Office Hours: M 1:30pm – 3:00pm
(in Park 169) W 11:00am – 12:00pm
or by appointment (email me)
or just email me with questions!

TA Hours w/ Dana: Th 6:00pm – 7:00pm
(in Park ____) F 4:30pm – 6:00pm

Q-center: https://www.brynmawr.edu/inside/offices-services/q-center/q-center-schedule

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Unit Conversion

Brief History of Atomic Theory

9/4/2026

No recitation this afternoon.

Achieve HW #1 due Wednesday 9/9 at 10:00am

Quiz #1 in Recitation next Friday (9/11)

Learning Objectives

- Perform basic unit calculations and conversions in the metric and other unit systems
- Explain the dimensional analysis (factor label) approach to mathematical calculations involving quantities
- Use dimensional analysis to carry out unit conversions for a given property and computations involving two or more properties

- Apply the law of conservation of matter
- Define and give examples of atoms and molecules

- Outline milestones in the development of modern atomic theory
- Summarize and interpret the results of the experiments of Thomson, Millikan, Rutherford, and Chadwick

- Write and interpret symbols that depict the atomic number, mass number, and charge of an atom or ion

Unit Conversion

Given one or more quantities, convert them into different units.

Units are multiplied, divided, and canceled like any other algebraic quantities.

Always write every number with its associated unit!!! No shortcuts!!

Some conversion factors

Length	1 km = 0.6214 mi 1 m = 39.37 in = 1.094 yd 1 ft = 30.48 cm 1 in = 2.54 cm	Mass	1 kg = 2.205 lb 1 lb = 453.59 g 1 oz = 28.35 g
Volume	1 L = 1000 mL = 1000 cm^3 1 L = 1.057 qt 1 gal = 3.785 L		

You will always be provided with any unit conversion factors needed for a problem.

You **do not** need to memorize unit conversion factors. (i.e. 1 kg = 2.205 lb)

You **do** need to memorize conversion factors for the unit *prefixes* (i.e. 1 kg = 10^3 g) indicated a few slides ago.

Problem Solving Using the Factor-Label Method

Conversion factor: A term that converts a quantity in one unit to a quantity in another unit.

$$\boxed{\text{original quantity}} \times \boxed{\text{conversion factor}} = \boxed{\text{desired quantity}}$$

Conversion factors are usually written as equalities.

2.21 lb = 1 kg

To use them, they must be written as fractions.

Solving Problems Using Conversion Factors

Factor-label method: Using conversion factors to manage a complex problem involving many units. Also called Dimensional Analysis.

- units are treated like numbers
- make sure all unwanted units cancel
- ***all*** quantities in the calculation have units **labeled**!

To convert 130 lb into kilograms:

$$1.3\times10^{2}\ \text{lb} \times \boxed{\text{conversion factor}} = ?\ \text{kg}$$

original quantity | | desired quantity

How many kg in 1.3×10^2 lb ?   2.21 lb = 1 kg

$$1.3 \times 10^2 \text{ lb} \times \boxed{\frac{2.21 \text{ lb}}{1 \text{ kg}}} \text{ or } \boxed{\frac{1 \text{ kg}}{2.21 \text{ lb}}} = 59 \text{ kg}$$

Set up the conversion factor with original unit in the <u>bottom</u> of the fraction.

- The unwanted unit lb cancels.
- The desired unit kg does not cancel, and is on the **<u>top</u>** of the fraction
  → final unit is kg

Solving Multistep Unit Conversion Problems

Each step should have a conversion factor set up to cancel the units of the previous step

Example: How many km are there in 1.2×10^4 ft?

1 foot = 0.3048 m

Conversion with Units Raised to a Power

Example: converting cm^3 to in^3

1 in = 2.54 cm

Must cube both sides of the equality to obtain the proper conversion factor.

How many cubic inches in 251 cm^3?

Density

The density of a substance is the ratio of its mass to its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \text{or} \quad d = \frac{m}{V}$$

Water has a density of 1.0 g/mL (or 1.0 g/cm^3)

Things that are less dense (like oil) will float in water.

Things that are more dense (like CH_2Cl_2) will sink.

Calculating Density

Example: a sample of liquid has a volume of 22.5 mL and a mass of 27.2 g.

Assuming this liquid is not *miscible* with water (that is, they will separate like oil and water and not mix), will this liquid float or sink in water?

Density as a Conversion Factor

We can use the density of a substance as a conversion factor between the mass of the substance and its volume.

For a liquid substance with a density of 1.32 g/cm^3, what volume in liters should be measured to deliver a mass of 68.4 g?

A 23.5 kg sample of ethanol is needed for a large scale reaction. What volume in liters of ethanol should be used? The density of ethanol is 0.789 g/cm^3.

Conversion factors: 1 cm^3 = 1 mL

Convert 2.6 lb/in^3 to g/ml .

Mass	1 kg = 2.205 lb
	1 lb = 453.59 g
	1 oz = 28.35 g
Length	1 km = 0.6214 mi
	1 m = 39.37 in = 1.094 yd
	1 ft = 30.48 cm
	1 in = 2.54 cm

Law of Conservation of Mass

There is no new matter.

- Matter is neither created nor destroyed in a **chemical reaction.**
  - In a **nuclear reaction**, significant changes in mass can occur.
- During physical and chemical changes, the total amount of matter remains constant.

Ex: Conservation of Mass

Butane + Oxygen → Carbon Dioxide + Water

58 g 208 g 176 g 90 g

Example: 12 g of natural gas combines with 48 g of oxygen in a flame. The chemical reaction produces 33 g of carbon dioxide and how many grams of water?

Natural gas + oxygen → carbon dioxide + water

12 g 48 g 33 g ?

Early Ideas About Atoms

<u>**ca. 400 BCE**</u>: Ancient Greek philosophers Leucippus and Democritus

All matter is made of irreducible "building blocks" that couldn't be divided further

"atomos" = "indivisible"

Empedocles (and Aristotle) believed matter was composed of four "elements:"

Atomic Theory

1808 CE: John Dalton's Atomic Theory expanded on the centuries-old Greek philosophies…

1. **All matter** is composed of **atoms**.

2. For a given element, all atoms have the same mass and other properties.

3. Different elements have atoms with different properties.

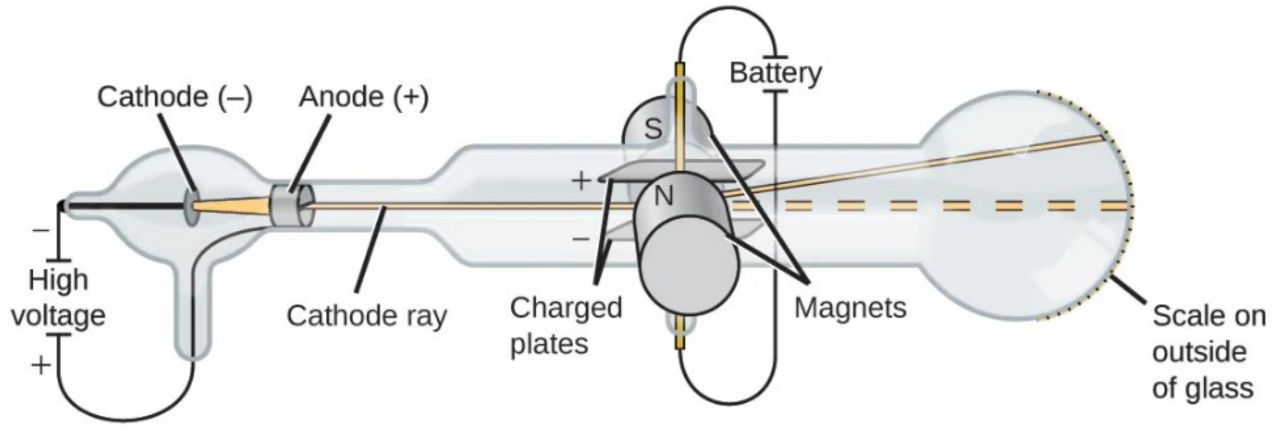
4. A compound consists of atoms of two or more elements combined in whole-number ratios.

   Example: Water H_2O has 2 atoms of hydrogen for every 1 atom of water

5. Atoms are not created or destroyed in a chemical change. They rearrange to make new compounds (with new ratios of atoms).

Revising Dalton's Atomic Theory

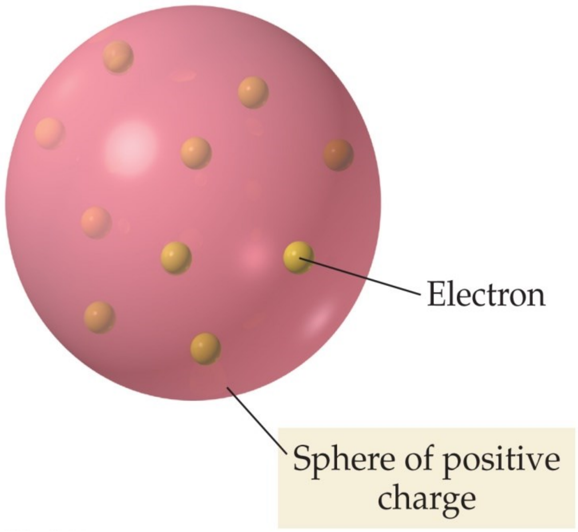
<u>1897 CE</u>: J.J. Thompson built on (and challenged) Dalton's atomic theory



- Electricity applied in a vacuum generates a beam of negatively charged particles.
- Experimentation allowed calculation of the mass-to-charge ratio of these particles.
- They were negatively charged, and much lighter than any atoms that had been observed!
- Atomic theory was revised to account for new observations.

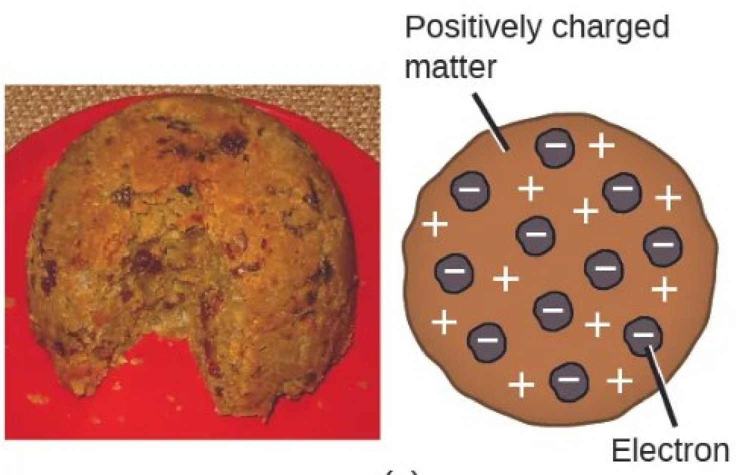
Plum Pudding Model of the Atom

Atoms were known to be neutral so there must be positive charges to balance these negatively charged “electrons”



<u>1904 CE</u>: “Plum Pudding Model”

Atom is a sphere of positive charge with negative particles (electrons) mixed in



(a)

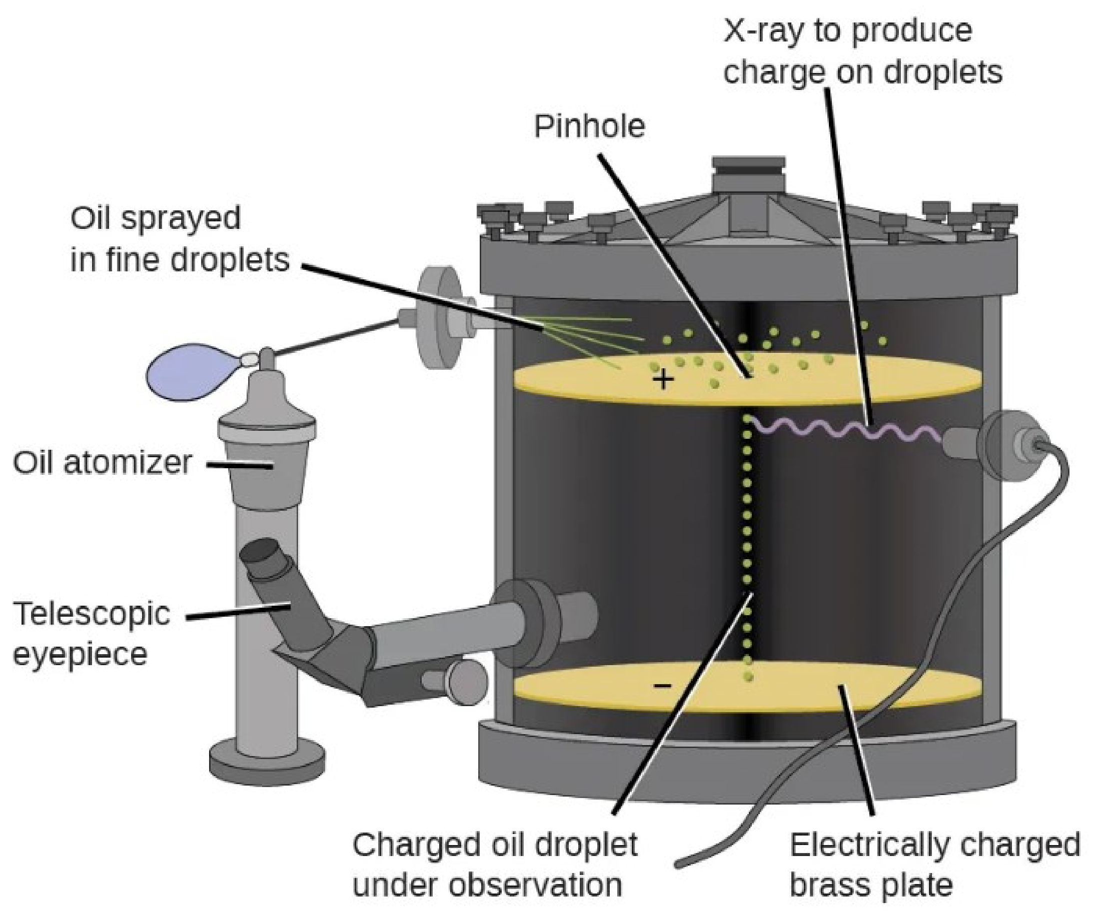
Millikan's Oil Drop Experiment

<u>1909 CE</u>: Further investigation into negatively charged electrons.

Experiments produced tiny oil droplets with slight negative charges

Observed that charge on droplets was always a multiple of the same number!

Oil drop	Charge in coulombs (C)
A	4.8×10^{-19} C
B	3.2×10^{-19} C
C	6.4×10^{-19} C
D	1.6×10^{-19} C
E	4.8×10^{-19} C



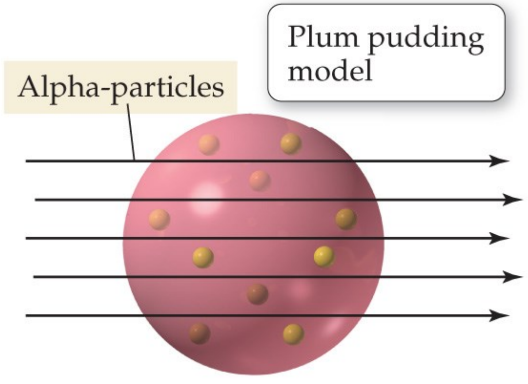
Determined the smallest unit of negative charge must be 1.6×10^{-19} C

Combined with Thompson's data, allowed calculation of mass of one electron

Rutherford's Gold Foil Experiment

<u>ca. 1909 CE</u>: Ernest Rutherford and co. tried to confirm Thompson's Plum Pudding Model

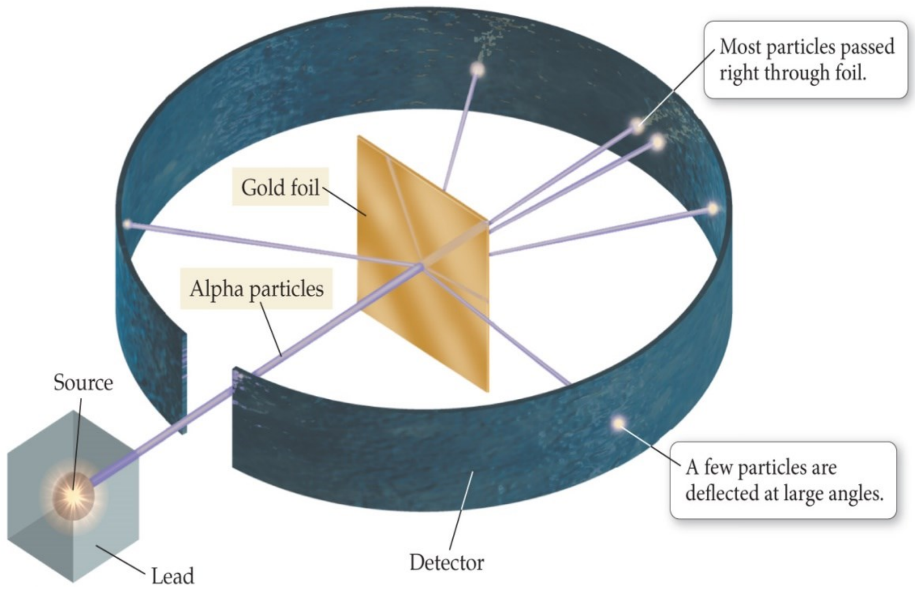
Tiny alpha-particles were directed at a thin sheet of gold foil.



(a) Rutherford's expected result

Most of the particles passed directly through the foil.

A few were deflected, some of them at sharp angles.

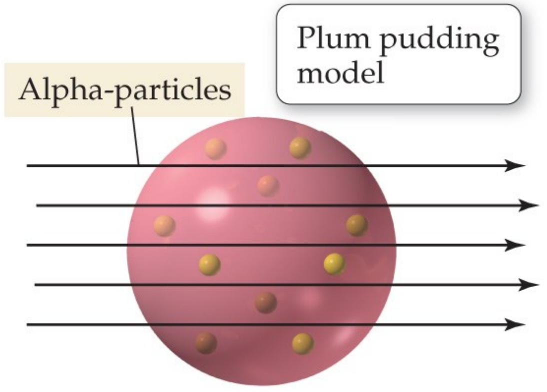


Nuclear Theory of the Atom (1911 CE)

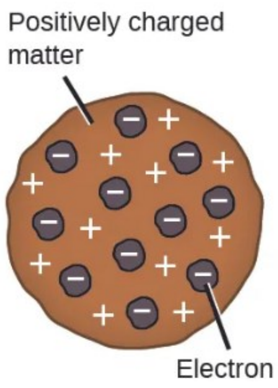
a) Rutherford's Expected result:

Alpha-particles should pass through gold foil with minimal deflection.

Deflections should be roughly uniform.



(a) Rutherford's expected result

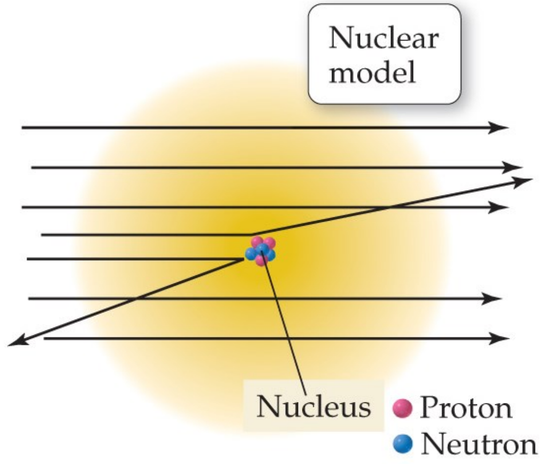


"Plum Pudding" model

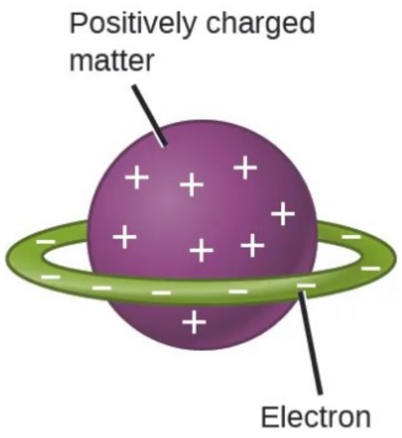
(b) Actual result:

A small number of alpha-particles were deflected or bounced back.

Supported Hantaro Nagaoka's "planetary" model of the atom (1903)

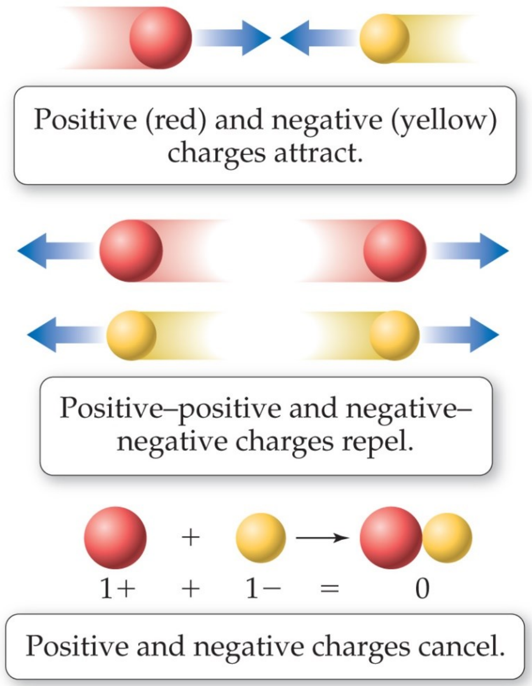


(b) Rutherford's actual result



"planetary" model

Nuclear Theory of the Atom (1911 CE)



1. Most of atom's mass and positive charge is contained in a small central core called the nucleus

2. Atom is mostly __________ __________, with small negatively charged electrons interspersed.

3. Amount of positive charge = amount of negative charge (atom is neutral)

Experiments showed that nuclei of **all elements** contained Hydrogen nuclei as "building blocks"

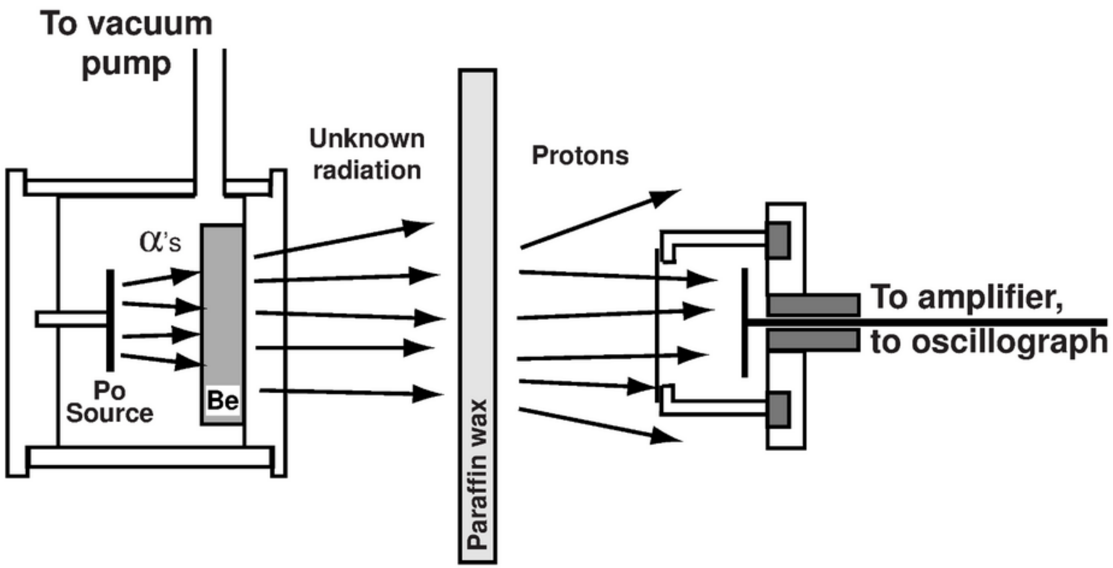
Rutherford named this building block of nuclear mass and positive charge the "**proton**."

James Chadwick and the Neutron

Experiments to this point had determined:

- Atoms contain negatively (-) charged e^- which have very little mass.
- Most of an atom's mass is in the nucleus
- The nucleus contains positive (+) charged protons
- An atom of Helium is 4x as heavy as Hydrogen, but the nucleus only has 2x as much (+) charge.

Data suggested there was a ____________ particle contributing to the nucleus mass!



<u>1932 CE</u>: James Chadwick discovered a new type of radiation.

Particles had similar mass to a Hydrogen nucleus, but no charge.

Protons, Neutrons, & Electrons (Subatomic Particles)

Protons (+ charge) and neutrons (neutral) make up nucleus (99.9% of atom's mass)

Electrons (- charge): cloud of negatively charged particles around nucleus; very little mass

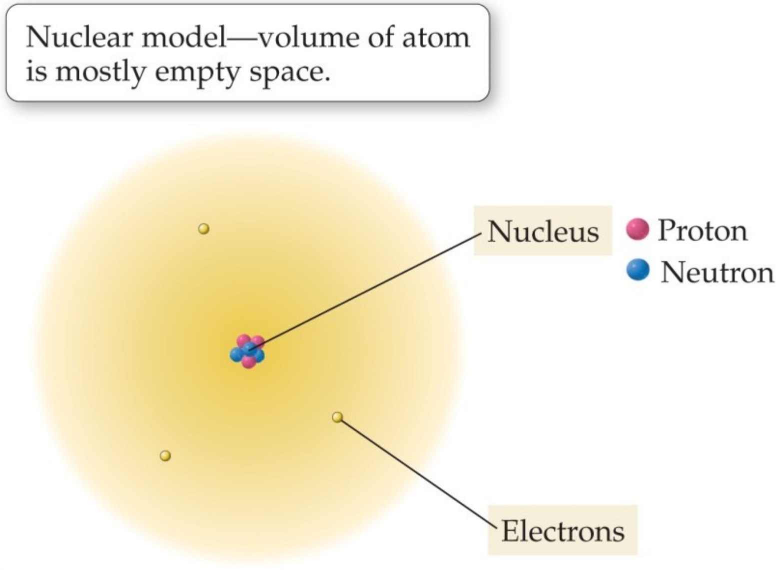
Atomic mass unit (amu): convenient unit for the mass of subatomic particles

$$1 \text{ amu} = 1.66\text{x}10^{-27} \text{ kg}$$

Based on 1/12 mass of a ^{12}C atom.

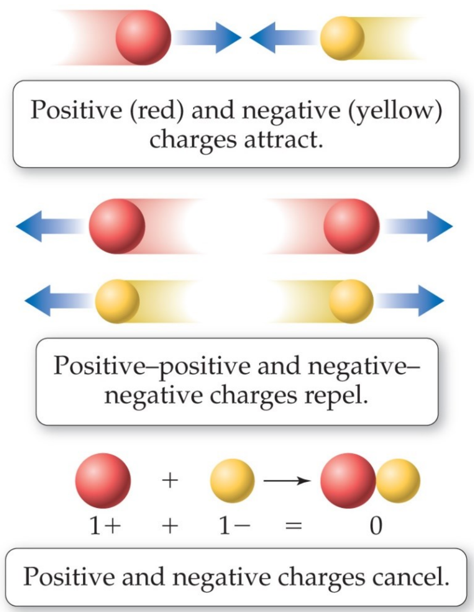
amu is also called ________________ , especially

by ___________________.



Subatomic Particles

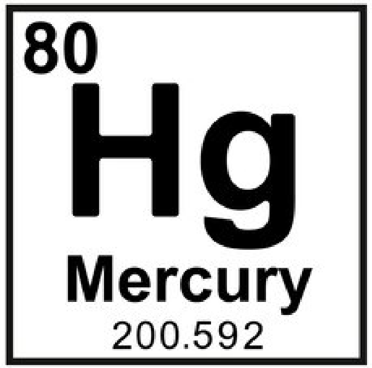
	Mass (kg)	Mass (amu)	Charge
Proton	1.67273×10^{-27}	1.0073	+1
Neutron	1.67493×10^{-27}	1.0087	0
Electron	9.1×10^{-31}	0.00055	-1



If a proton had the mass of a baseball,
an electron would have the mass of a grain of rice.

A proton is nearly 2000 times more massive than an electron.

Atomic Numbers & Symbols



Elements are defined by their number of protons

Atomic Number (Z) = number of protons

Chemical symbol = abbreviation for an element

Example: Carbon (C), Silicon (Si), Lead (Pb), Mercury (Hg)

Some symbols are based on the Latin names

Atomic Numbers & Symbols

2 = Atomic Number (Z)

He = Chemical Symbol

4.00 = Atomic Mass (in amu)

Helium = Name

2
He
4.00
Helium