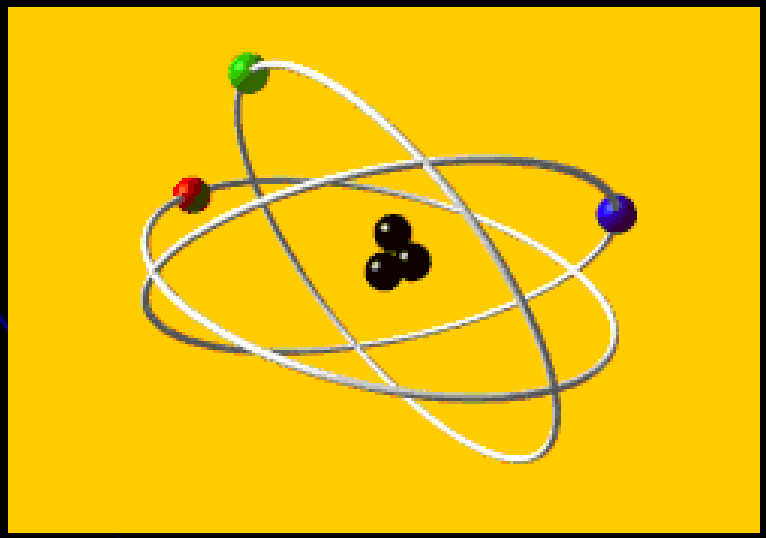
All atoms of the same element have the same number of protons in the nucleus, Z

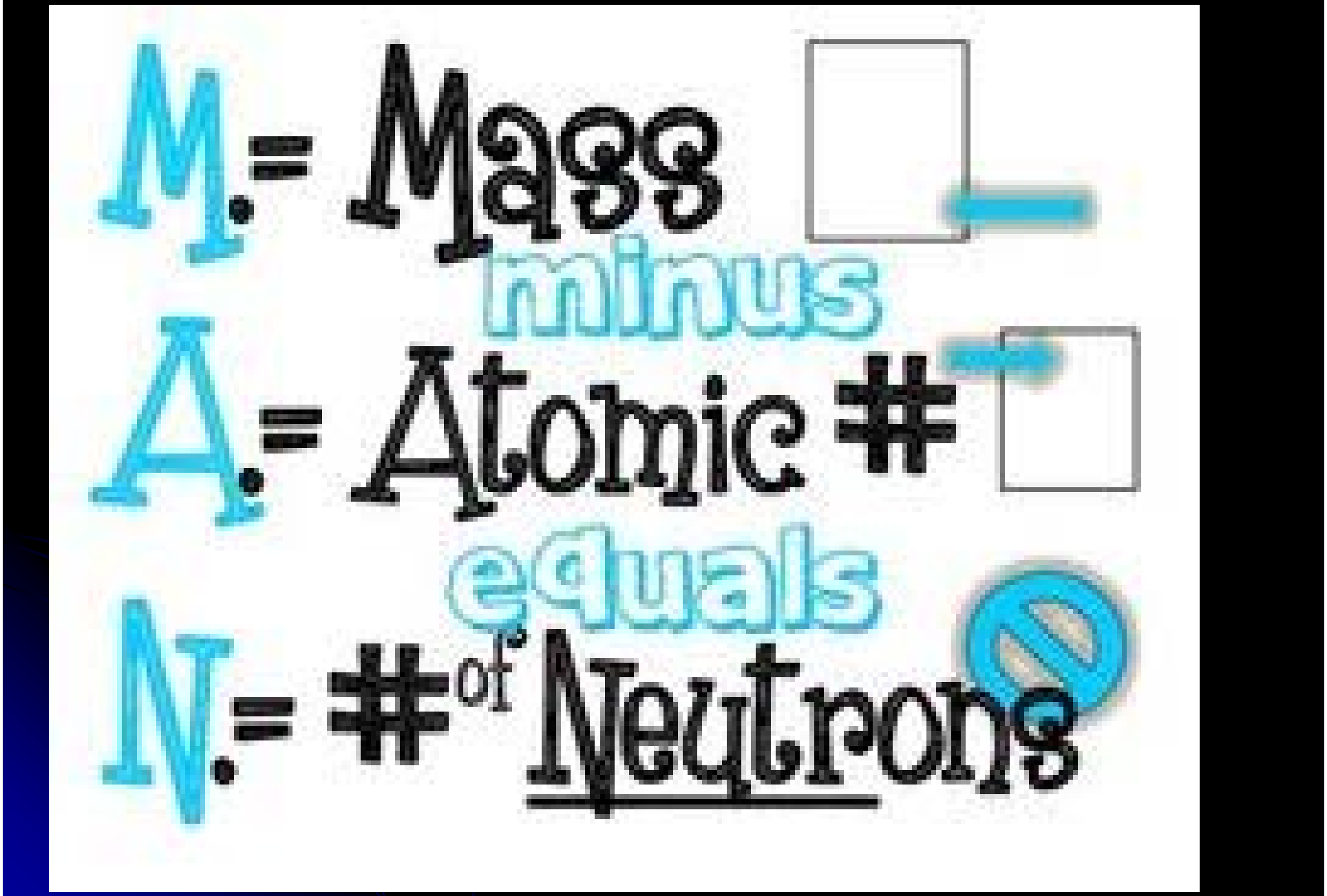


Mass Number

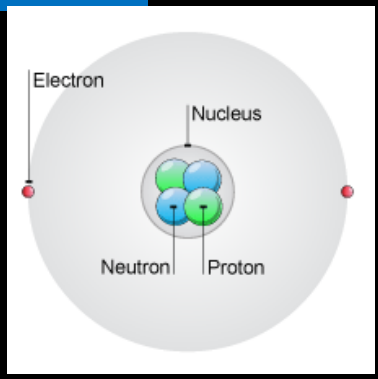
Mass number is the number of protons and neutrons in the nucleus of an isotope:

Mass # = # protons + # neutrons




M.= Mass
minus
A.= Atomic #
equals
N.= # of Neutrons

Subatomic Particles



- ATOM
  - NUCLEUS
    - PROTONS
      - POSITIVE CHARGE
    - NEUTRONS
      - NEUTRAL CHARGE
  - ELECTRONS
    - NEGATIVE CHARGE

Most of the atom's mass

Atomic number equals the # of...

of ... equal in a neutral atom