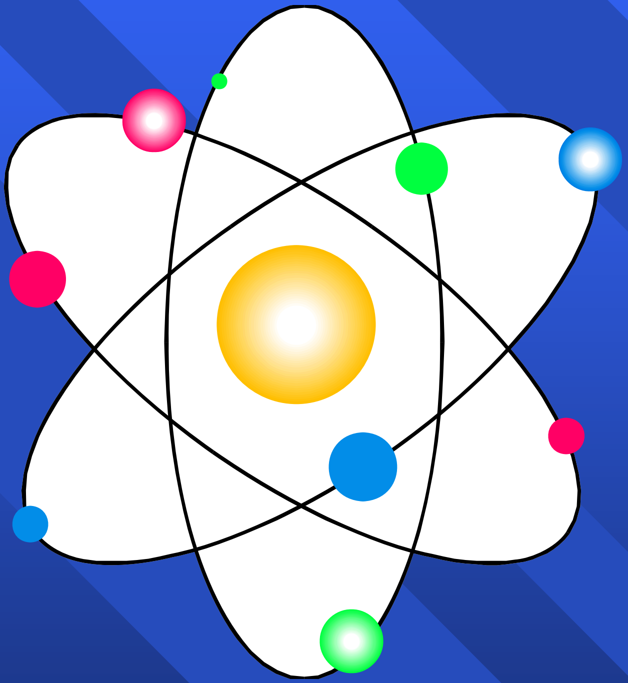


Atoms and their structure

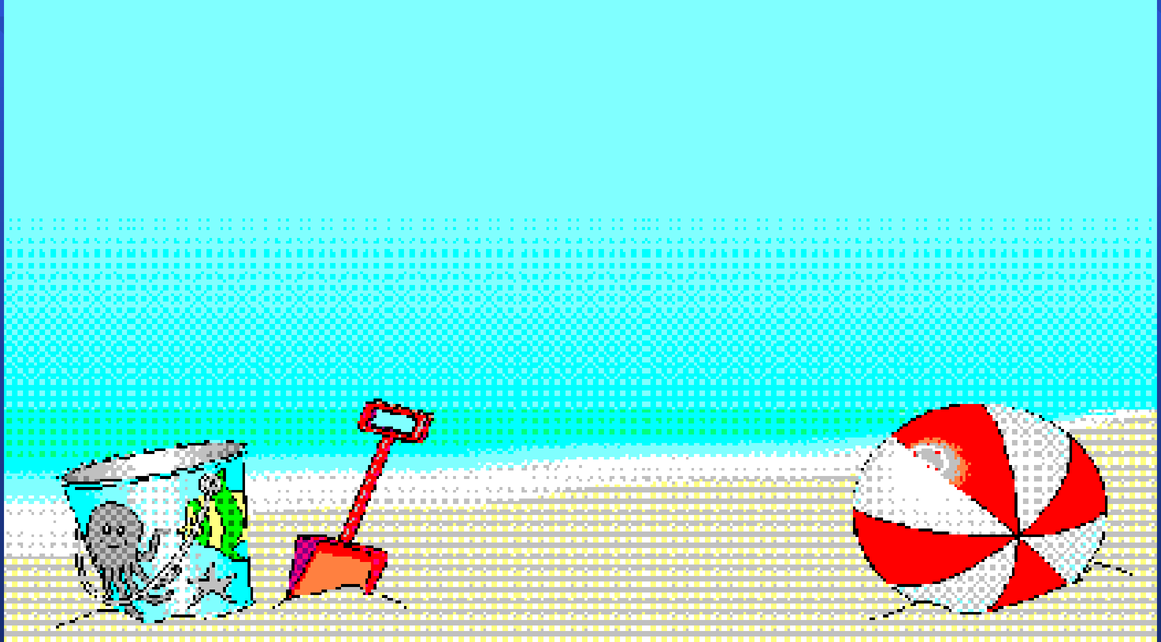
History of the atom

- Not the history of atom, but the idea of the atom
- Original idea Ancient Greece (400 B.C..)
- Democritus and Leucippus Greek philosophers

History of Atom

- Looked at beach
- Made of sand
- Cut sand - smaller sand

- Smallest possible piece?
- Atomos - not to be cut



Another Greek

- Aristotle - Famous philosopher
- All substances are made of 4 elements
- Fire - Hot
- Air - light
- Earth - cool, heavy
- Water - wet
- Blend these in different proportions to get all substances

Who Was Right?

- Greek society was slave based
- Beneath Famous to work with hands
- did not experiment
- Greeks settled disagreements by argument
- Aristotle was more famous
- He won
- His ideas carried through middle ages.
- Alchemists change lead to gold

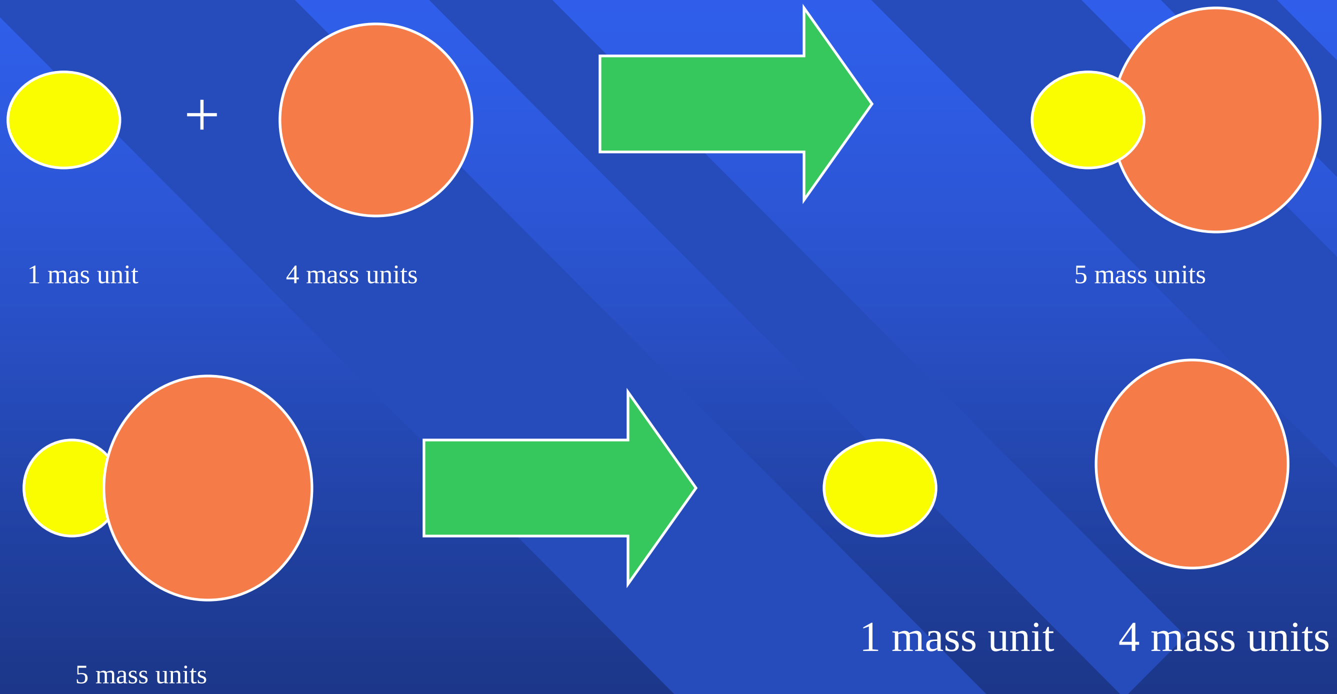
Who’s Next?

- Late 1700’s - John Dalton- England
- Teacher- summarized results of his experiments and those of other’s
- In Dalton’s Atomic Theory
- Combined ideas of elements with that of atoms

Dalton’s Atomic Theory

1. All matter is made of tiny indivisible particles called atoms.
2. Atoms of the same element are identical, those of different atoms are different.
3. Atoms of different elements combine in whole number ratios to form compounds
4. Chemical reactions involve the rearrangement of atoms. No new atoms are created or destroyed.

Dalton’s Theory and Law of Conservation of mass



1 mas unit + 4 mass units → 5 mass units

5 mass units → 1 mass unit 4 mass units

Law of Definite Proportions (#3)

- Each compound has a specific ratio of elements
- It is a ratio by mass
- Water is always 16 grams of oxygen to 2 grams of hydrogen
- H_2O = 2 g H to 16 g O (always)
- H_2O_2 = 2 g H to 32 g O
- CO = 12 g C to 16 g O
- CO_2 = 12 g C to 32 g O

Law of Multiple Proportions

- If two or more different compounds are composed of the same two elements, the masses of the second element combined with a certain mass of the first element can be expressed as ratios of small whole numbers.
- Example: H_2O & H_2O_2

  Water has 16 g O, peroxide 32 g O

  32g/16g = 1:2 ratio

What?

- Another example:

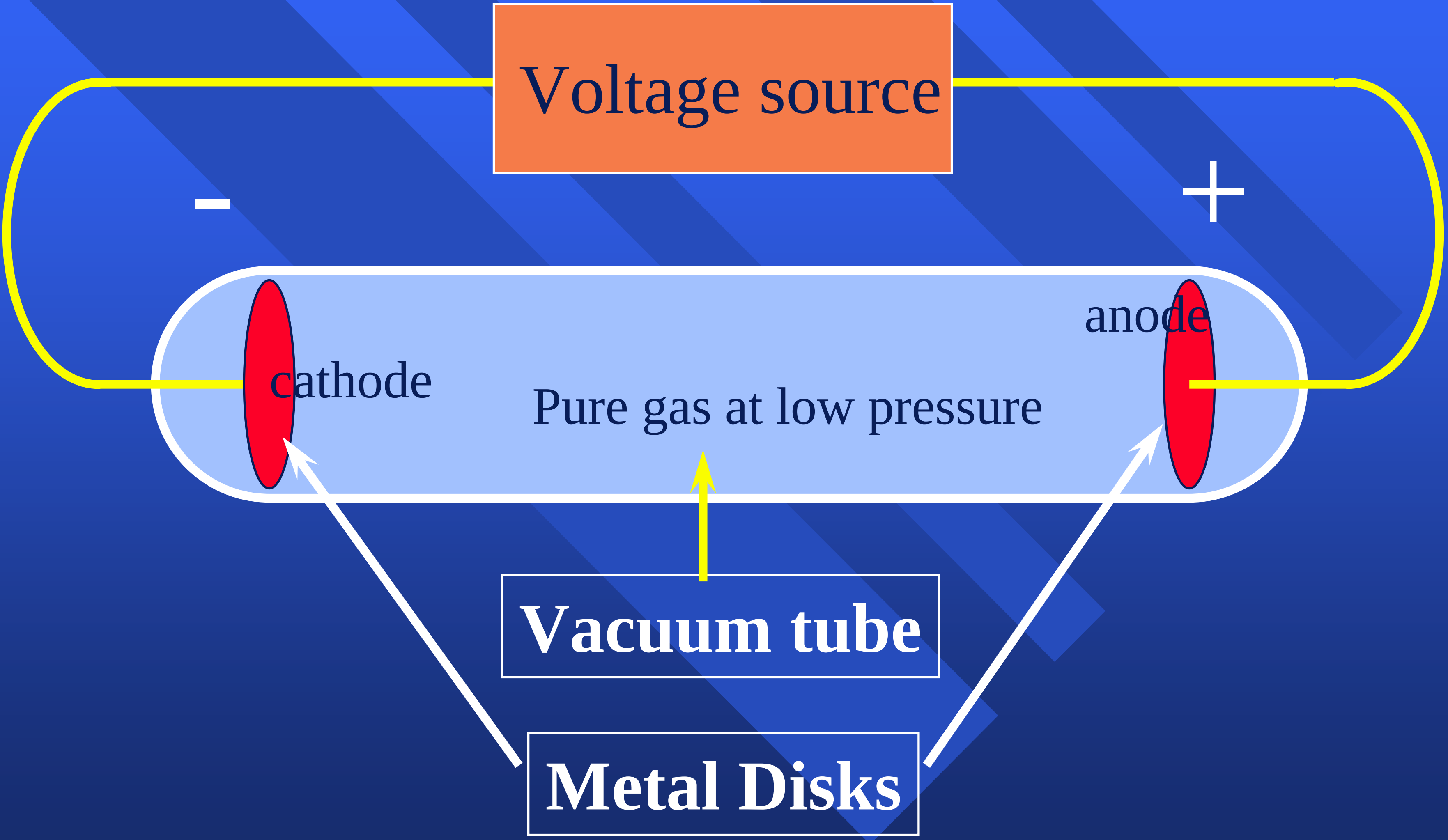
  CO is Carbon monoxide

  CO_2 is Carbon dioxide

Parts of Atoms

- J. J. Thomson - English physicist. 1897
- Made a piece of equipment called a cathode ray tube (CRT)
- It is a vacuum tube - all the air has been pumped out.
- Thompson pumped a pure gas at low pressure into the CRT
- A current flows easily through a gas at low pressure. Why?

Thomson’s Experiment



Voltage source

-

+

cathode

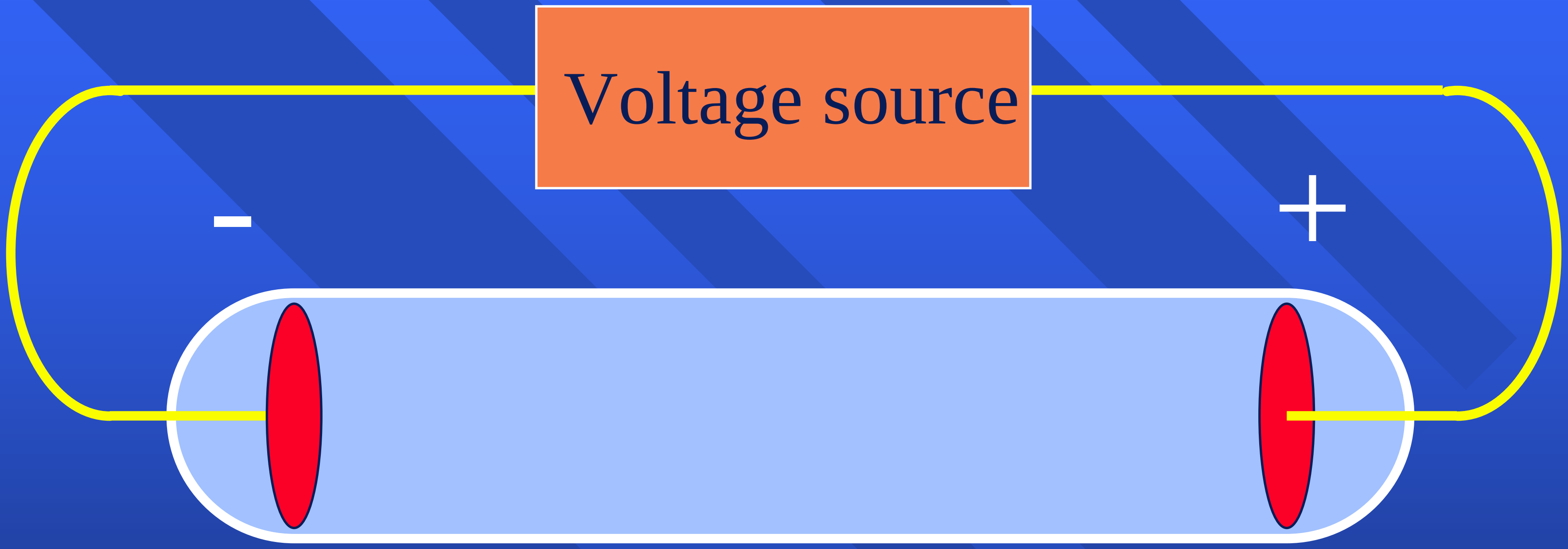
anode

Pure gas at low pressure

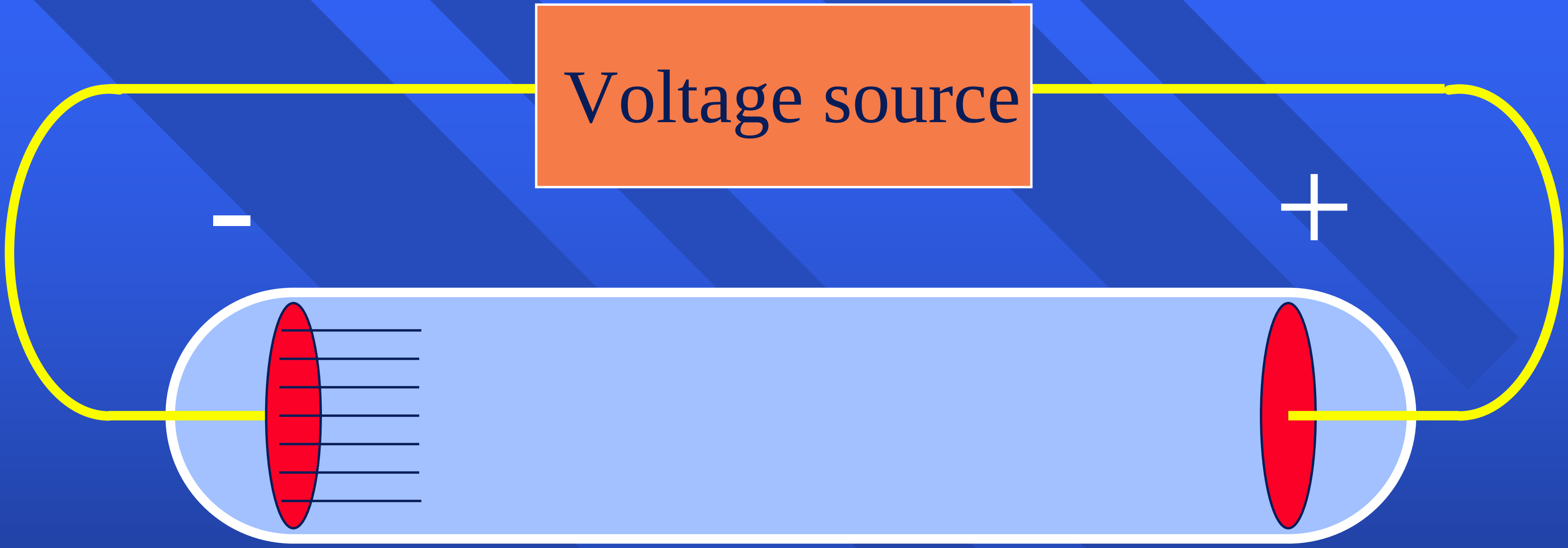
Vacuum tube

Metal Disks

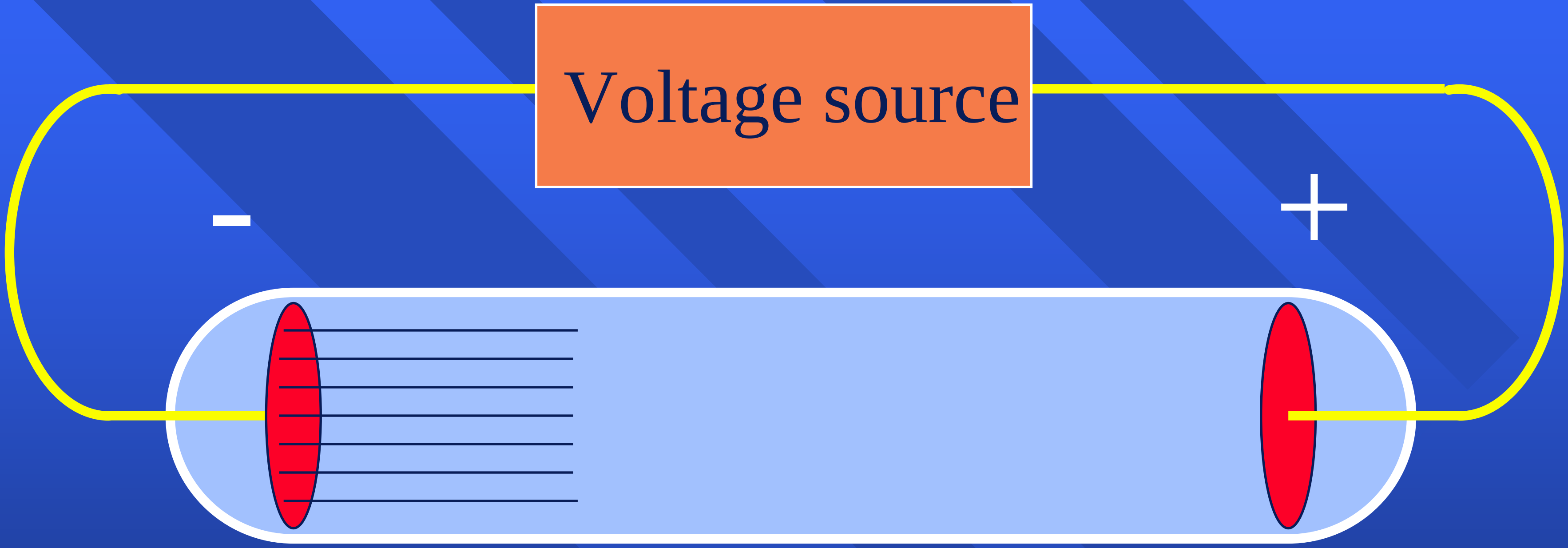
Thomson’s Experiment



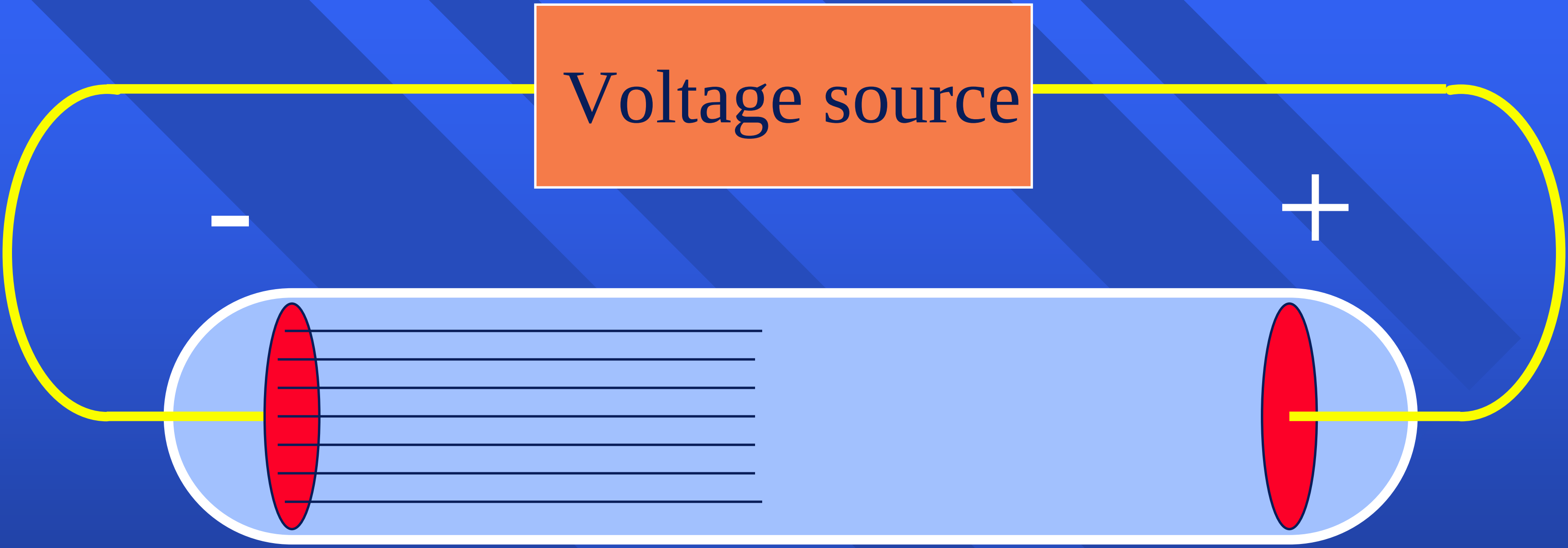
Thomson’s Experiment



Thomson’s Experiment

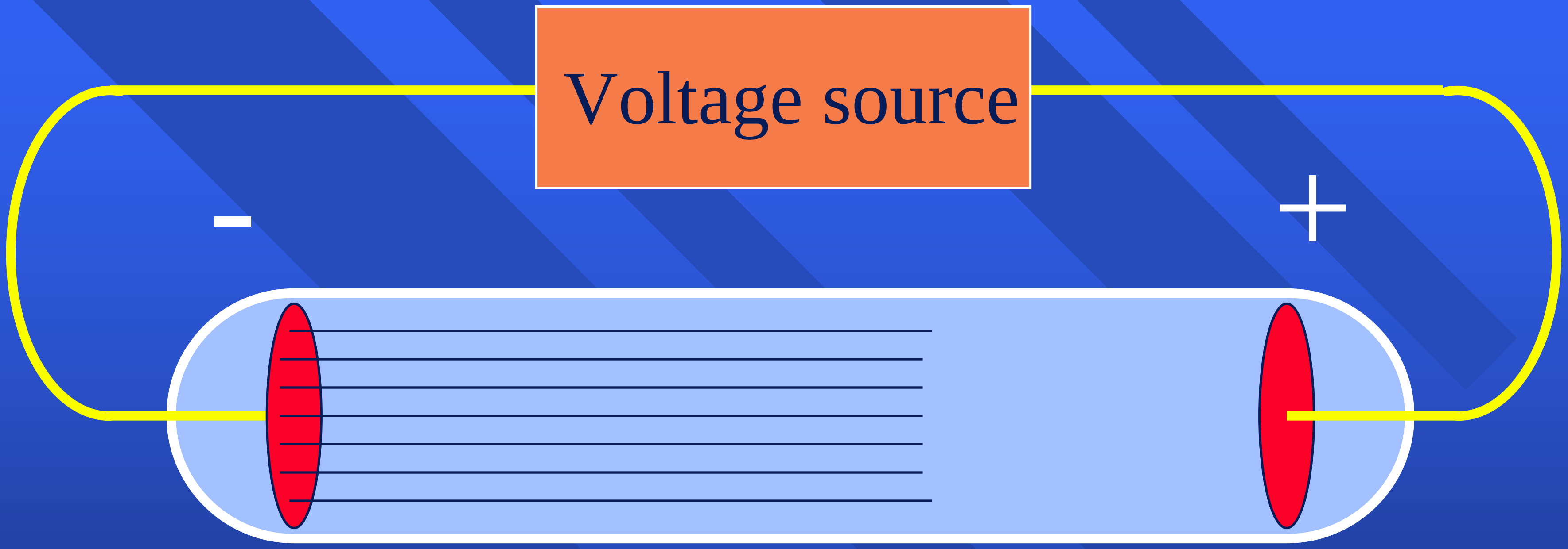


Thomson’s Experiment



- Passing an electric current makes a beam appear to move from the negative to the positive end

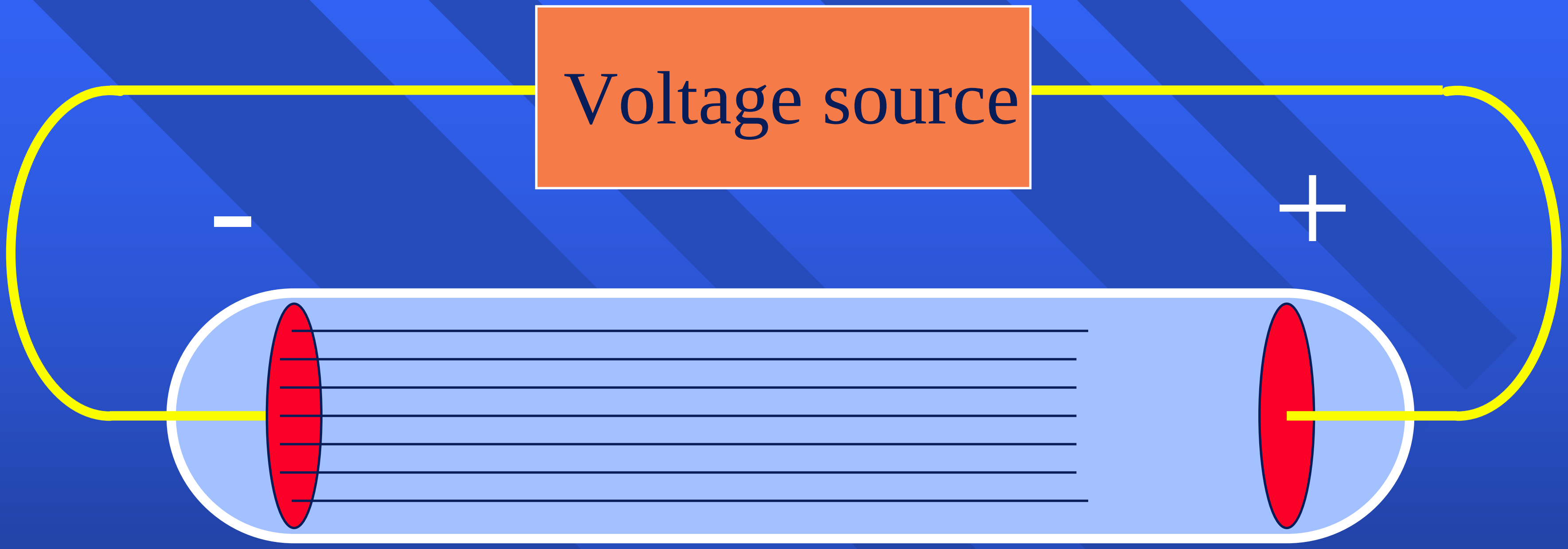
Thomson’s Experiment



Voltage source

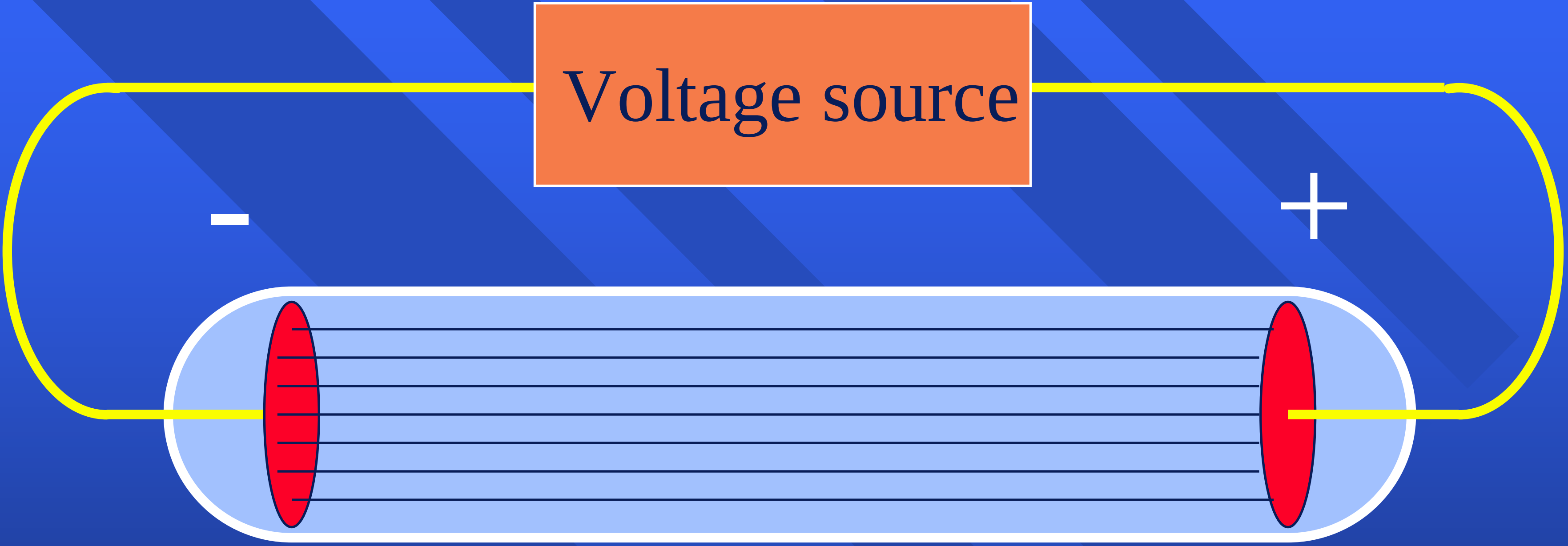
- Passing an electric current makes a beam appear to move from the negative to the positive end

Thomson’s Experiment



- Passing an electric current makes a beam appear to move from the negative (cathode) to the positive end (anode)

Thomson’s Experiment

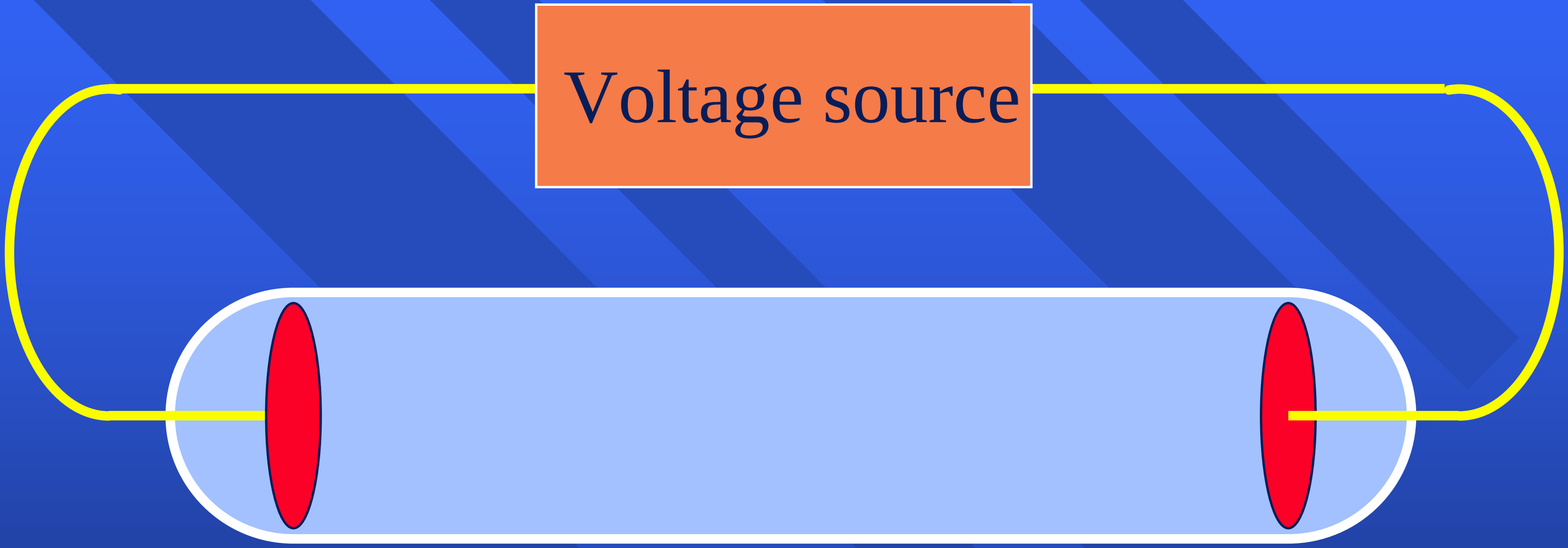

Voltage source

-

+

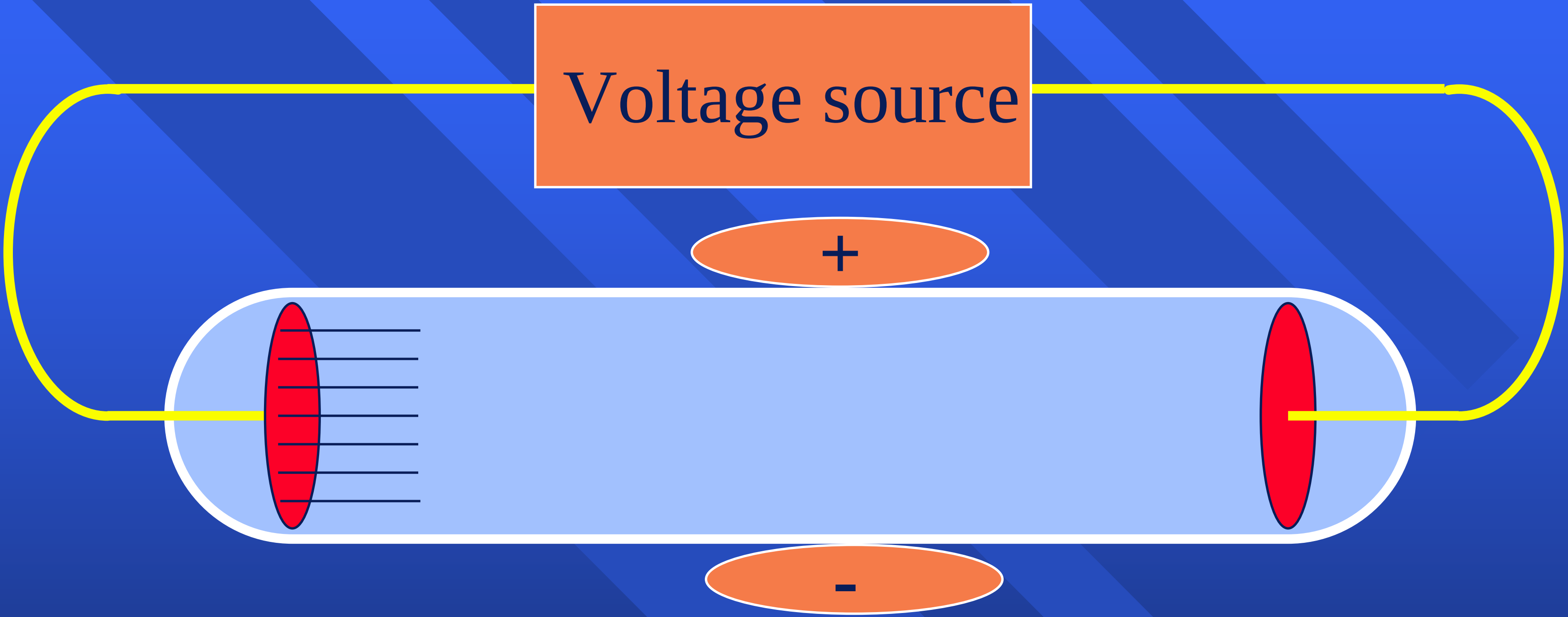
- Passing an electric current makes a beam of light appear to move from the cathode to the anode
- Stream of light changed colors if he changed gases. Why?

Thomson’s Experiment



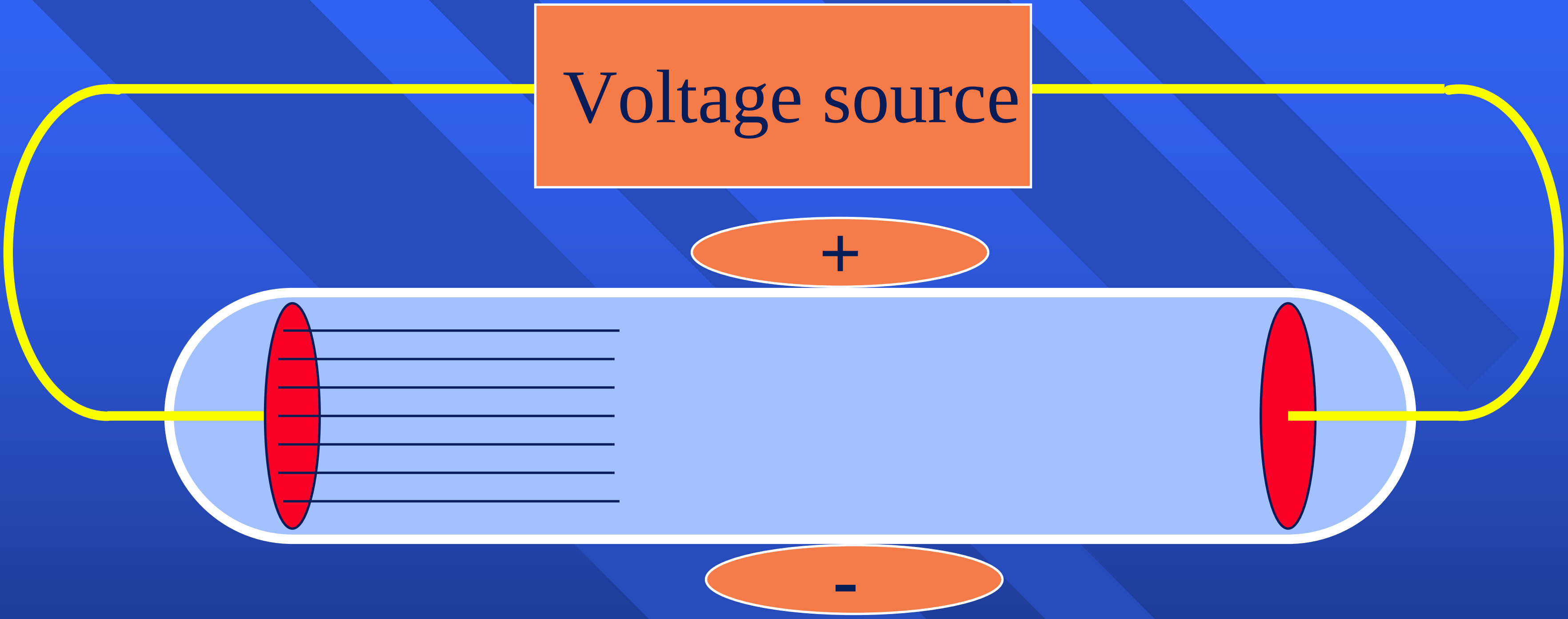
- By adding an electric field

Thomson’s Experiment



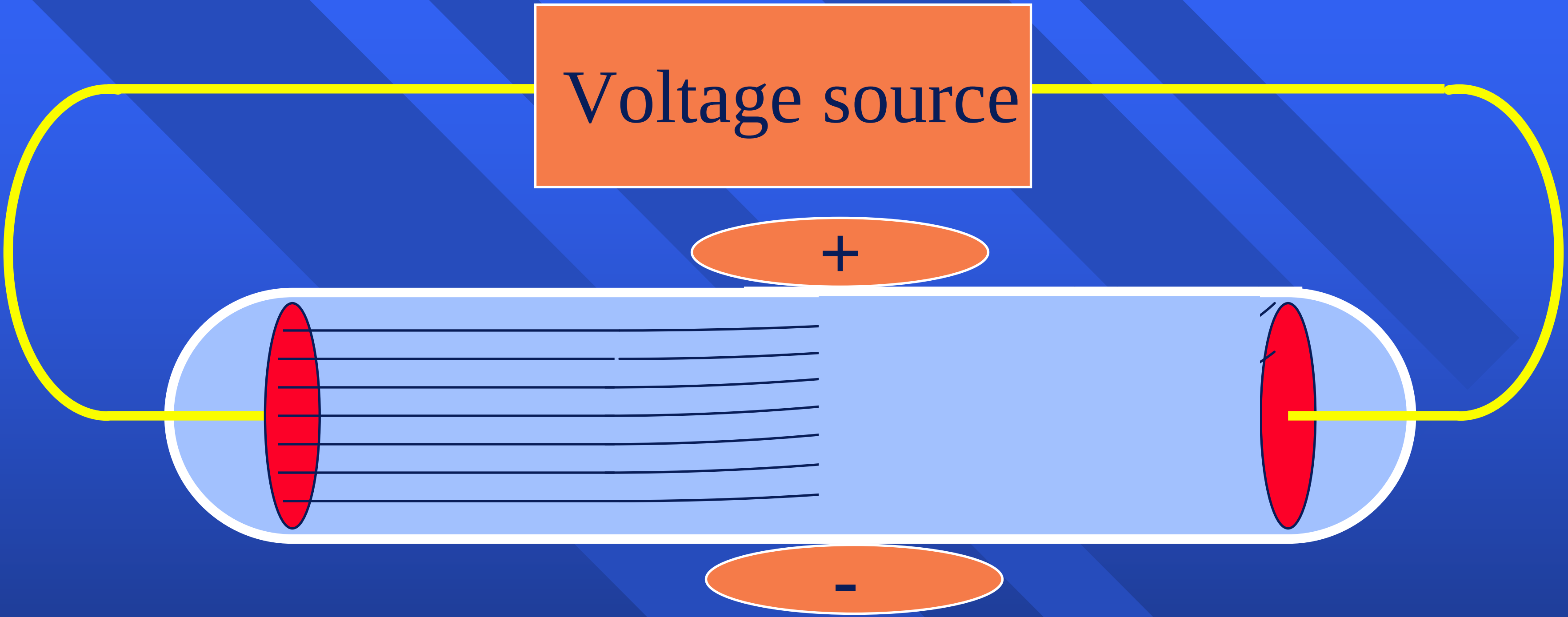
- By adding an electric field

Thomson's Experiment



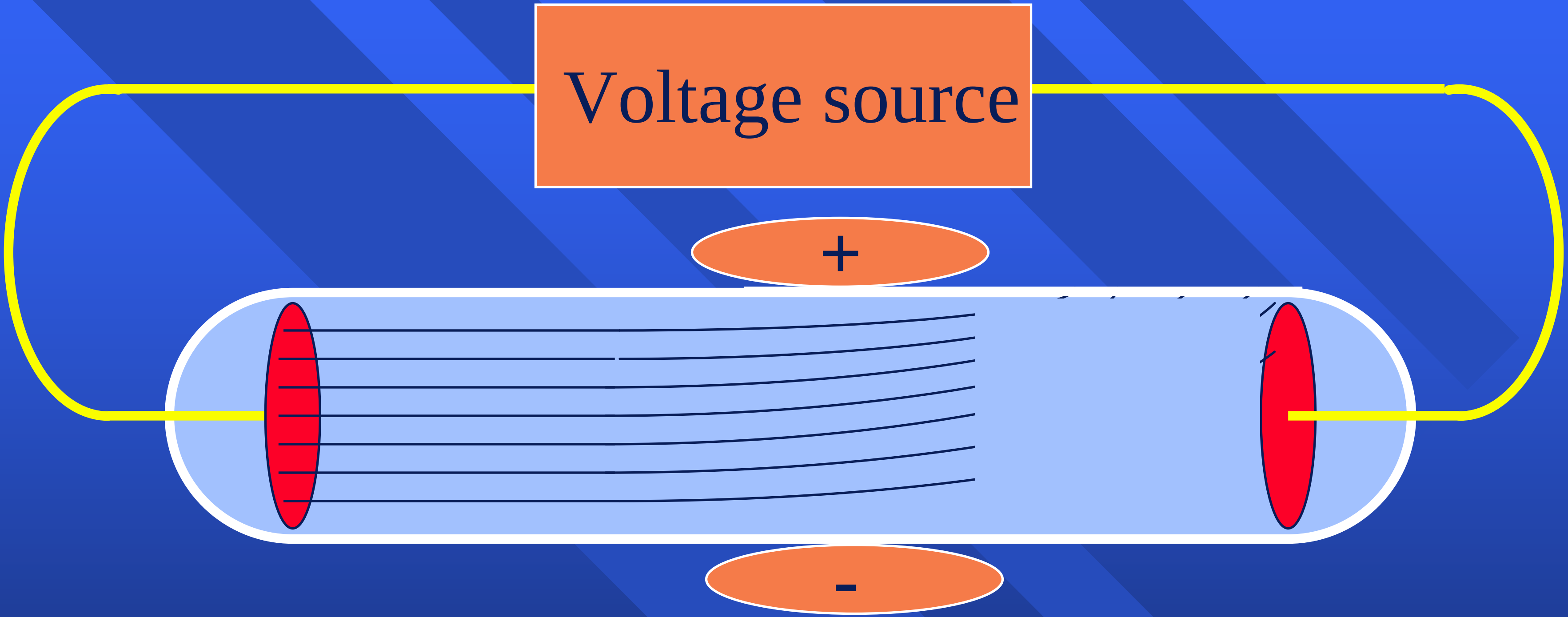
- By adding an electric field

Thomson’s Experiment



- By adding an electric field

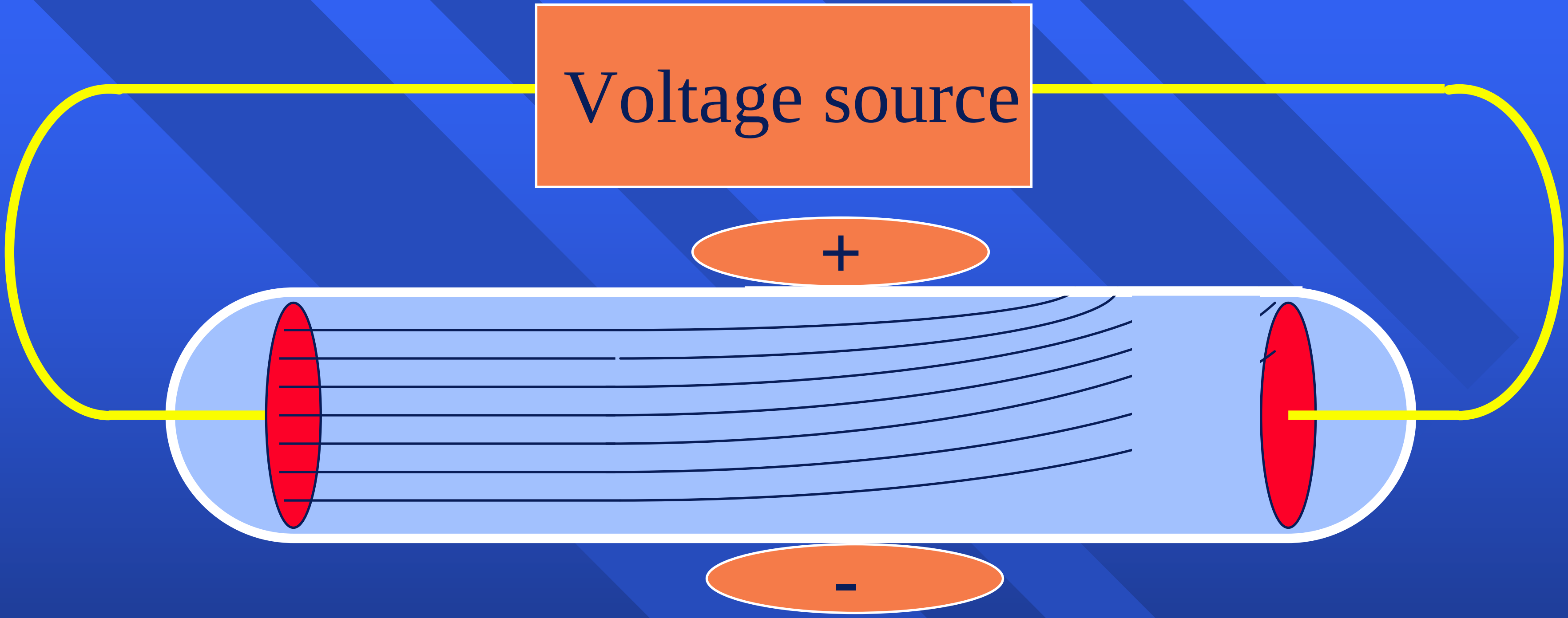
Thomson’s Experiment



Voltage source

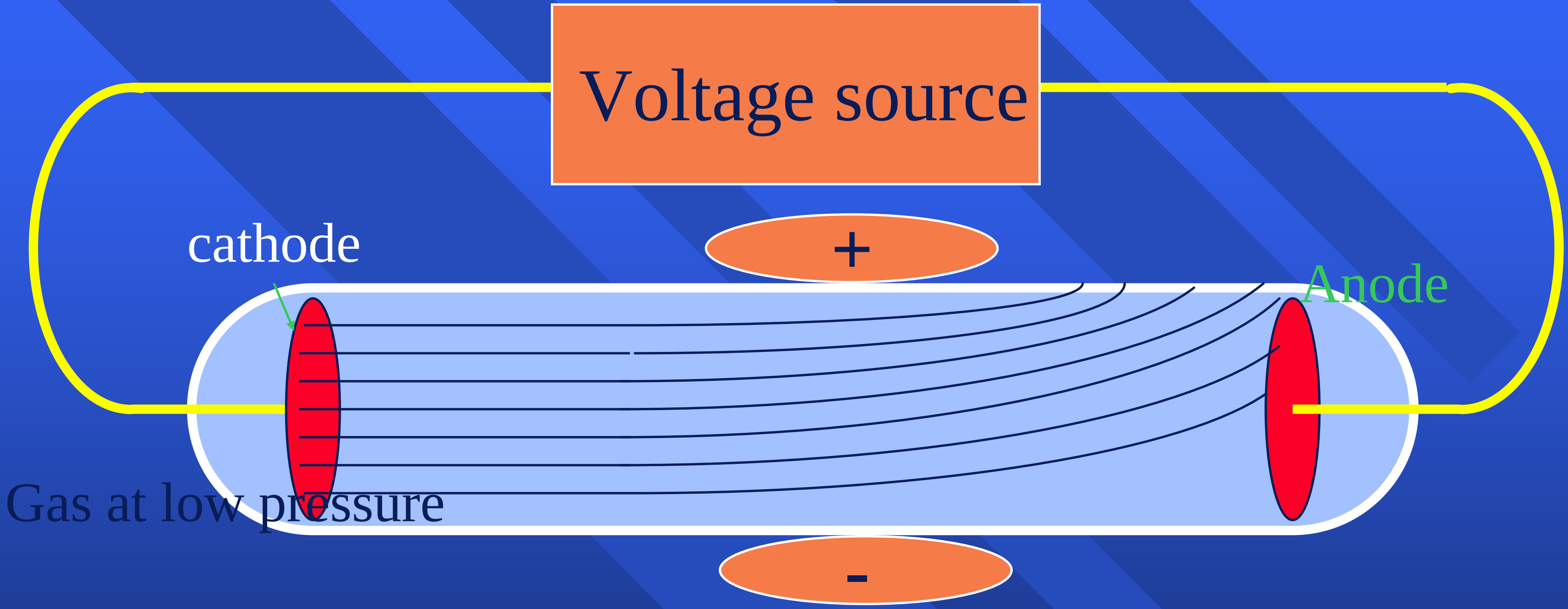
- By adding an electric field

Thomson’s Experiment



- By adding an electric field

Thomson’s Experiment



- By adding an electric field he found that the beam of light took a curved path towards the positive plate.
- Hypothesis: Something in light has a neg charge

Facts

- Different gases glow with different colors as current passes through the tube
- The part of glass tube directly opposite the cathode glows
- An object placed between the cathode and the opposite end of tube casts a shadow on the glass
- A paddlewheel between the electrodes rolls along on its rails from the cathode towards the anode

How did he know the particles charge was negative?

Thomson measured the charge/mass ratio of the negatively charged particle and found it to be very high:

$$\frac{\text{charge}}{\text{mass}}$$

1. If neg charged particle was in light it must be very small
2. Same charge to mass ratio no matter what gas was used
3. Used different types of metals for electrodes and still got the same ratio

Thomson’s Final Hypothesis

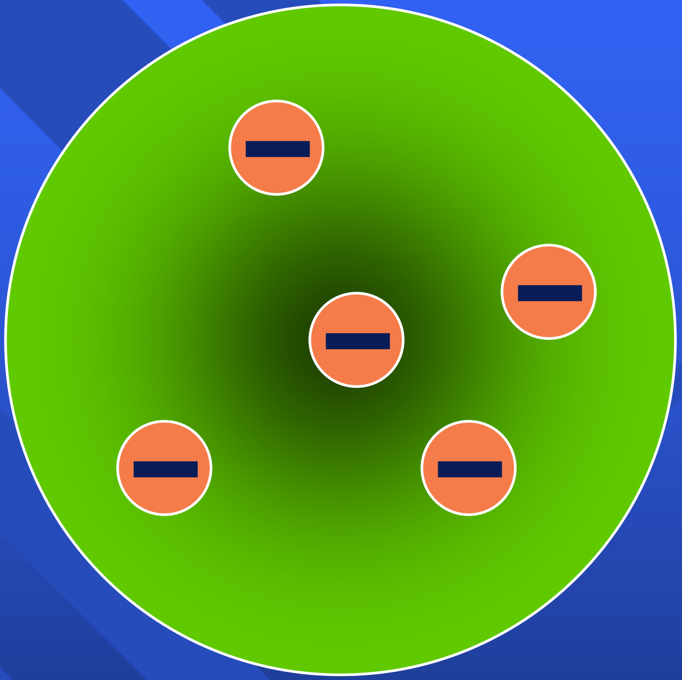
- Mysterious particle is a fundamental part of all matter
- Smaller than the atom
- Named: electron

What about a positive charge?

- Thomson wanted to find a positive particle
- He repeated his experiment with a different tube
- When the negative particles go in one direction the positive must travel the opposite way
- He put holes in the cathode (neg electrode) and the +charged particles passed through the holes and let off scintillations on a screen behind the cathode
- He discovered the proton but not the location,charge, or mass

Thomsom’s Model

- Found the electron
- Couldn’t find positive (for a while)
- Said the atom was like plum pudding
- A bunch of positive stuff, with the electrons able to be removed
- Mass evenly spread out



Robert Millikan

- Found the charge and mass on the electron

Handout: Oil Drop Experiment

Read- answer questions

Other pieces

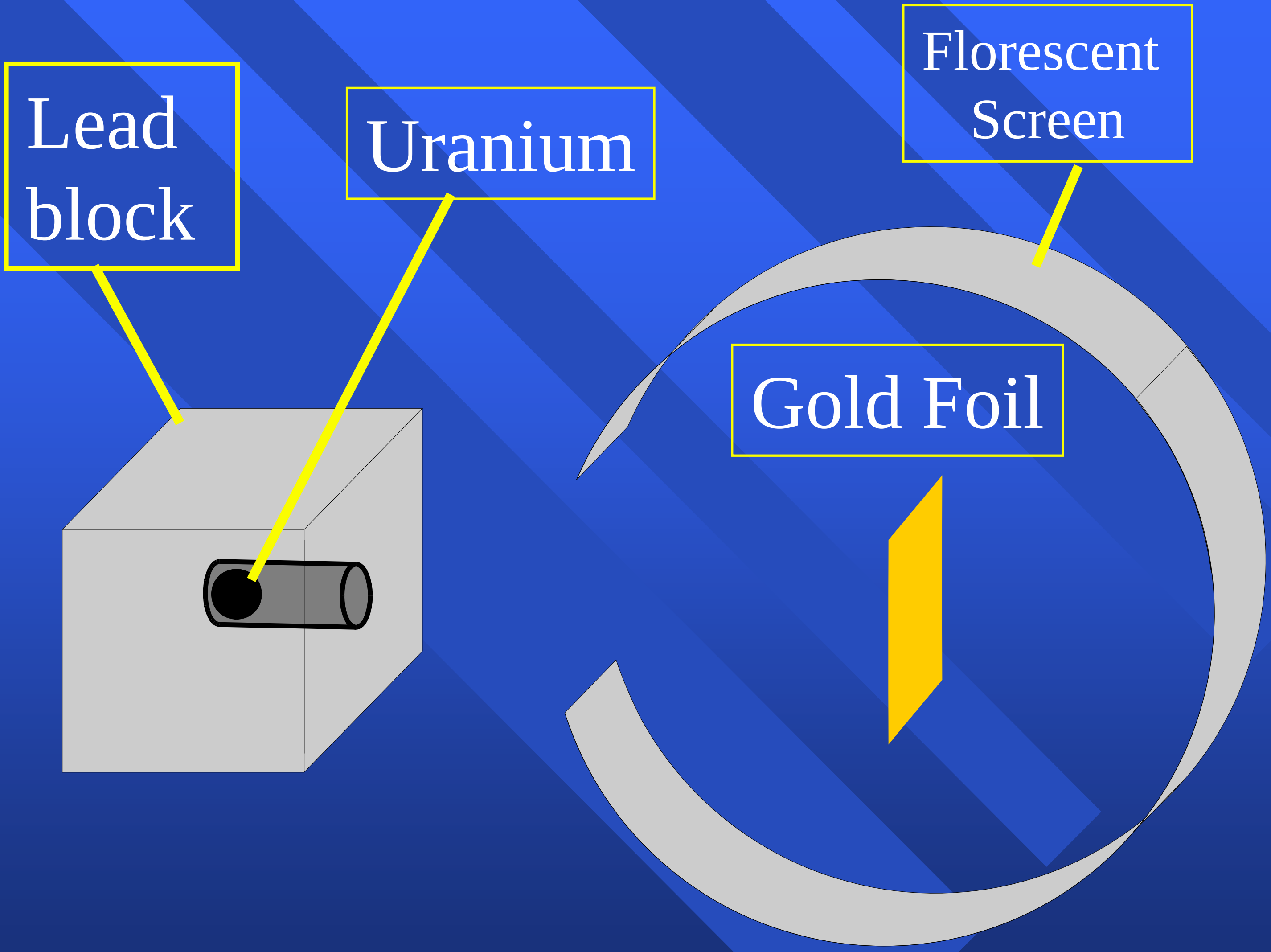
- Proton - positively charged pieces 1840 times heavier than the electron
- Neutron - no charge but the same mass as a proton.
- Where are the pieces?

Rutherford’s experiment

- Ernest Rutherford English physicist. (1910)
- Believed in the plum pudding model of the atom.
- Wanted to see how big they are
- Used radioactivity
- Alpha particles - positively charged pieces given off by uranium
- Shot them at gold foil which can be made a few atoms thick

Rutherford’s experiment

- When the alpha particles hit a florescent screen, it glows.
- Here’s what it looked like (pg 72)



Lead block

Uranium

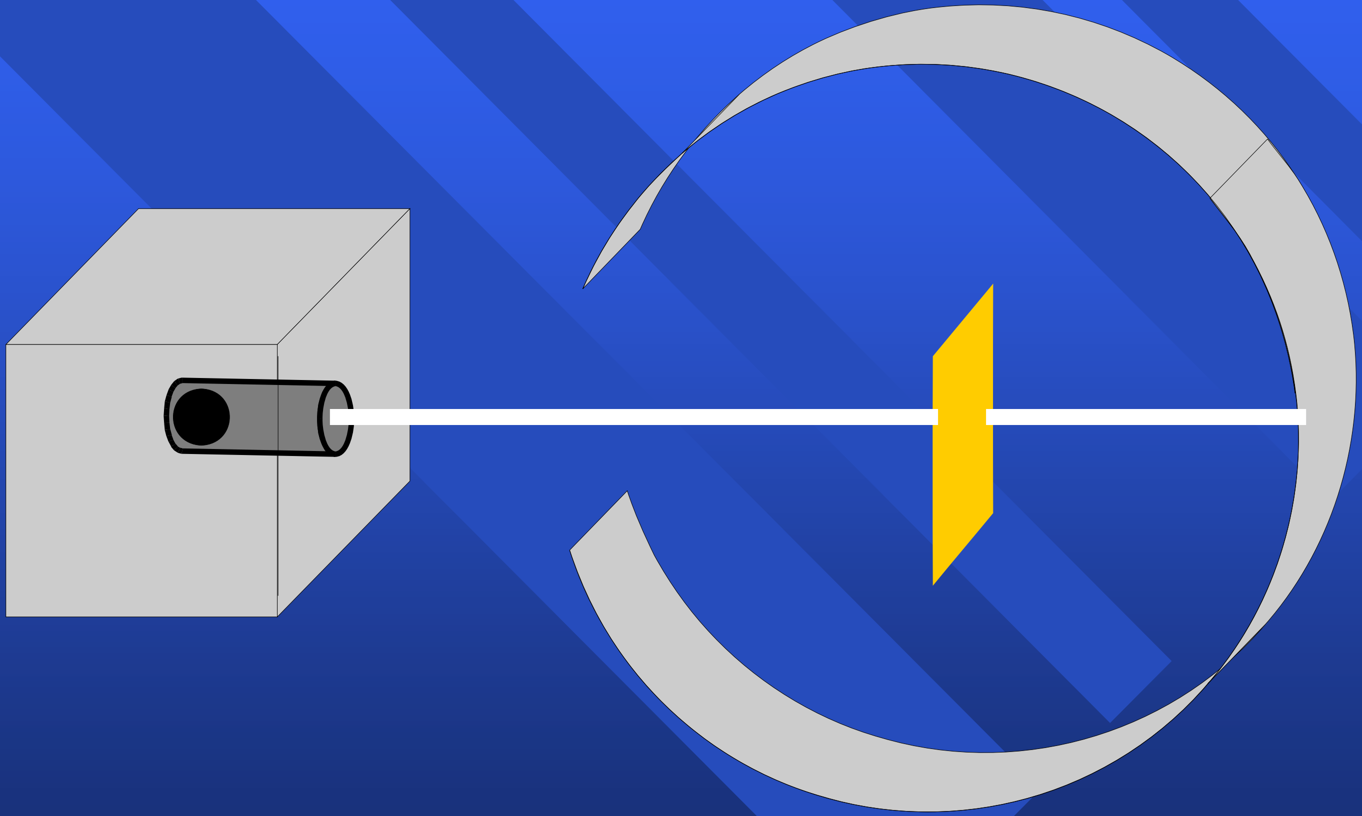
Florescent Screen

Gold Foil

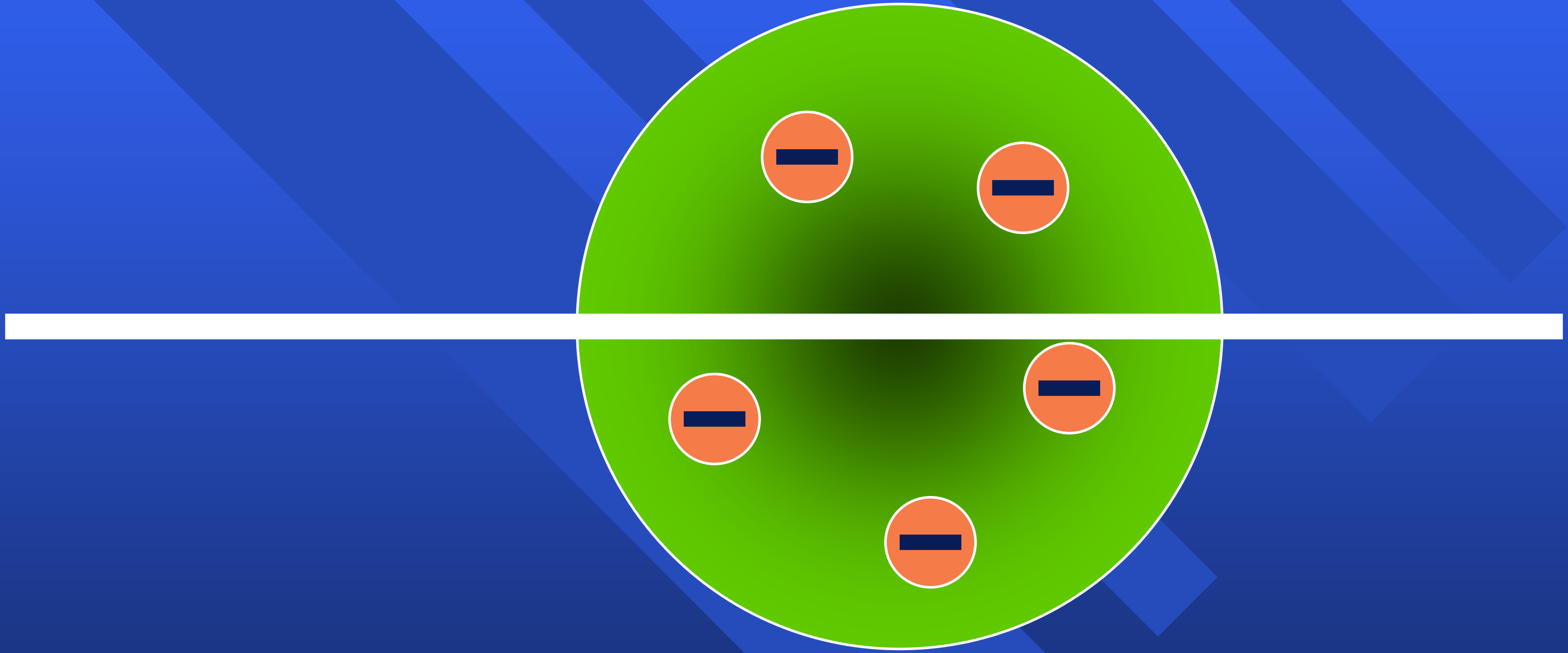
He Expected

- The alpha particles to pass through without changing direction very much
- Because
- The positive charges were spread out evenly. Alone they were not enough to stop the alpha particles

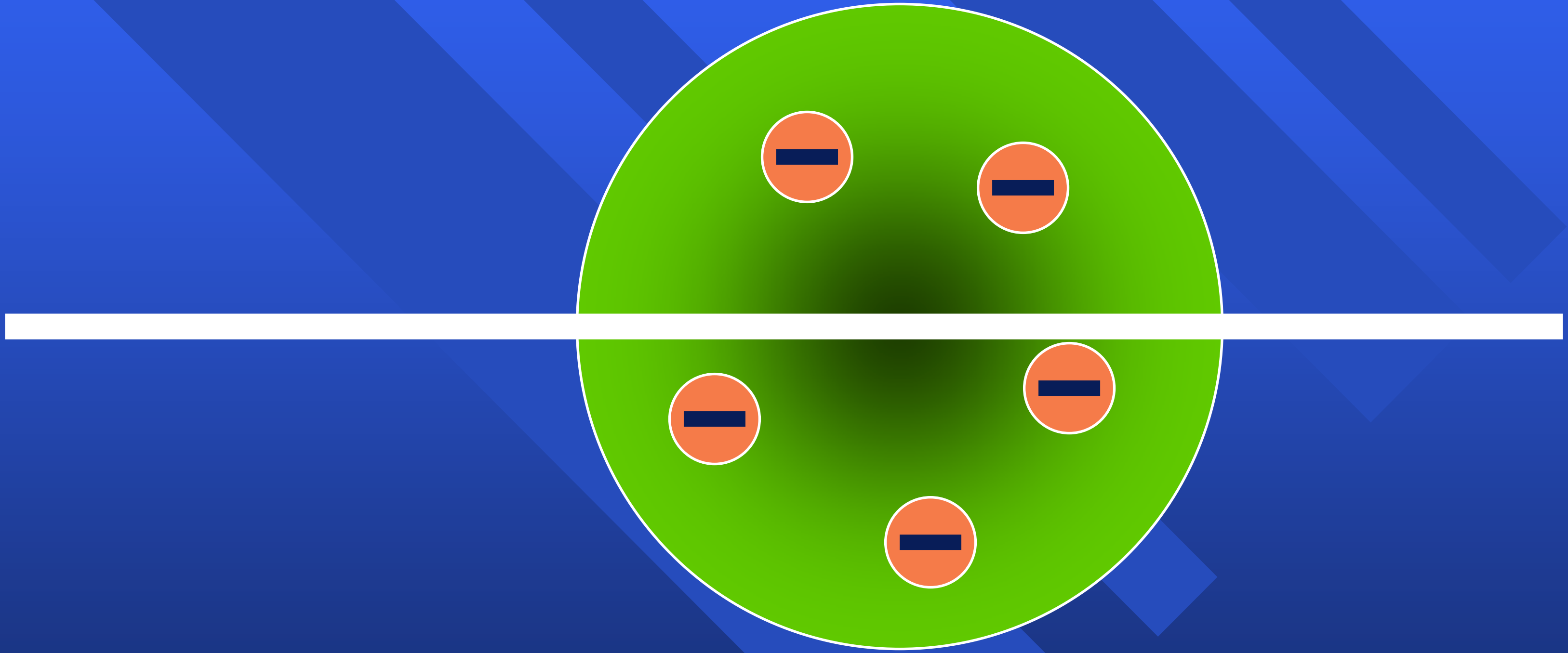
What he expected



Because



Because, he thought the mass was evenly distributed in the atom



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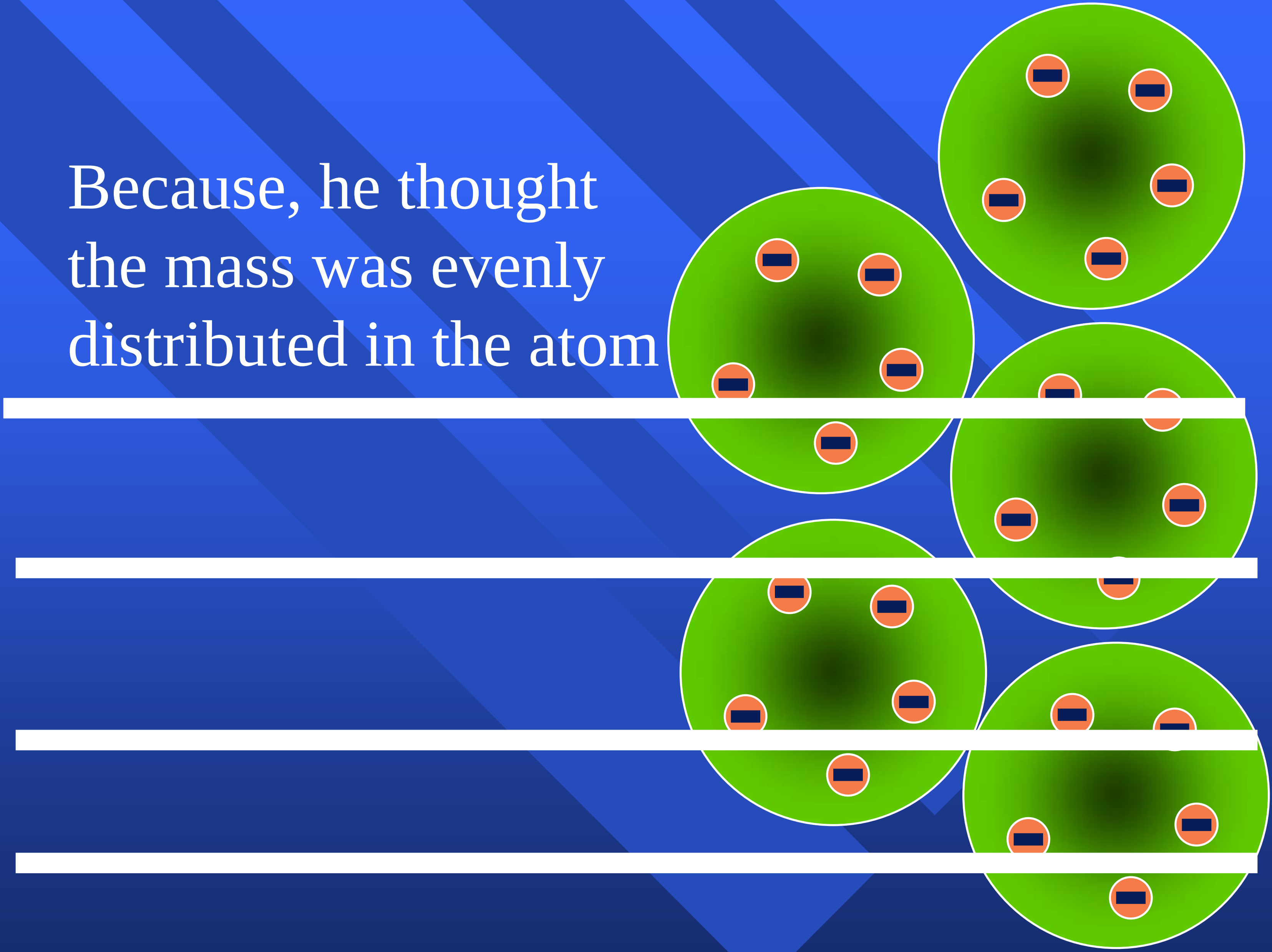
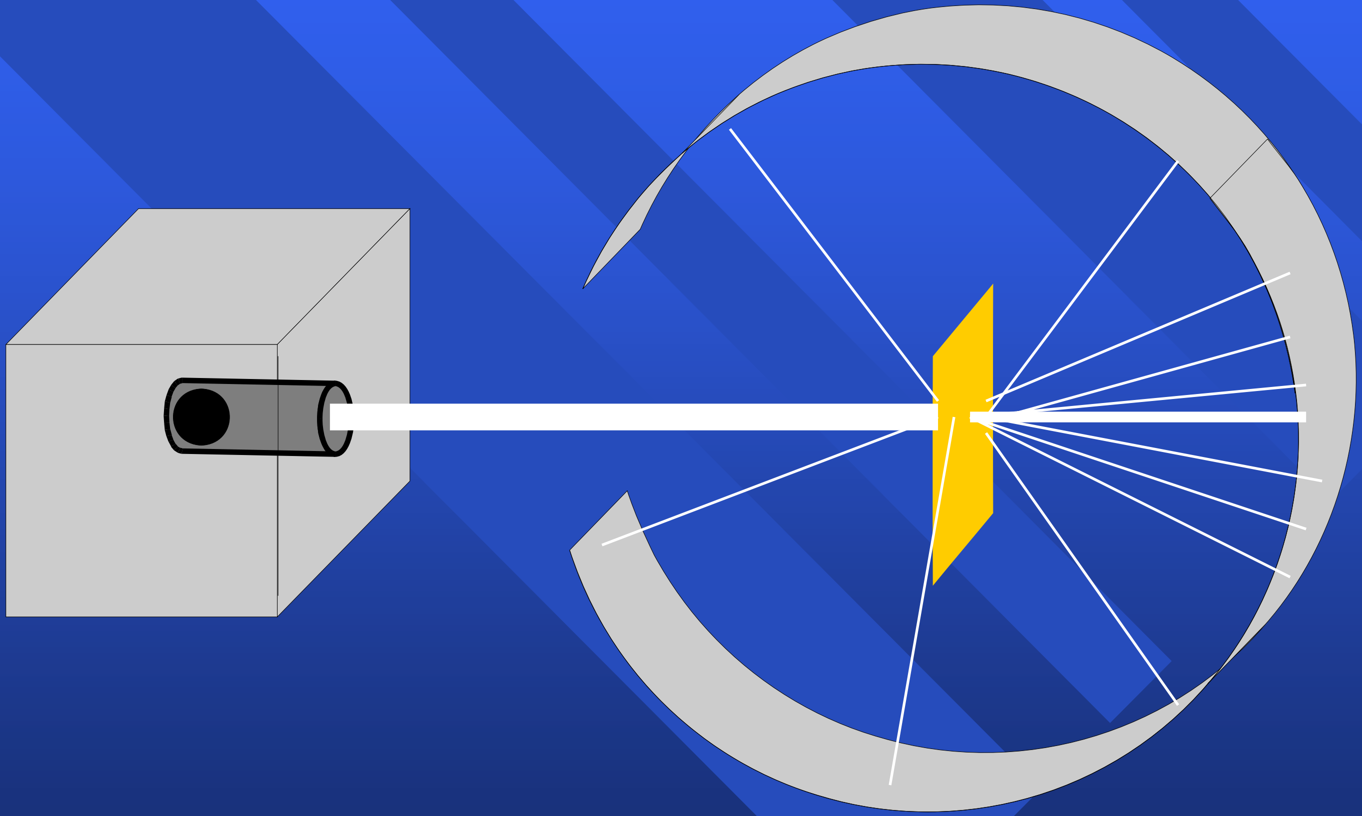
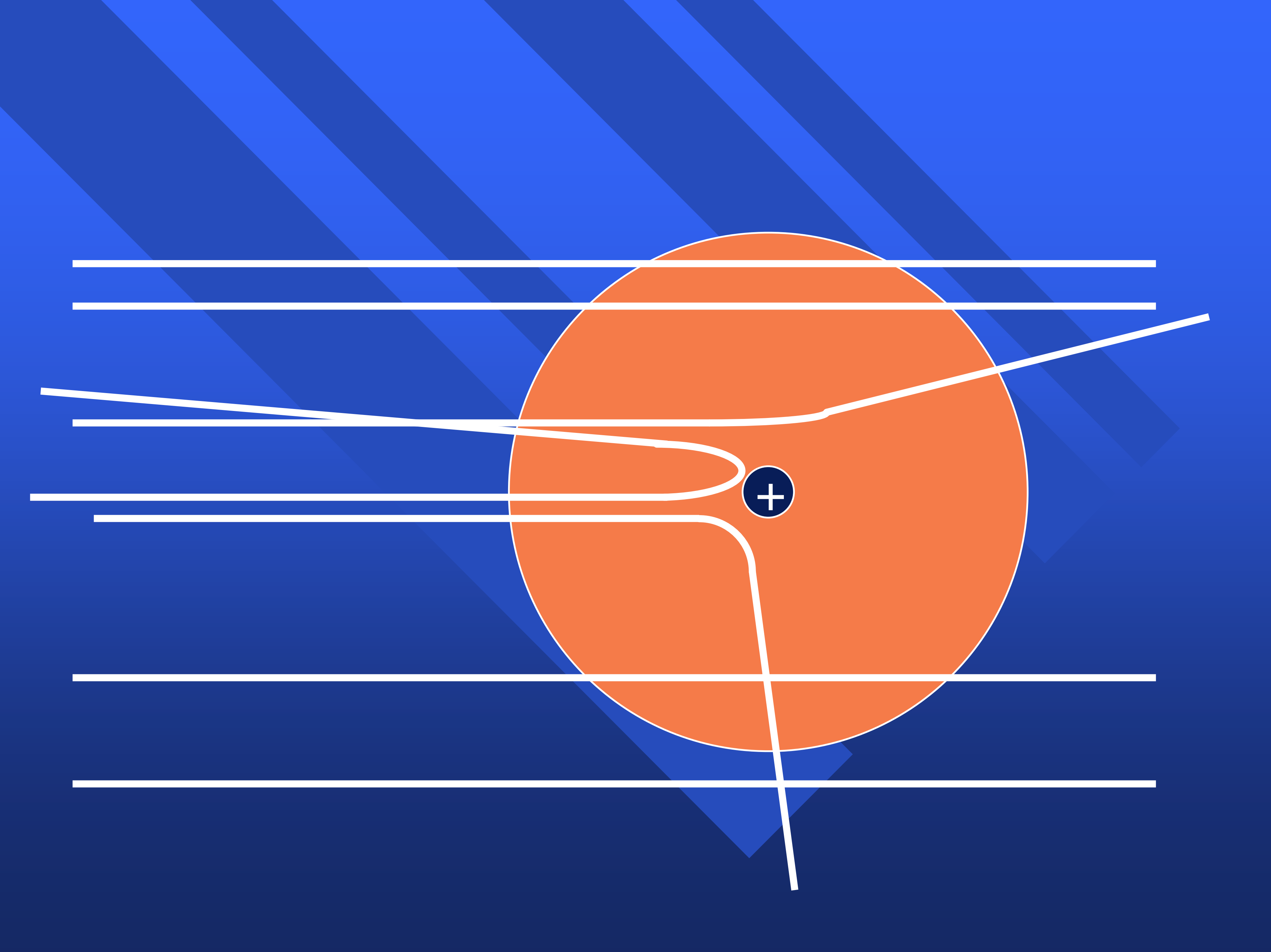


What he got



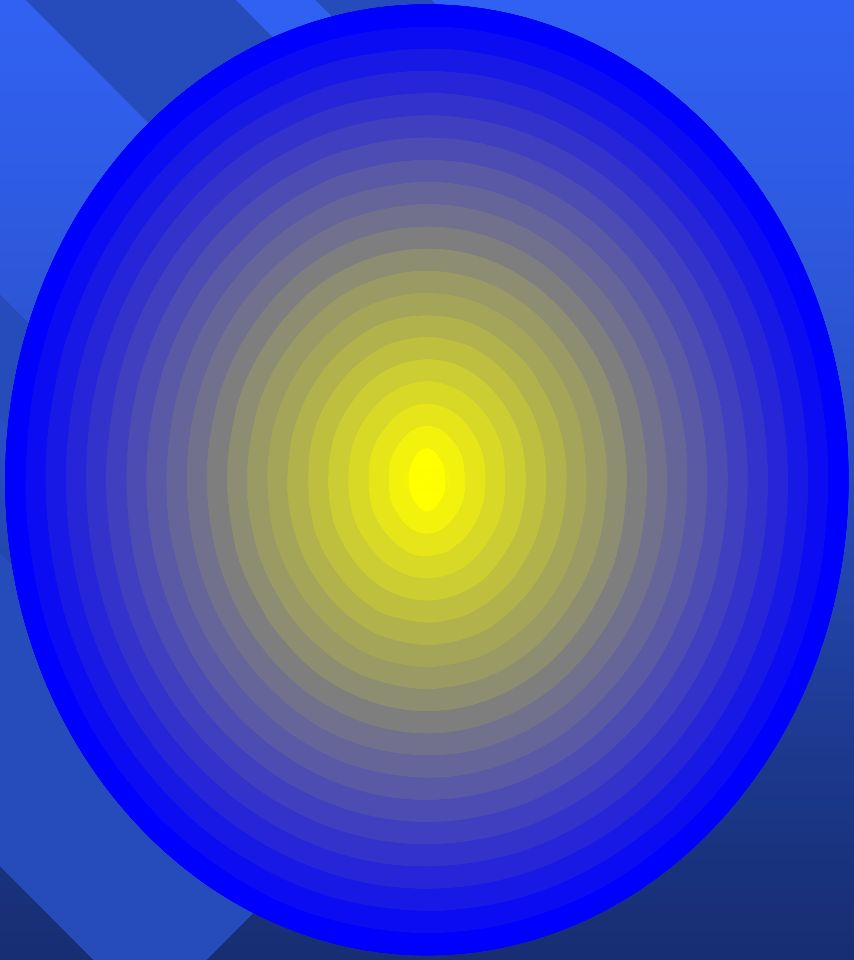
How he explained it

- Atom is mostly empty
- Small dense, positive piece at center
- Alpha particles are deflected by it if they get close enough



Modern View

- The atom is mostly empty space
- Two regions
- Nucleus- protons and neutrons
- Electron cloud- region where you might find an electron



Density and the Atom

- Since most of the particles went through, it was mostly empty.
- Because the pieces turned so much, the positive pieces were heavy.
- Small volume, big mass, big density
- This small dense positive area is the nucleus

Subatomic particles

Name	Symbol	Charge	Relative mass	Actual mass (g)
Electron	e^-	-1	1/1840	9.11×10^{-28}
Proton	p^+	+1	1	1.67×10^{-24}
Neutron	n^0	0	1	1.67×10^{-24}

Structure of the Atom

- There are two regions
- The nucleus
- With protons and neutrons
- Positive charge
- Almost all the mass
- Electron cloud- Most of the volume of an atom
- The region where the electron can be found

Size of an atom

- Atoms are small.
- Measured in picometers, 10^{-12} meters
- Hydrogen atom, 32 pm radius
- Nucleus tiny compared to atom
- IF the atom was the size of a stadium, the nucleus would be the size of a marble.
- Radius of the nucleus near 10^{-15}m.
- Density near 10^{14} g/cm

Counting the Pieces

- Atomic Number = number of protons
- # of protons determines kind of atom
- the same as the number of electrons in the neutral atom
- Mass Number = the number of protons + neutrons
- All the things with mass

Isotopes

- Dalton was wrong.
- Atoms of the same element can have different numbers of neutrons
- different mass numbers
- called isotopes

Symbols

- Contain the symbol of the element, the mass number and the atomic number

Symbols

- Contain the symbol of the element, the mass number and the atomic number

Mass number

X

Atomic number

Symbols

- Find the
  - number of protons
  - number of neutrons
  - number of electrons
  - Atomic number
  - Mass Number

$$^{19}_{9}\mathrm{F}$$

Symbols

- Find the
  - number of protons
  - number of neutrons
  - number of electrons
  - Atomic number
  - Mass Number

$$^{80}_{35}\mathrm{Br}$$

Symbols

- if an element has an atomic number of 34 and a mass number of 78 what is the
  - number of protons
  - number of neutrons
  - number of electrons
  - Complete symbol

Symbols

- if an element has 91 protons and 140 neutrons what is the
  - Atomic number
  - Mass number
  - number of electrons
  - Complete symbol

Symbols

- if an element has 78 electrons and 117 neutrons what is the
  - Atomic number
  - Mass number
  - number of protons
  - Complete symbol

Naming Isotopes

- Put the mass number after the name of the element
- carbon- 12
- carbon -14
- uranium-235

Atomic Mass

- How heavy is an atom of oxygen?
- There are different kinds of oxygen atoms.
- More concerned with average atomic mass.
- Based on abundance of each element in nature.
- Don’t use grams because the numbers would be too small

Measuring Atomic Mass

- Unit is the Atomic Mass Unit (amu)
- One twelfth the mass of a carbon-12 atom.
- 12.01 amu – most abundant isotope is carbon-12
- Other isotopes must be greater than this because the average is over 12
- Each isotope has its own atomic mass we need the average from percent abundance.

- Lithium = 6.941 amu
  - – Most abundant is lithium – 7
  - – Others are probably lower since average is less than 7

  - – A relative measure is usually compared to a known standard
  - – First – define the standard
  - – *Standard for periodic table – Carbon –12 = exactly 12.000 amu

Calculating averages

- You have five rocks, four with a mass of 50 g, and one with a mass of 60 g. What is the average mass of the rocks?
- Total mass = $4 \times 50 + 1 \times 60 = 260$ g
- Average mass = $\dfrac{4 \times 50 + 1 \times 60}{5} = \dfrac{260\text{ g}}{5}$
- Average mass = $\dfrac{4 \times 50}{5} + \dfrac{1 \times 60}{5} = \dfrac{260\text{ g}}{5}$

Calculating averages

- Average mass = $\frac{4}{5} \times 50 + \frac{1}{5} \times 60 = \frac{260 \text{ g}}{5}$
- Average mass = .8 x 50 + .2 x 60
- 80% of the rocks were 50 grams
- 20% of the rocks were 60 grams
- Average = % as decimal x mass +
  % as decimal x mass +
  % as decimal x mass +

Atomic Mass

- Calculate the atomic mass of copper if copper has two isotopes. 69.1% has a mass of 62.93 amu and the rest has a mass of 64.93 amu.

Atomic Mass

- Magnesium has three isotopes. 78.99% magnesium 24 with a mass of 23.9850 amu, 10.00% magnesium 25 with a mass of 24.9858 amu, and the rest magnesium 25 with a mass of 25.9826 amu. What is the atomic mass of magnesium?
- If not told otherwise, the mass of the isotope is the mass number in amu

Atomic Mass

- Is not a whole number because it is an average.
- are the decimal numbers on the periodic table.

Atomic Weight/Relative Atomic Mass

- 12.01 amu – most abundant isotope is carbon – 12.
  Other isotopes of carbon must be greater than this since average is over 12

6.941 amu most abundant is ^{7}Li
others are probably lower since avg is less than 7

What is a “relative mass”?

- A relative measure is usually compared to a known standard.
- 1st – you must define the standard

- Standard on periodic table:
  - Carbon – 12 = 12.000 amu exactly
  - 1 amu = 1/12 carbon-12 atom
  - 1 amu = 1.66 x 10^{-24}g (mass of a proton)

- Calculate the number of atoms in 1.00794 g of H.

- Calculate the number of atoms in 12.011 gram of Carbon

Avogadro’s Number/The Mole

- 1 mole = 6.022×10^{23} = Avogadro’s Number

- 1 mole of H atoms = 6.022×10^{23} atoms
- 1 mole of C atoms = 6.022×10^{23} atoms

- From periodic table:
- 1 mole of C = 12.011g
- 1 mole of H = 1.00794 g
- How much tells you how many

Calculations with the mole

- Calculate the number of atoms of Ag in 1.25 g of Ag.

- Calculate the mass of 1,000,000 Au atoms

How about molecules?

- Remember there are some elements that exist as molecules alone
  - Examples: The diatomic “7”
  - Oxygen gas O_2 Hydrogen gas H_2
  - Nitrogen gas N_2 Iodine I_2
  - Flourine gas F_2
  - Chlorine gas Cl_2
  - Bromine gas Br_2

Example

- In a sample of the air in this room there are approximately 2.33×10^{23} molecules of oxygen gas (O_2). How many moles of oxygen gas are in this sample?

More Mole Fun

- Calculate the number of atoms in a cube of Au that is 3 cm by 2 cm by 2cm. The density of gold is 19.3 g/cm^3

- 1 amu = 1.66 x 10^{-24} g
- How many atoms are there in 1.00794g of hydrogen?