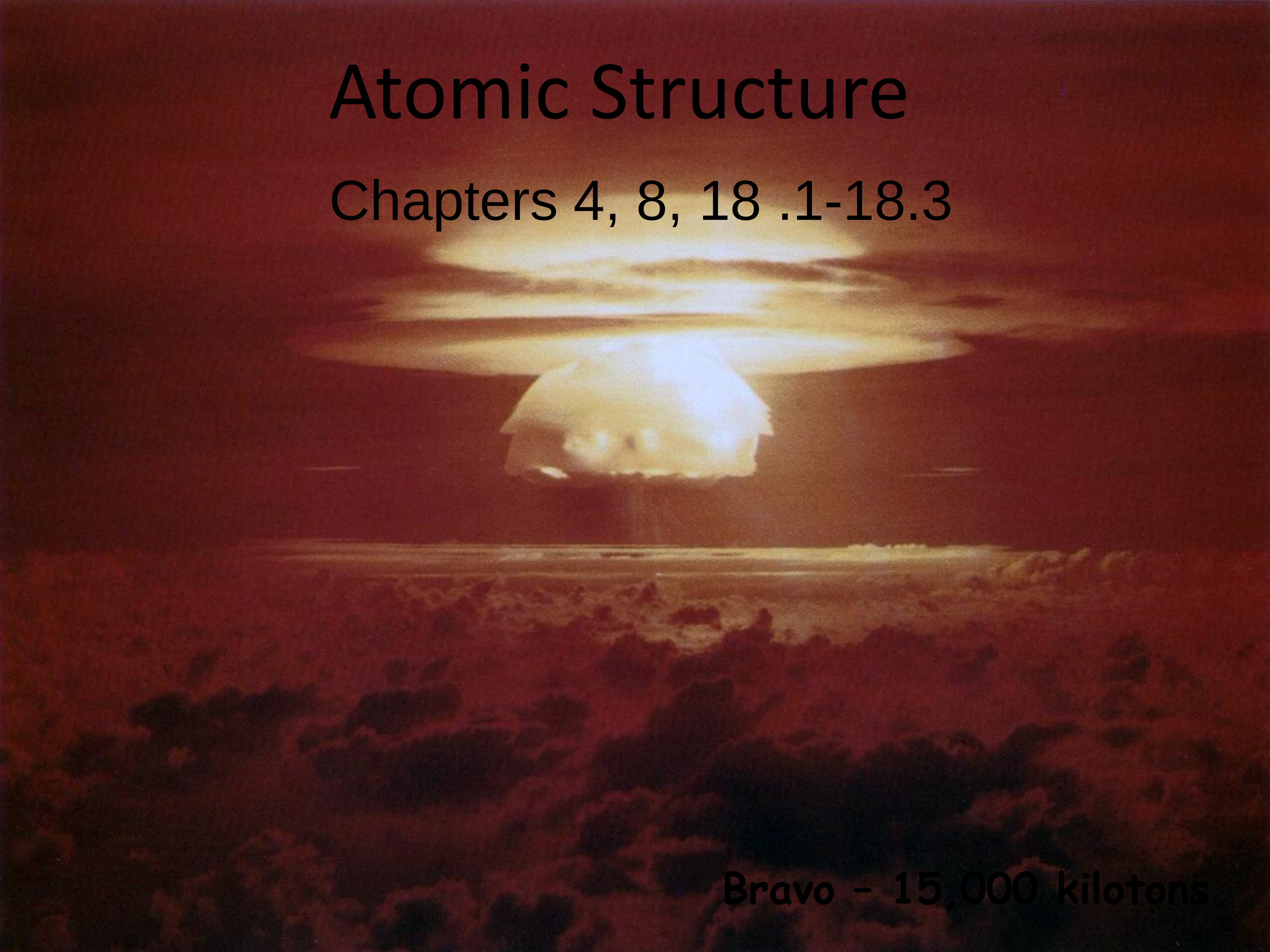
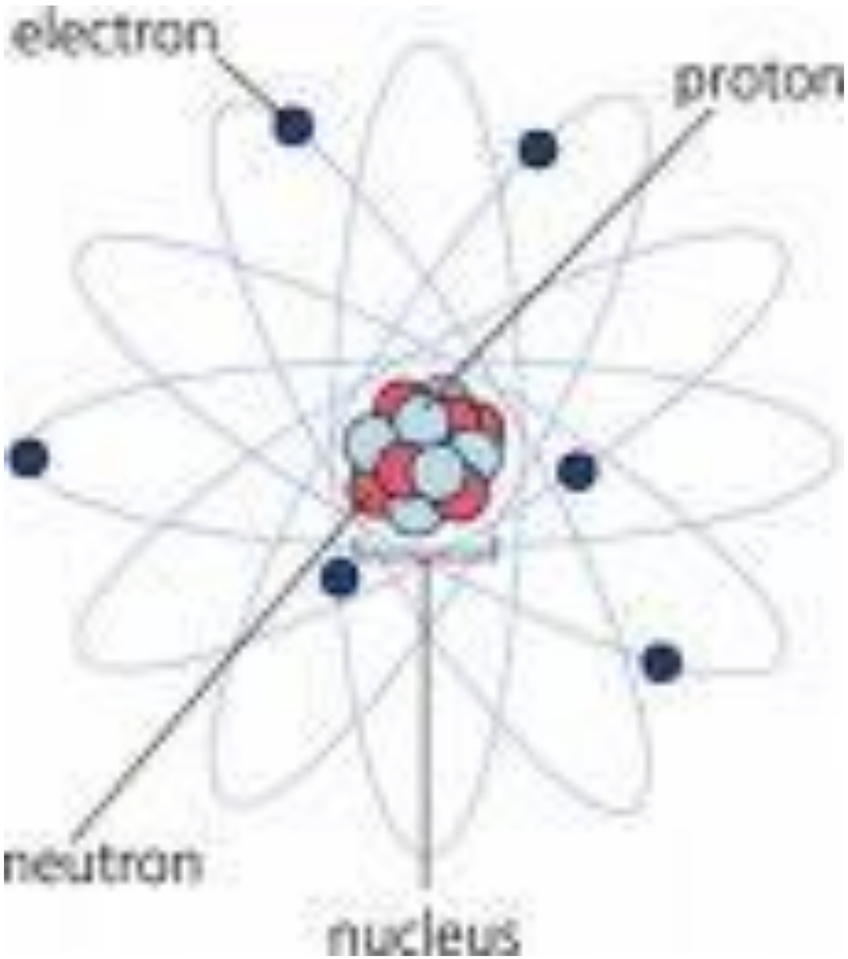
Atomic Structure

Chapters 4, 8, 18 .1-18.3



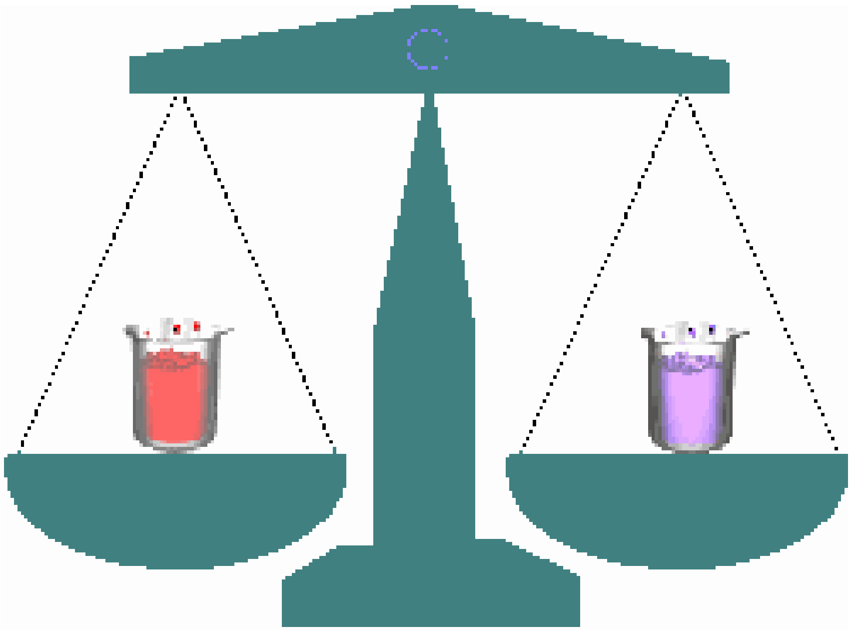
Bravo – 15,000 kilotons

What is an atom?



- Smallest unit of an element that retains all the properties of the element
- Can combine with other atoms to form compound
- Named by Democritus 400BC from the Greek word indivisible

Law of Conservation of Matter



- Mass is not created (gained) nor destroyed (lost) during ordinary physical and chemical reactions.
- Proven by Antoine Lavoisier 200 years ago

Law of Definite Proportions

- Chemical compound contains the same elements in exactly the same proportions by mass regardless of sample size or source of substance
- 1700's Joseph Proust

- We all know the chemical formula for water is H_2O . It is essential for the body. The water from a Poland Spring bottle and from a your tap at home is always 2 hydrogen atoms to 1 oxygen atom

Law of Multiple Proportions

- Two elements may combine in different ratios to form different compounds.
- Change the ratio …Change the compound
- John Dalton

- Water is composed of hydrogen and oxygen in a 2 to 1 ratio needed for body
- Hydrogen Peroxide is H_2O_2 in a ratio of 2 to 2. Used as an antiseptic poisonous to body

John Dalton

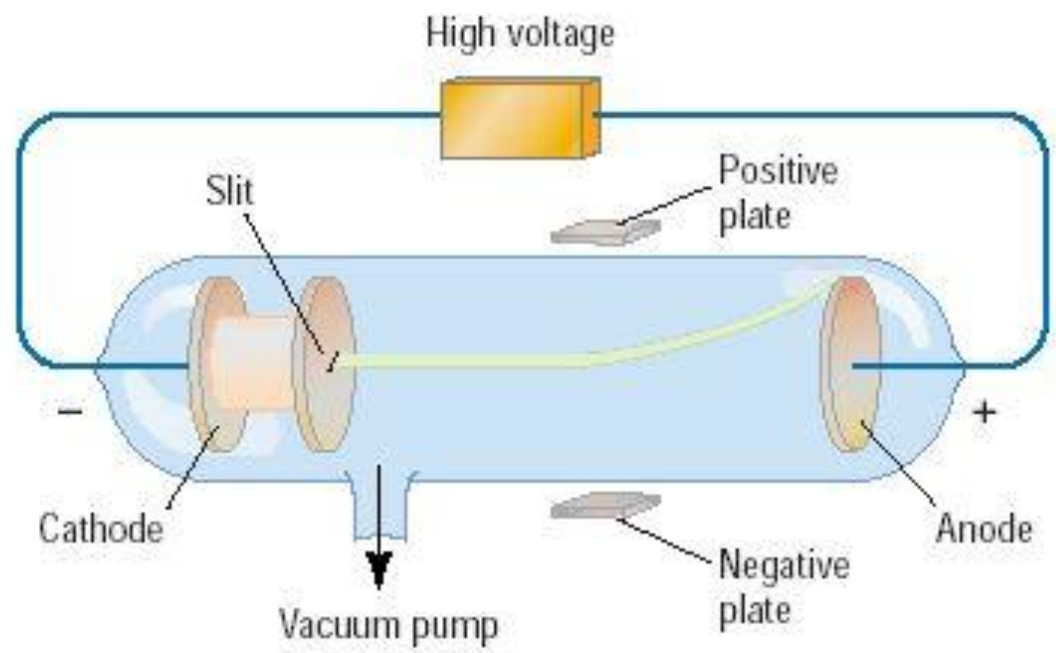
- English Scholar 1808- founding father of the atomic theory
- (Didn't know about subatomic particles or isotopes made adjustments and is now our modern atomic theory)

Modern Atomic Theory

- **All matter is composed of atoms**
- **Atoms cannot be subdivided, created, or destroyed in ordinary chemical reactions. However, these changes CAN occur in nuclear reactions!**
- **Atoms of an element have a characteristic average mass which is unique to that element.**
- **Atoms of any one element differ in properties from atoms of another element**

Discovery of the Electron

In 1897, J.J. Thomson used a cathode ray tube to deduce the presence of a negatively charged particle.

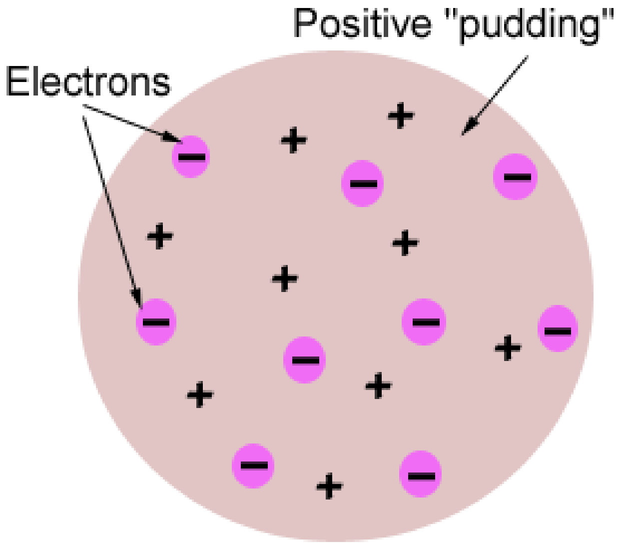


Cathode ray tubes pass electricity through a gas that is contained at a very low pressure.

Conclusions from the Study of the Electron

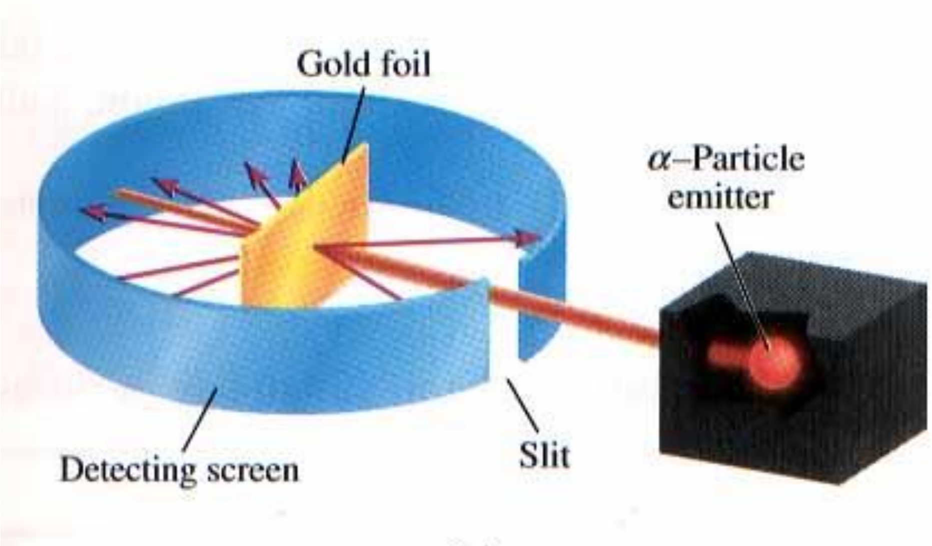
- **Cathode rays have identical properties regardless of the element used to produce them. All elements must contain identically charged electrons.**
- **Atoms are neutral, so there must be positive particles in the atom to balance the negative charge of the electrons**
- **Electrons have so little mass that atoms must contain other particles that account for most of the mass**

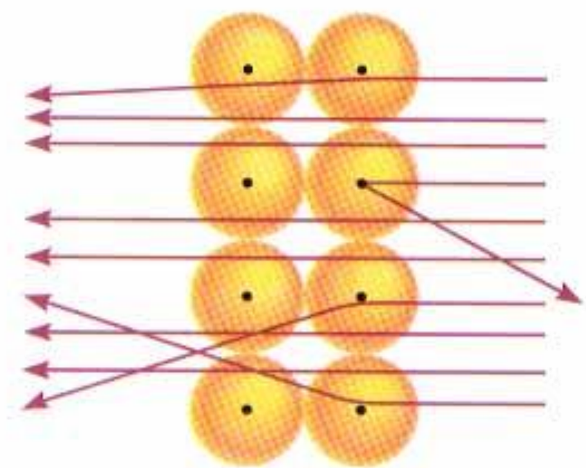
Thomson's Atomic Model



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

Rutherford’s Gold Foil Experiment

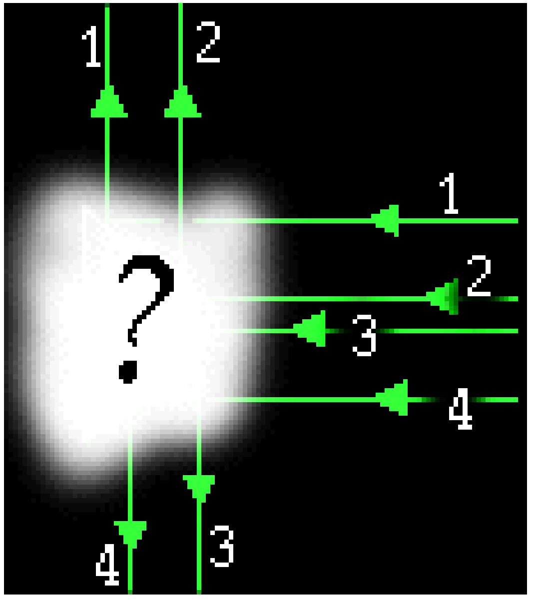


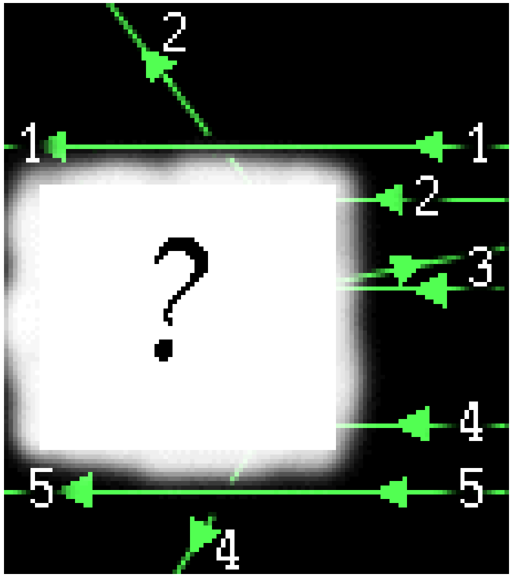


- Alpha particles are helium nuclei
- Particles were fired at a thin sheet of gold foil
- Particle hits on the detecting screen (film) are recorded

Try it Yourself!

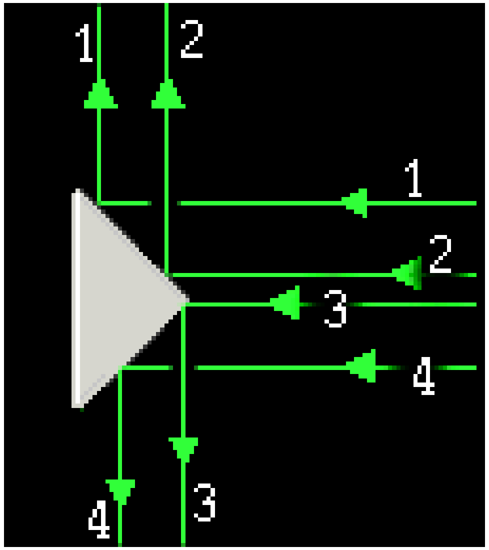
In the following pictures, there is a target hidden by a cloud. To figure out the shape of the target, we shot some beams into the cloud and recorded where the beams came out. Can you figure out the shape of the target?



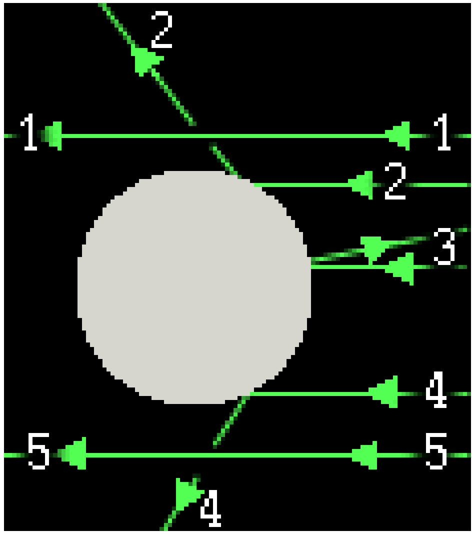


The Answers

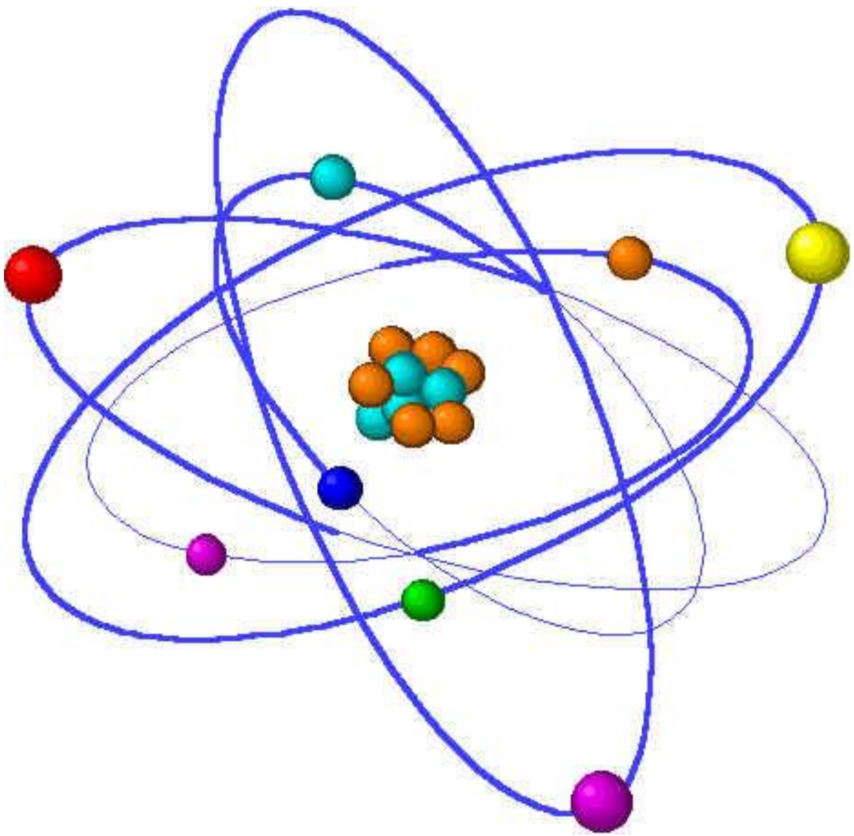
Target #1



Target #2



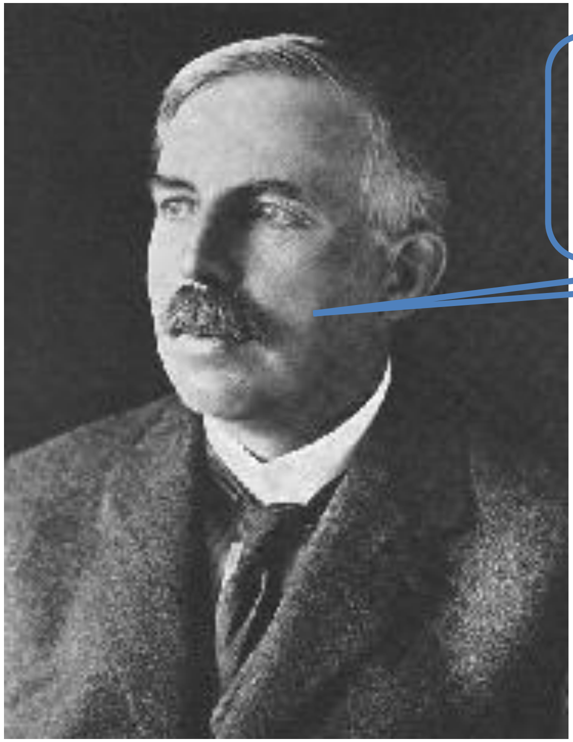
OK Lets Think



- If we know opposite charges attract…and the same repel… the nucleus has positive charges together and the electrons are in the cloud and are negative on the outside…
- WHY DOESN’T THE NUCLEUS SPLIT OR
- WHY DOESN’T THE ATOM IMPLODE!

Rutherford’s Findings

- Most of the particles passed right through
- A few particles were deflected
- VERY FEW were greatly deflected



“Like howitzer shells bouncing off of tissue paper!”

Conclusions:

- The nucleus is small
- The nucleus is dense
- The nucleus is positively charged

Discovery of Protons and Neutrons

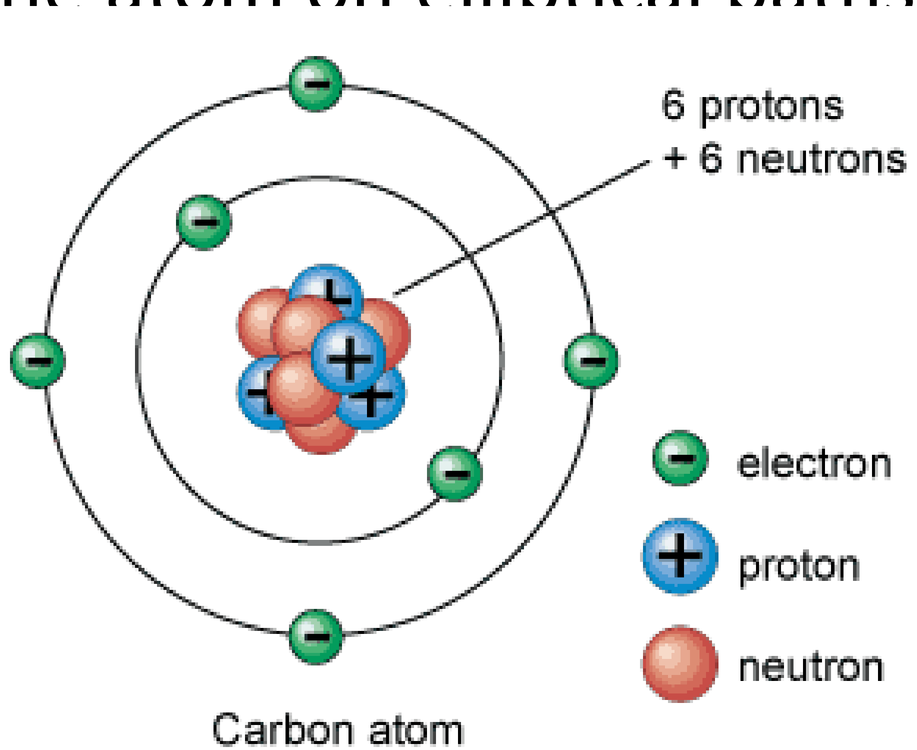
- By 1920 Ernest Rutherford finally determined that the nucleus contained positively charged particles called protons.
- James Chadwick, in 1932, determined that the nucleus contains a neutral particle as well and he called it the neutron. He was Rutherford’s lab partner and based his discovery off of the Gold Foil Experiment.

Max Planck

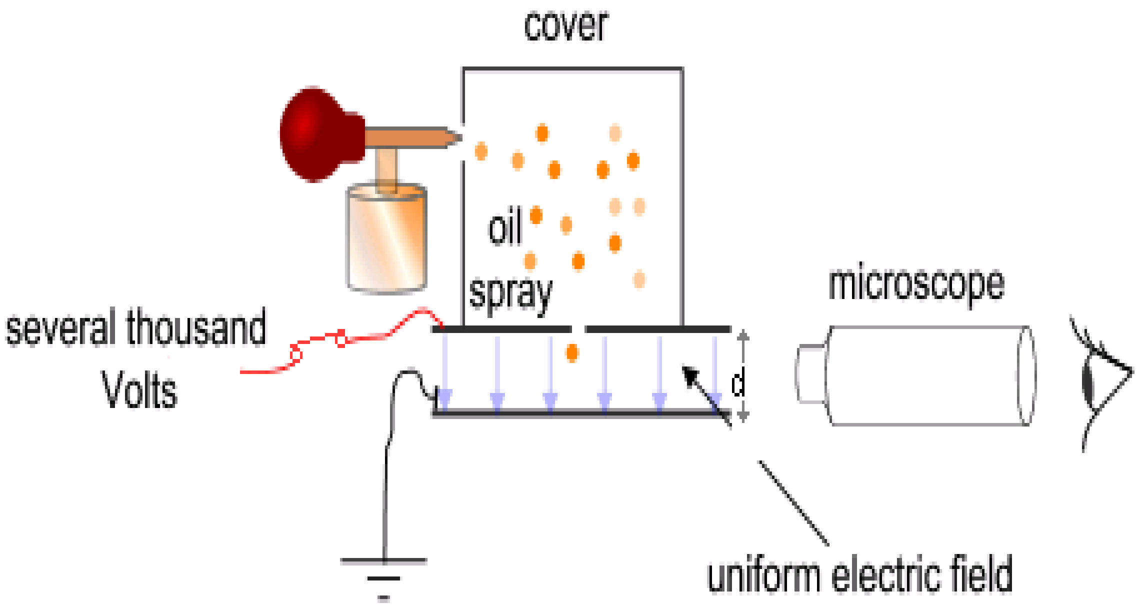
- figured out that when a solid substance is heated, it gives off energy in "chunks“
- later called quantums of energy
    - *quantum means fixed amount*
- noticed that different substances released different

Bohr Model of the Atom

- In 1913, Neils Bohr published a theory that proposed that electrons traveled about the nucleus of the atom on elliptical paths called orbits. Th system, with th electrostatic att



Miliken's Oil Drop Experiment



Oil drops were placed in an evacuated tube, then each drop had an electric charge applied.

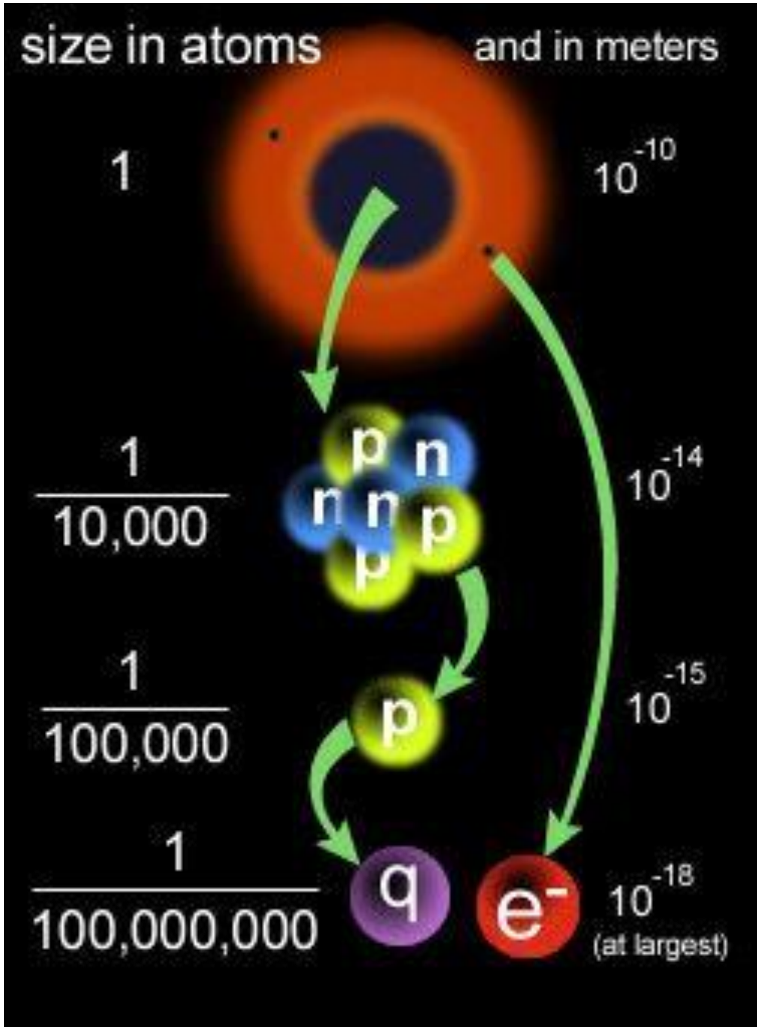
The distance the drop fell was due to the mass of the electron

Atomic Particles

Particle	Charge	Mass #	Location
Electron	-1	0	Electron cloud
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus

The Atomic Scale

- Most of the mass of the atom is in the nucleus (protons and neutrons)
- Electrons are found outside of the nucleus (the electron cloud)
- Most of the volume of the atom is empty space



"q" is a particle called a "quark"

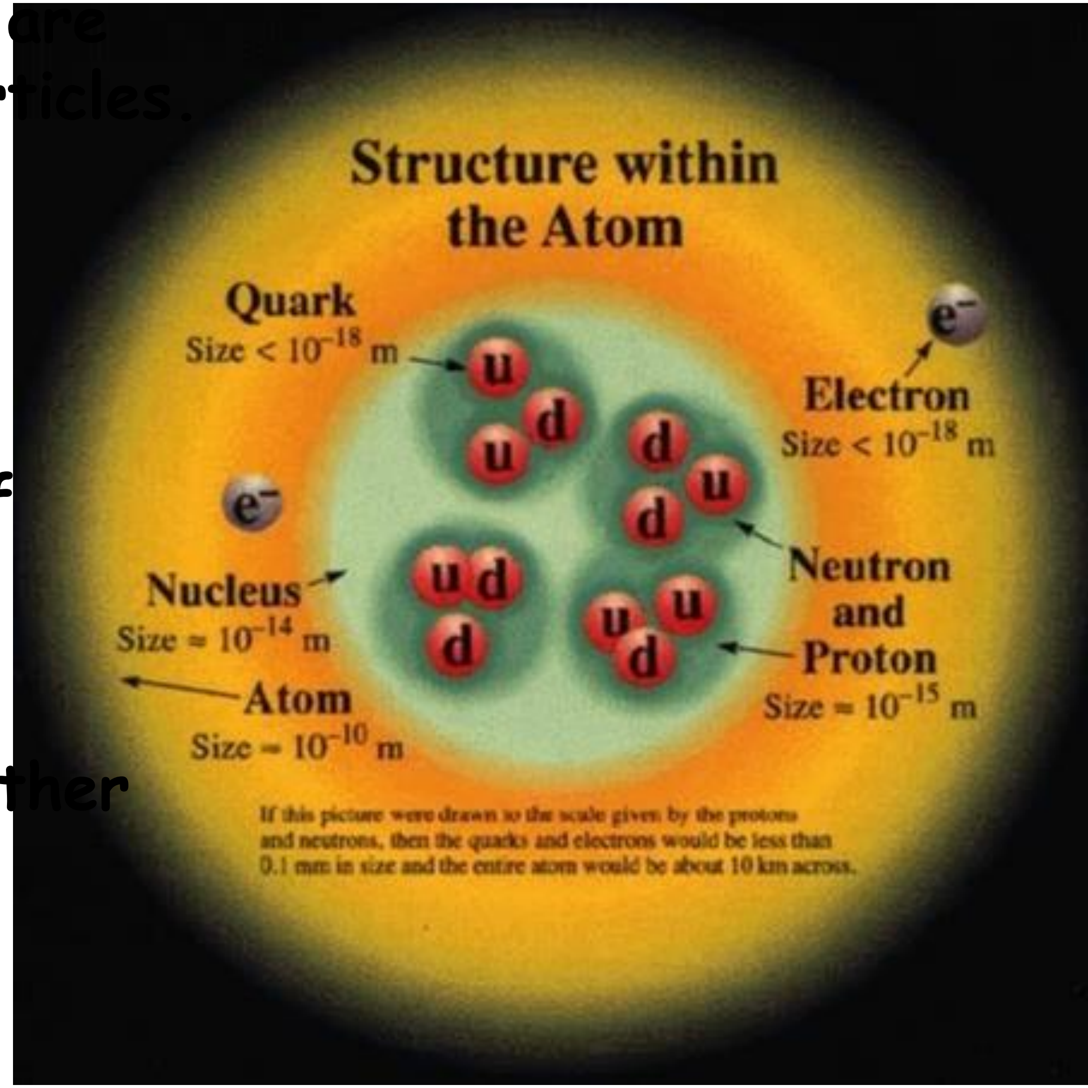
About Quarks…

Protons and neutrons are <u>NOT</u> fundamental particles.

Protons are made of two “up” quarks and one “down” quark.

Neutrons are made of one “up” quark and two “down” quarks.

Quarks are held together by “gluons”



Atomic Number

Atomic number (Z) of an element is the number of protons in the nucleus of each atom of that element.

Element	# of protons	Atomic # (Z)
Carbon	6	6
Phosphorus	15	15
Gold	79	79

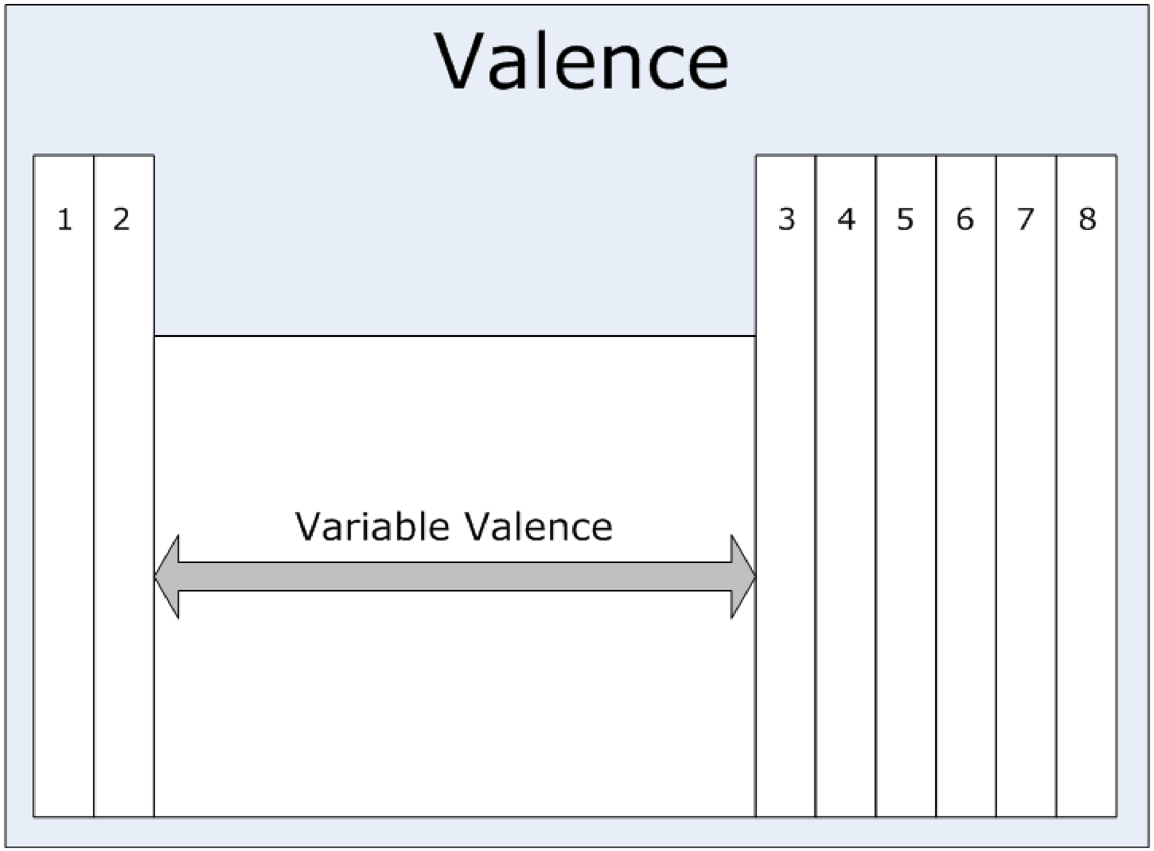
Mass Number (A)

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

Mass # = p^+ + n^0

Nuclide Element-	p^+	n^0	e^-	Mass #
Oxygen - 18	8	10	8	18
Arsenic - 75	33	42	33	75
Phosphorus - 31	15	16	15	31

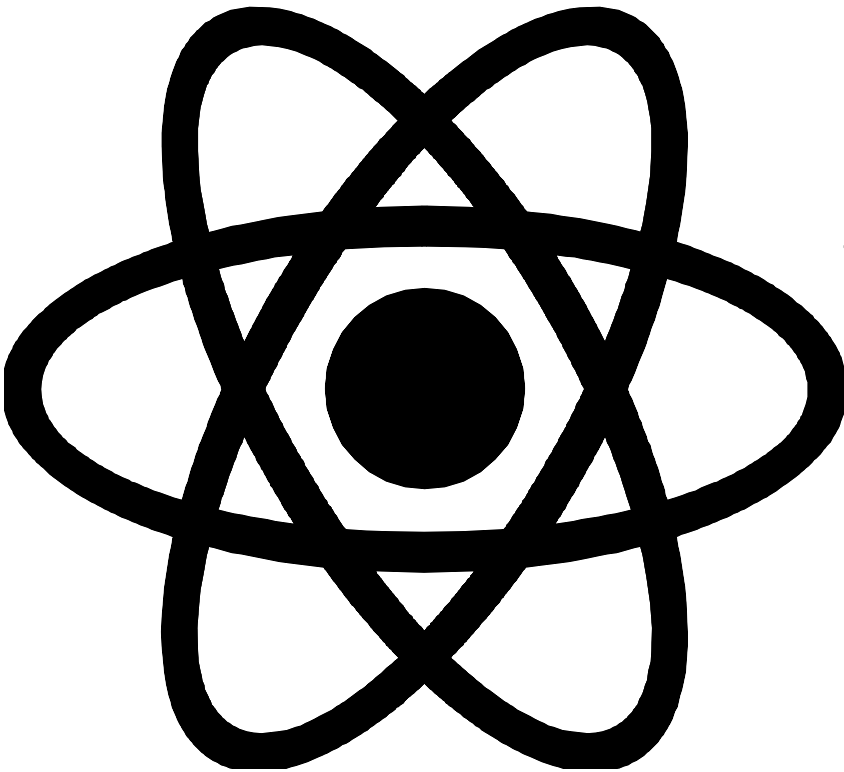
Valence Electrons- Outermost electrons – responsible for reactivity of the atom



Note: all the elements in the same group have the same number of valence electrons!

Therefore they are physically and chemically similar!

Valence electrons

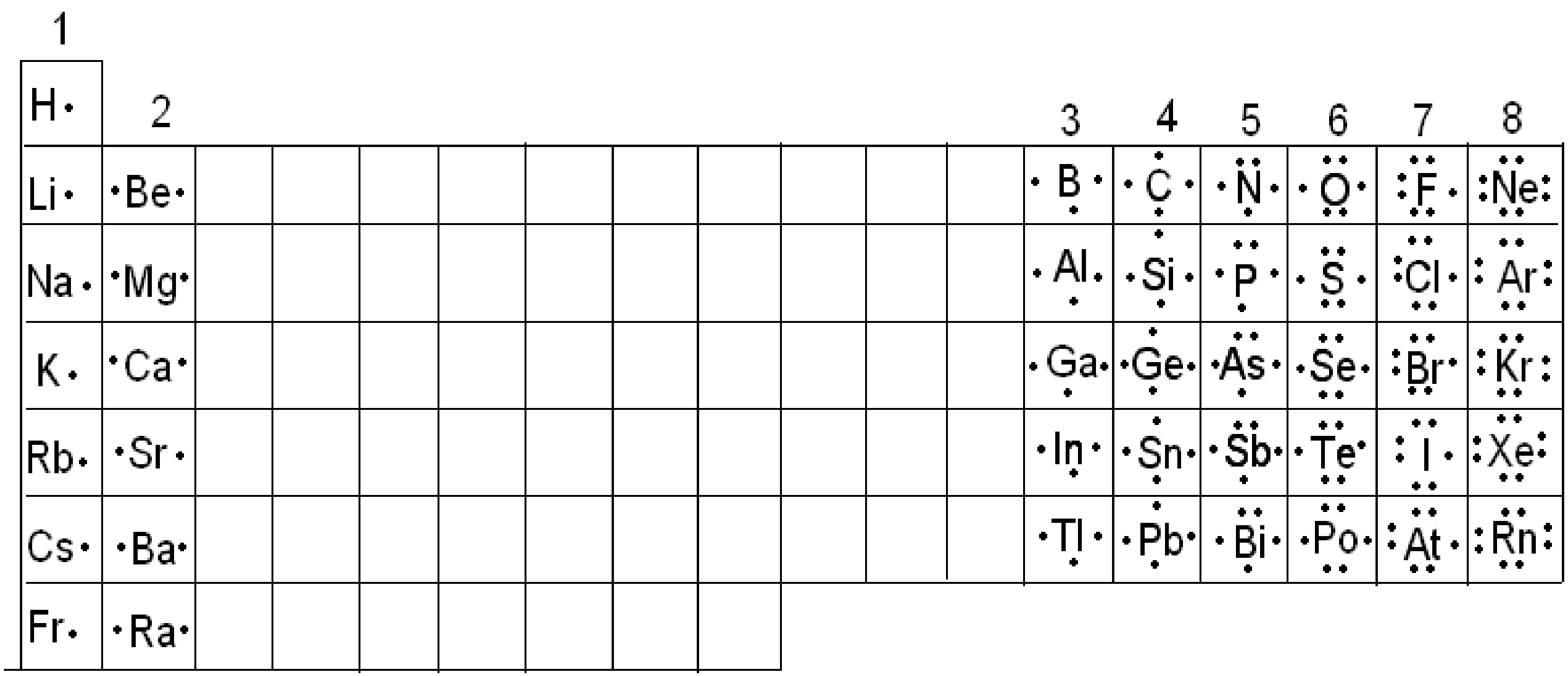


- Metals have low numbers, will tend to **lose** electrons to become stable with octet

- Nonmetals high number of valence electrons- tend to **gain** more to become stable with octet

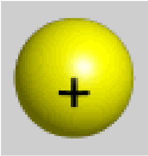
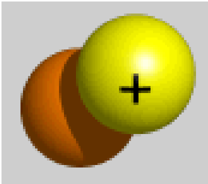
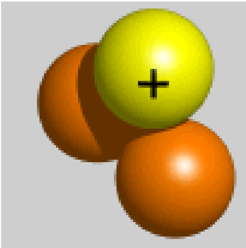
Lewis Dot Diagrams

- Shows the Kernal of the atom (all inner shells and nucleus) as the symbol and dots represent the outer electrons-



Isotopes

Isotopes are atoms of the same element having different masses due to varying numbers of neutrons.

Isotope	Protons	Electrons	Neutrons	Nucleus
Hydrogen-1 (protium)	1	1	0	
Hydrogen-2 (deuterium)	1	1	1	
Hydrogen-3 (tritium)	1	1	2	

AtomicMasses

Atomic mass is the average of all the naturally isotopes of that element.

Carbon = 12.011

Isotope	Symbol	Composition of the nucleus	% in nature
Carbon-12	^{12}C	6 protons 6 neutrons	98.89%
Carbon-13	^{13}C	6 protons 7 neutrons	1.11%
Carbon-14	^{14}C	6 protons 8 neutrons	<0.01%

Nuclear Symbols – Nuclear Shorthand – Shorthand Notation

Mass number
(p^+ + n^o)

$$^{235}_{92}U$$

Element symbol

Atomic number
(number of p^+)

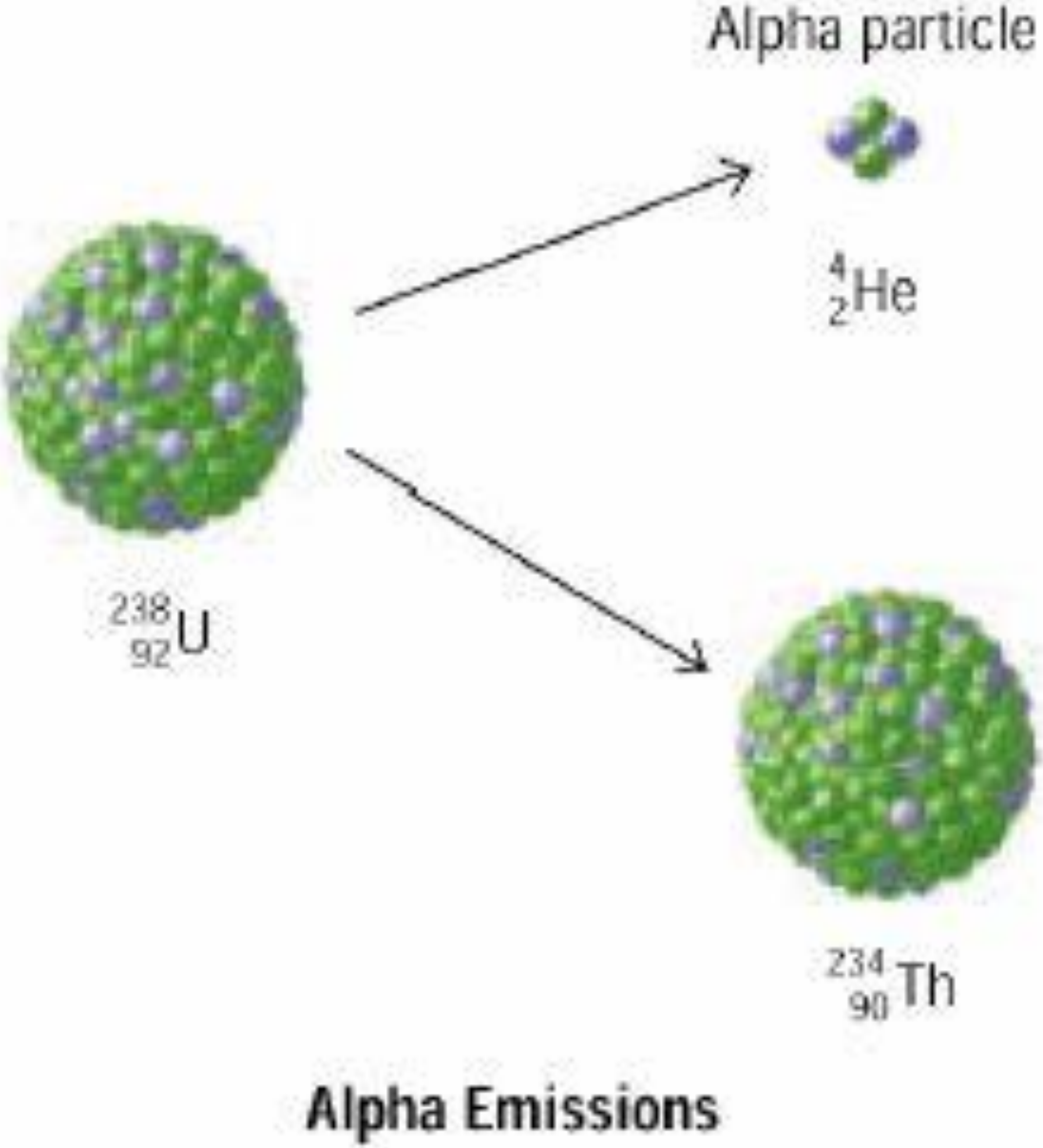
Types of Radioactive Decay

- alpha production (α): helium nucleus $^{2+}$

$$^{238}_{92}\mathrm{U} \rightarrow \, ^{4}_{2}\mathrm{He} + \, ^{234}_{90}\mathrm{Th}$$

- beta production (β):

$$^{234}_{90}\mathrm{Th} \rightarrow \, ^{234}_{91}\mathrm{Pa} + \, ^{0}_{-1}\mathrm{e}$$

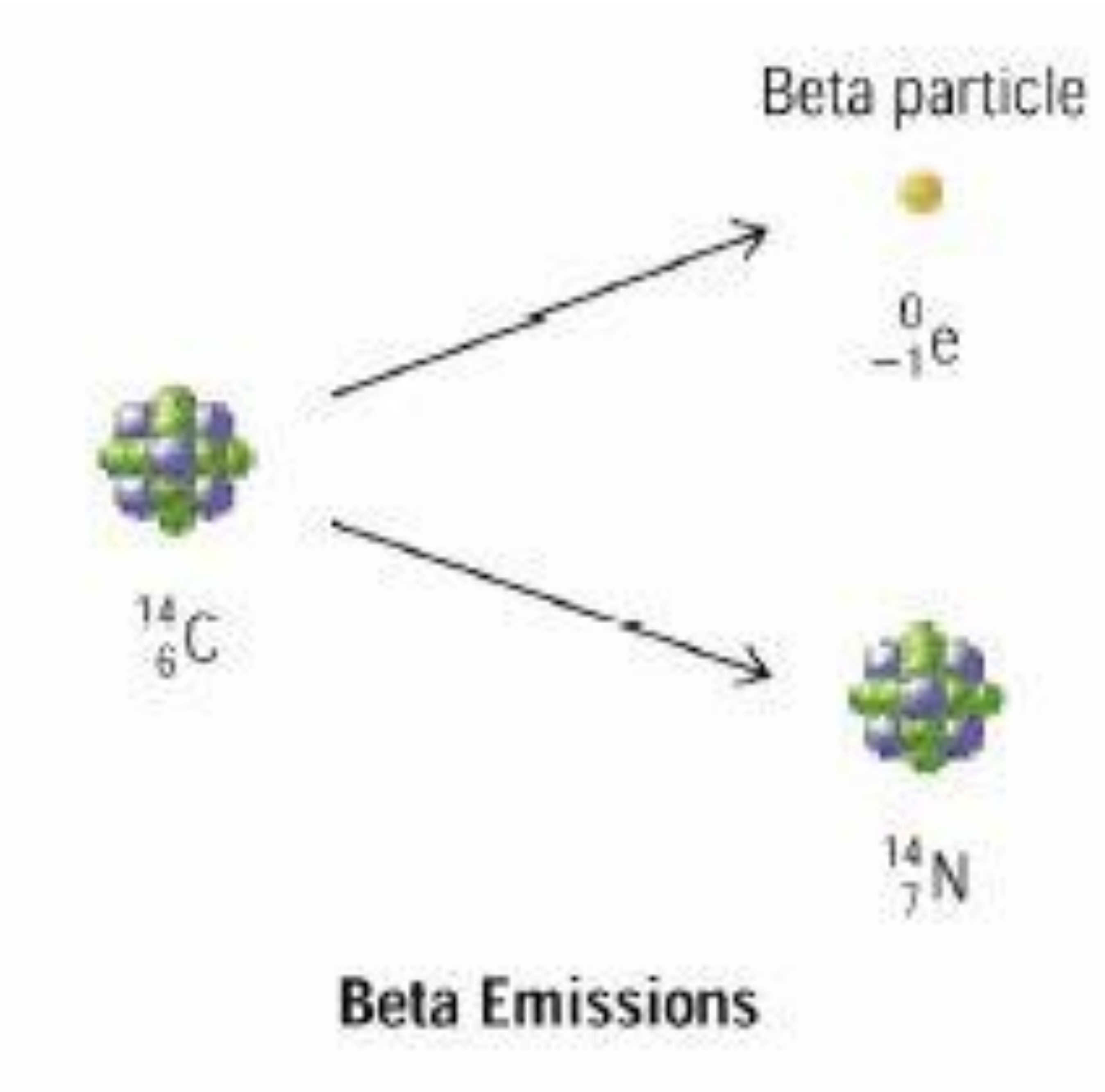


Alpha Radiation

Limited to VERY large nucleii.

Beta Radiation

Converts a neutron into a proton.



Types of Radioactive Decay

- gamma ray production (γ):

$$^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\text{He} + {}^{234}_{90}\text{Th} + 2\,{}^{0}_{0}\gamma$$

- positron production :

$$^{22}_{11}\text{Na} \rightarrow {}^{0}_{1}\text{e} + {}^{22}_{10}\text{Ne}$$

- electron capture: (inner-orbital electron is captured by the nucleus)

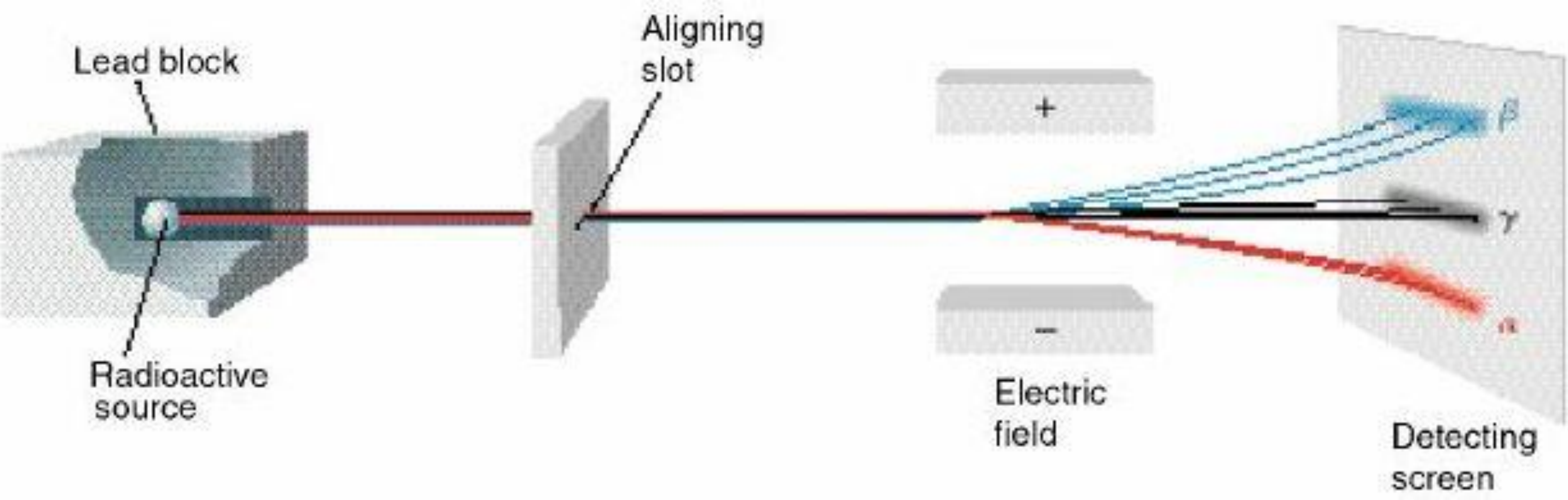
$$^{201}_{80}\text{Hg} + {}^{0}_{-1}\text{e} \rightarrow {}^{201}_{79}\text{Au} + {}^{0}_{0}\gamma$$

Characteristics of Some Ionizing Radiations

Property	Alpha radiation	Beta radiation	Gamma radiation
Composition	Alpha particle (helium nucleus)	Beta particle (electron)	High-energy electromagnetic radiation
Symbol	α, ${}^{4}_{2}He$	β, ${}^{0}_{-1}e$	γ
Charge	2+	1−	0
Mass (amu)	4	1/1837	0
Common source	Radium-226	Carbon-14	Cobalt-60
Approximate energy	5 MeV*	0.05 to 1 MeV	1 MeV
Penetrating power	Low (0.05 mm body tissue)	Moderate (4 mm body tissue)	Very high (penetrates body easily)
Shielding	Paper, clothing	Metal foil	Lead, concrete (incompletely shields)

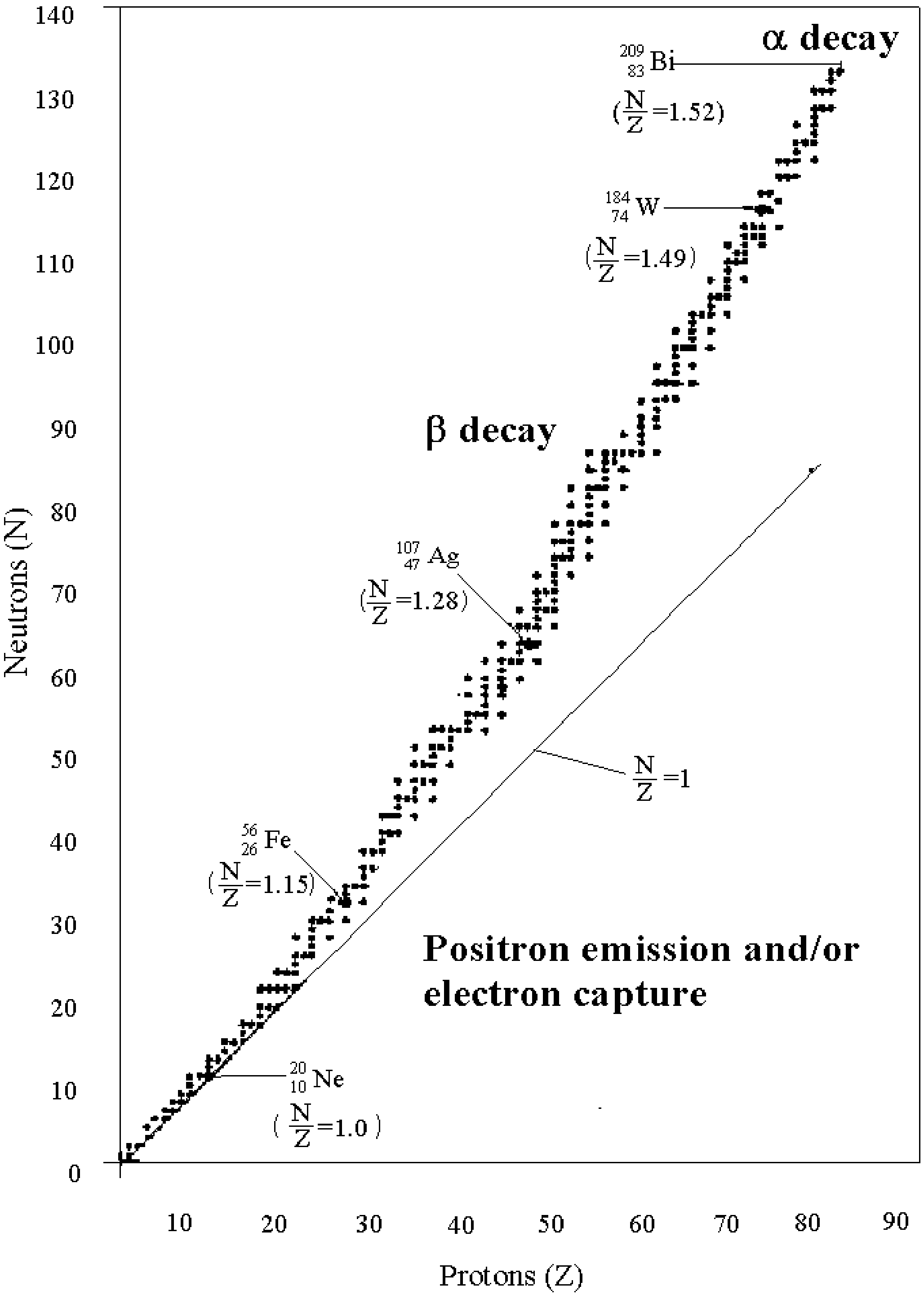
*(1 MeV = 1.60×10^{-13} J)

Deflection of Decay Particles



Opposite charges__attract__ each other.

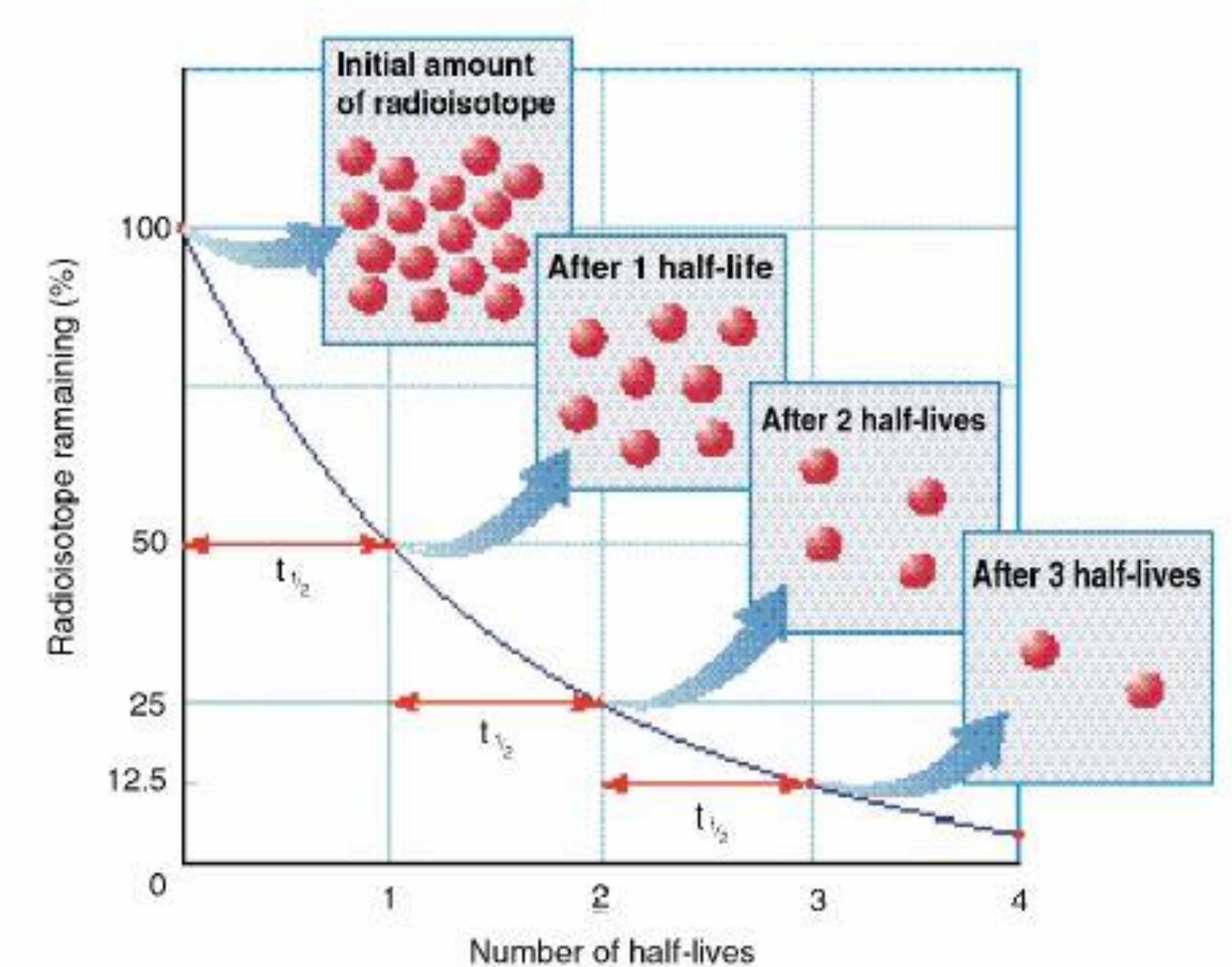
Like charges__repel__ each other.



Nuclear Stability

Decay will occur in such a way as to return a nucleus to the band (line) of stability.

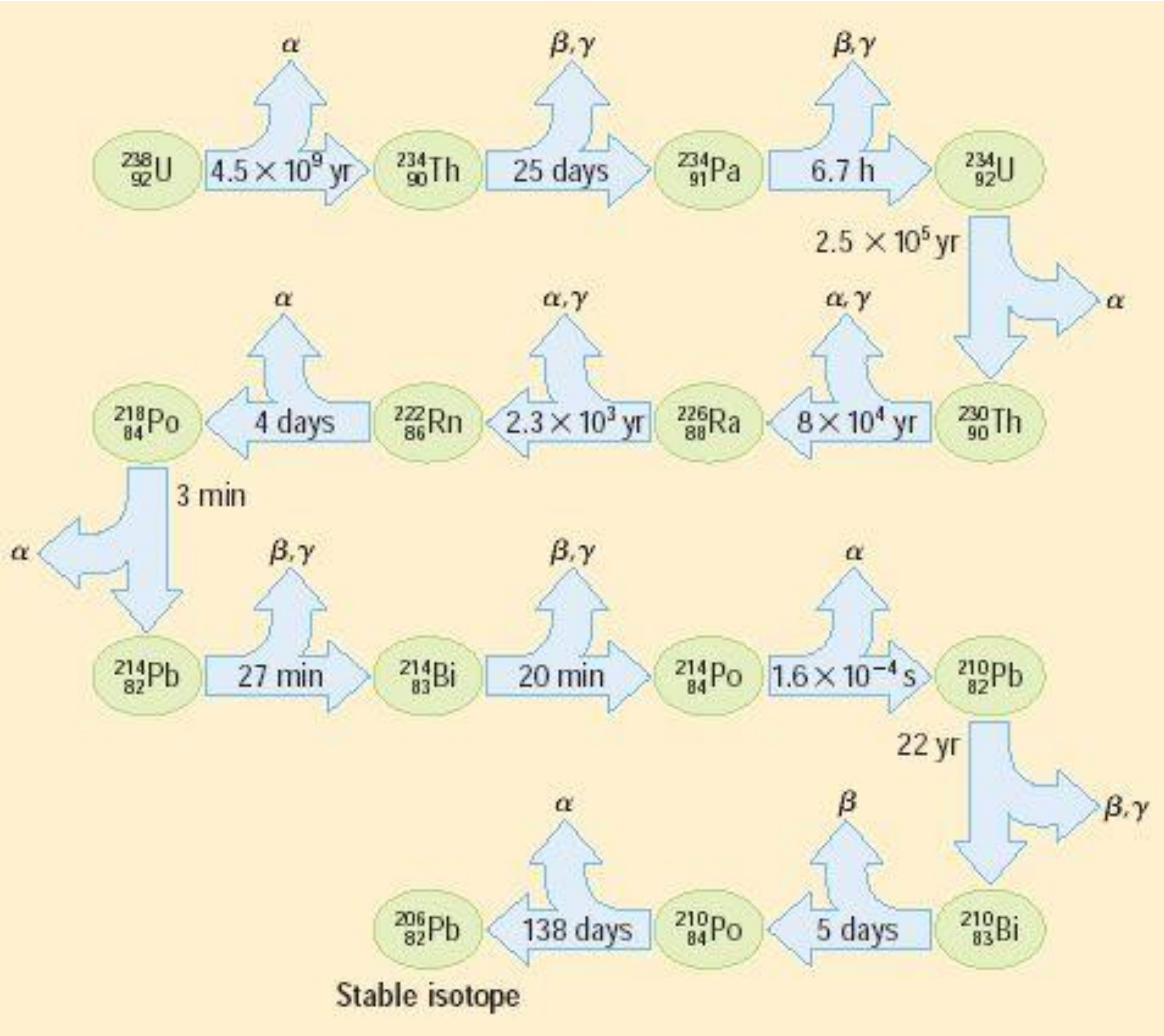
Half-life Concept



Sample Half-Lives

Half-Lives and Radiation of Some Naturally Occurring Radioisotopes		
Isotope	**Half-life**	**Radiation emitted**
Carbon-14	5.73×10^3 years	β
Potassium-40	1.25×10^9 years	β, γ
Radon-222	3.8 days	α
Radium-226	1.6×10^3 years	α, γ
Thorium-230	7.54×10^4 years	α, γ
Thorium-234	24.1 days	β, γ
Uranium-235	7.0×10^8 years	α, γ
Uranium-238	4.46×10^9 years	α

A radioactive nucleus reaches a stable state by a series of steps



A Decay Series

Nuclear Fission and Fusion

•Fusion: Combining two light nuclei to form a heavier, more stable nucleus.

$$ {}^{3}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{0}_{1}\mathrm{e} $$

•Fission: Splitting a heavy nucleus into two nuclei with smaller mass numbers.

$$ {}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} $$

Energy and Mass

Nuclear changes occur with small but measurable losses of mass. The lost mass is called the mass defect, and is converted to energy according to Einstein's equation:

$$\Delta E = \Delta mc^2$$

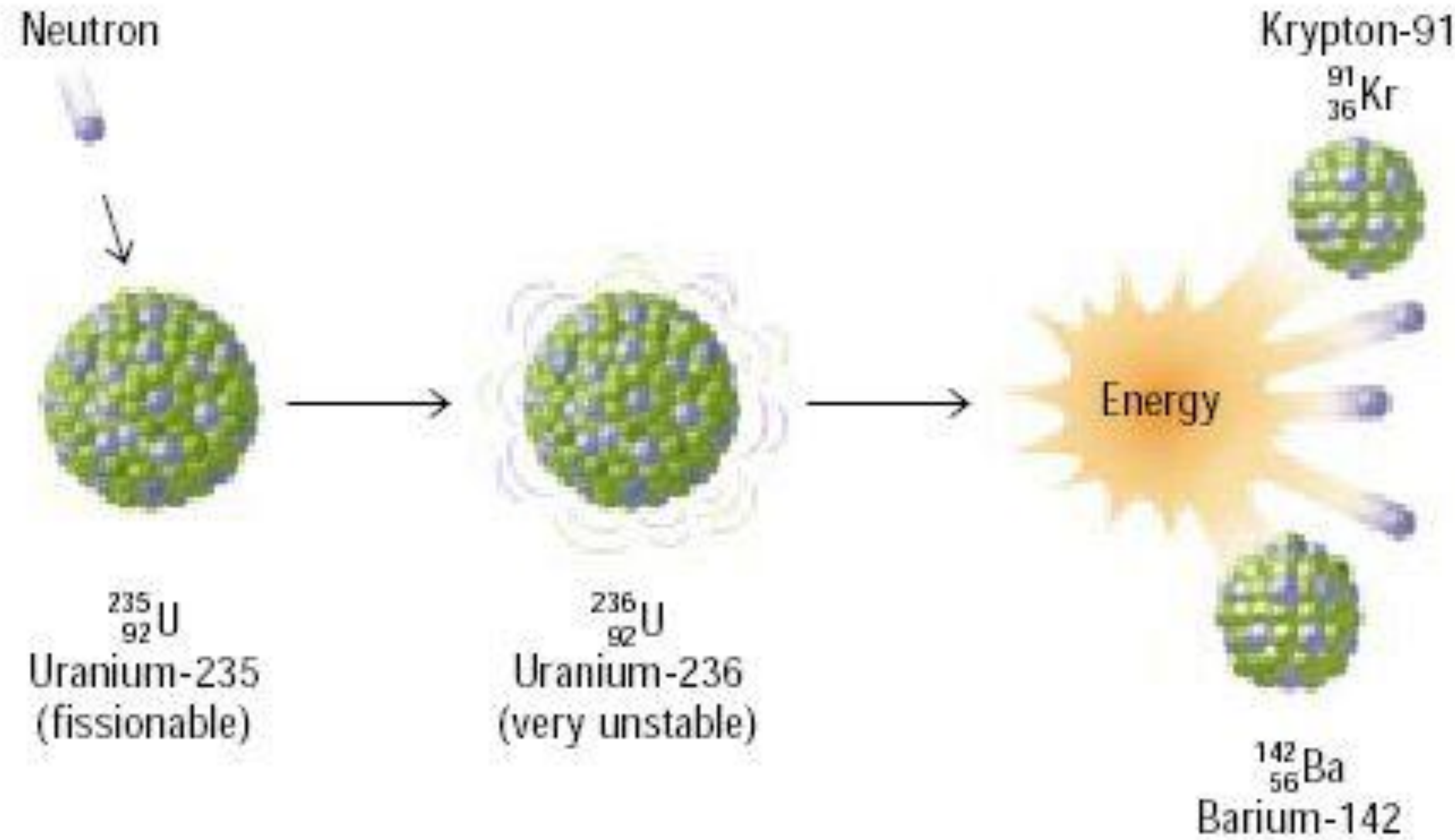
Δm = mass defect

ΔE = change in energy

c = speed of light

Because c^2 is so large, *<u>even small amounts of mass are converted to enormous amount of energy.</u>*

Fission



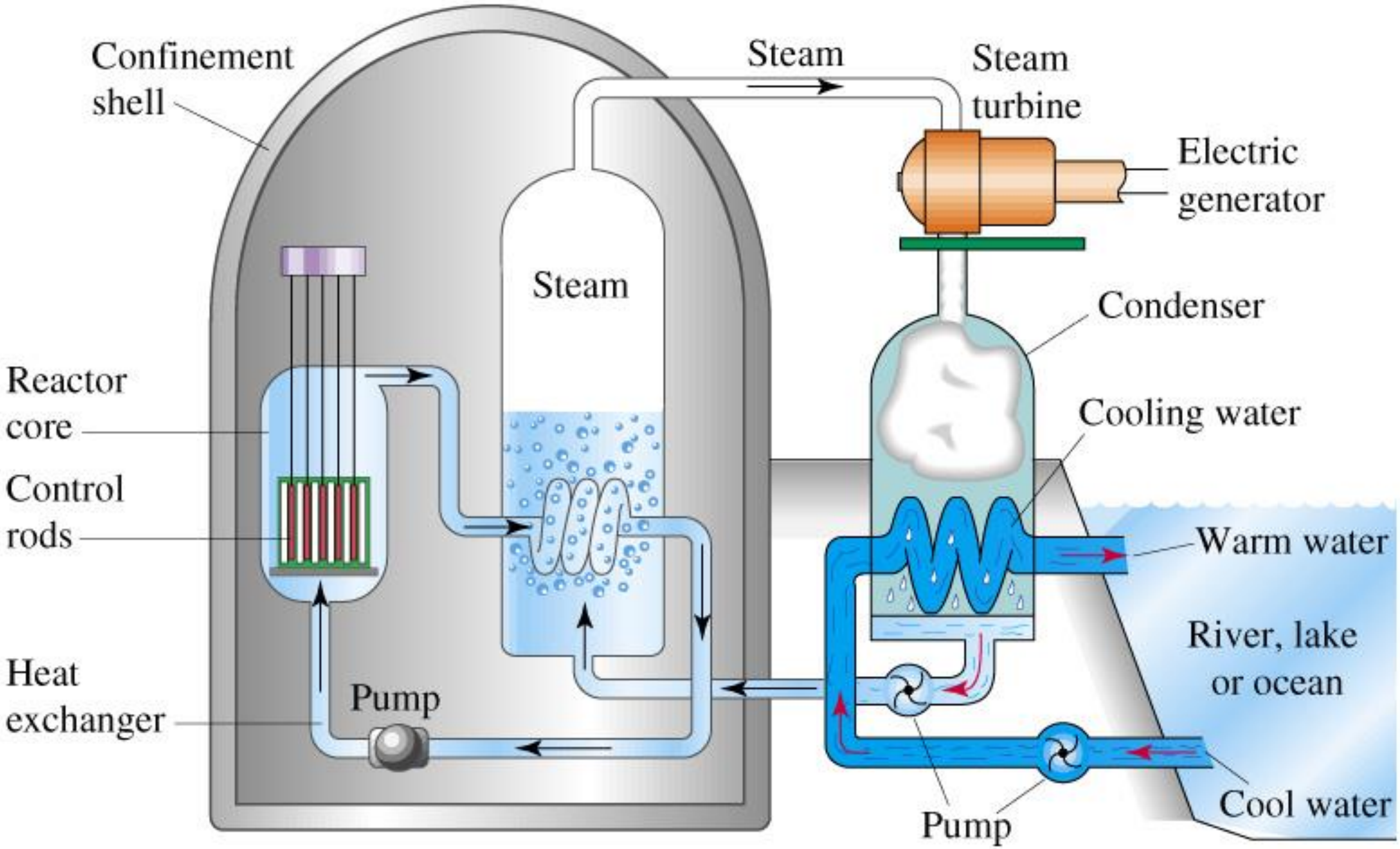
Neutron
Krypton-91
$^{91}_{36}Kr$
Energy
$^{235}_{92}U$
Uranium-235
(fissionable)
$^{236}_{92}U$
Uranium-236
(very unstable)
$^{142}_{56}Ba$
Barium-142

Fission Processes

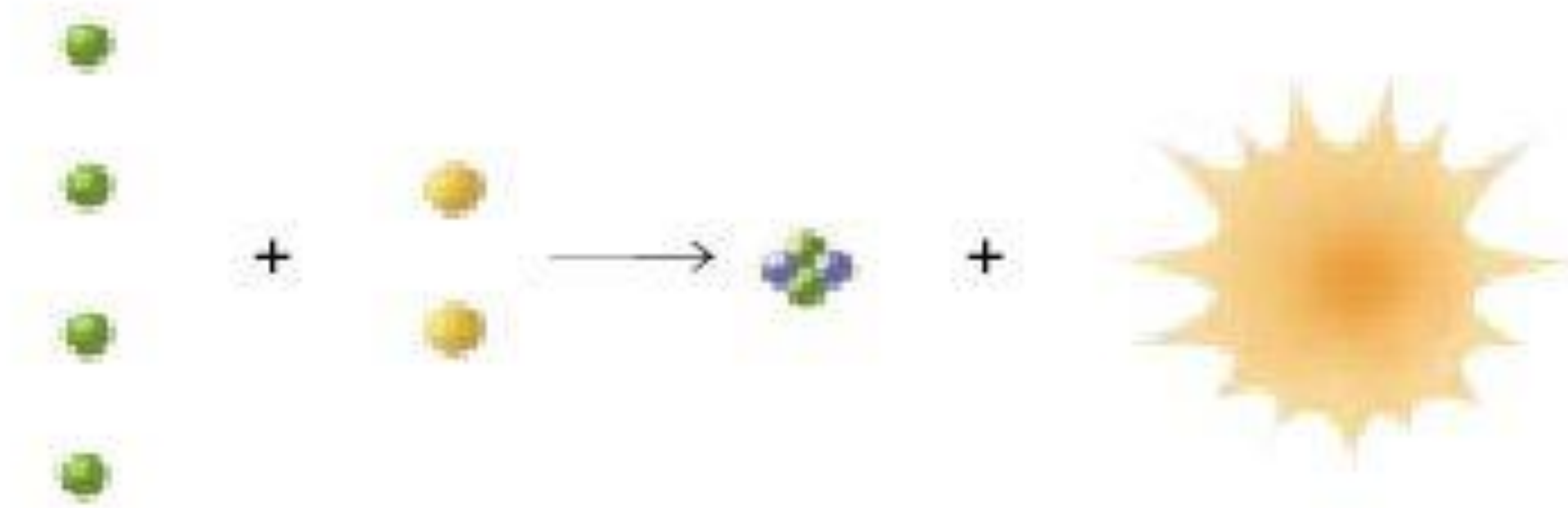
A self-sustaining fission process is called a chain reaction.

Event	Neutrons Causing Fission	Result
subcritical	< 1	reaction stops
critical	= 1	sustained reaction
supercritical	> 1	violent explosion

A Fission Reactor



Fusion

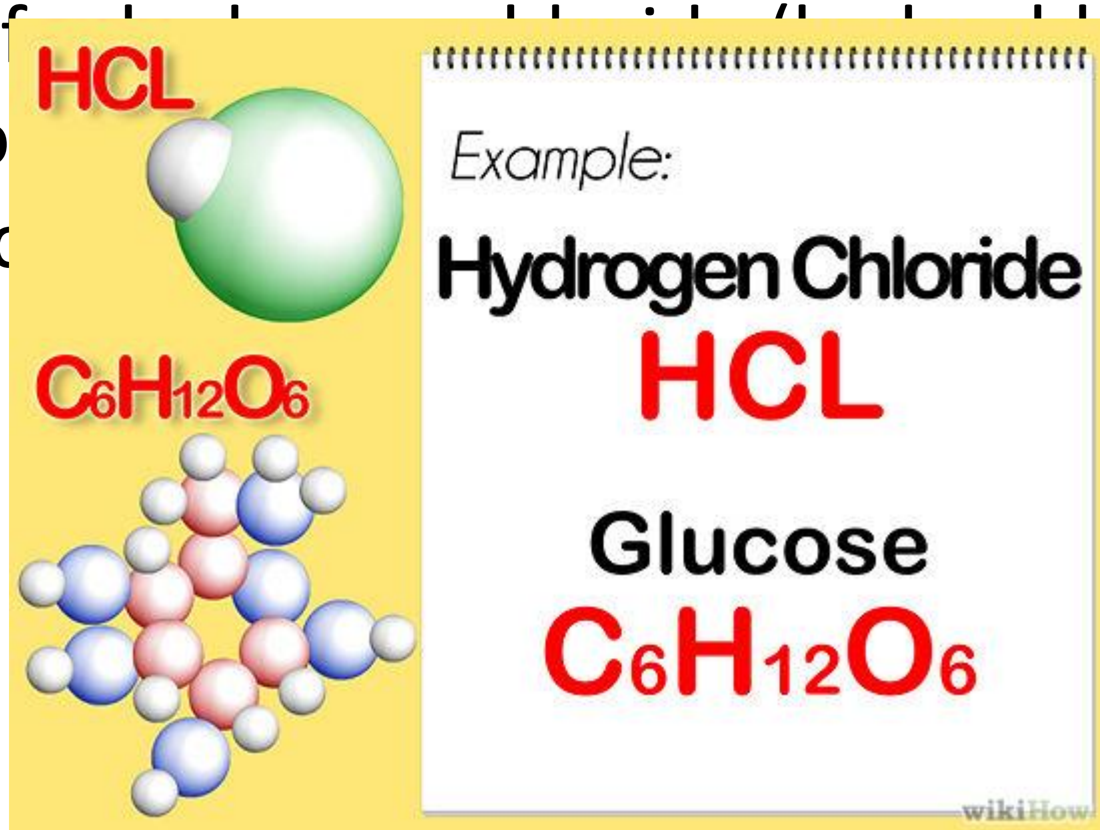


$$4\,{}^{1}_{1}H + 2\,{}^{0}_{-1}e \longrightarrow {}^{4}_{2}He + \text{Energy}$$

Four hydrogen nuclei (protons)	+	Two beta particles (electrons)	→	One helium nucleus	+	Energy

Calculating the Molar Mass of a Compound

1 Find the chemical formula for the compound. This is the number of atoms in each element that makes up the compound. For example, the formula f oric acid) is HCl; fo ans that glucose c rogen atoms, a



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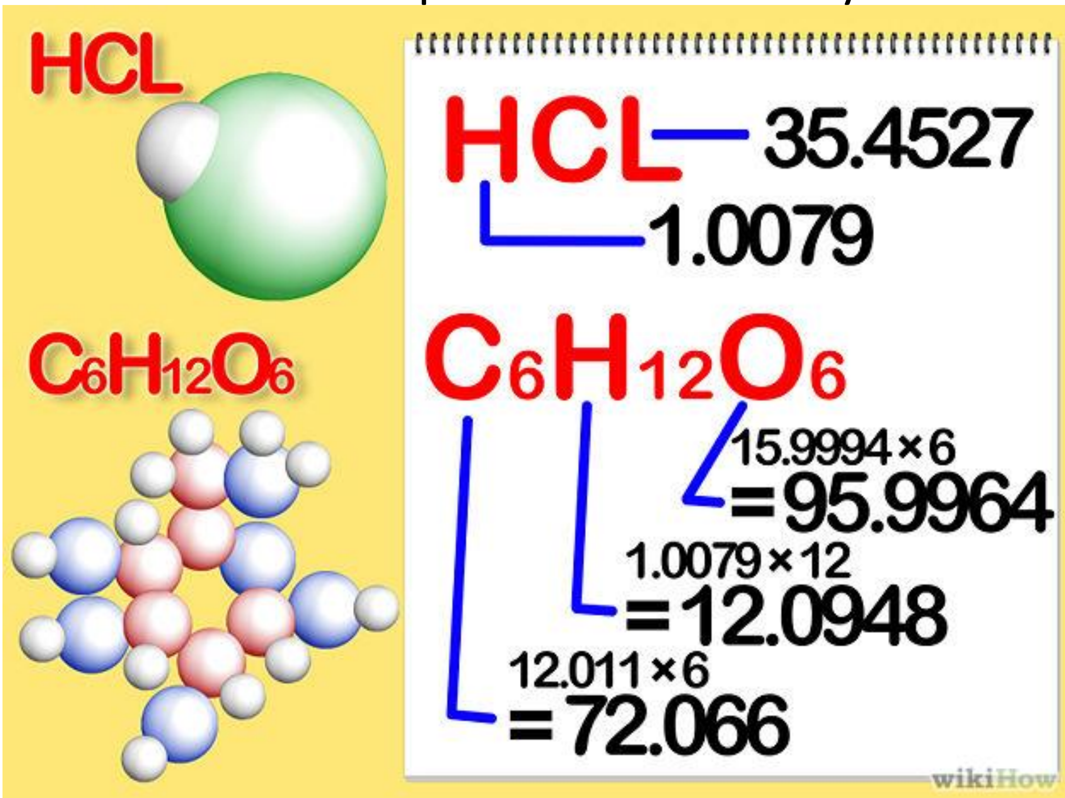
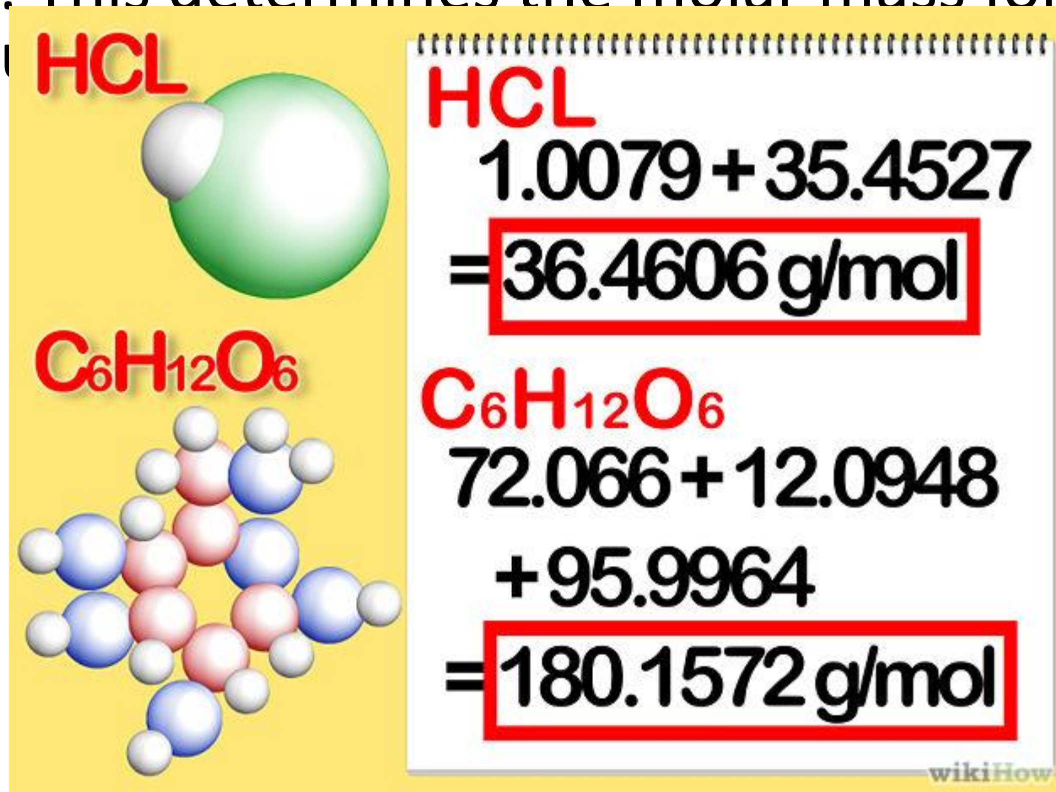
- Find the molar mass of each element in the compound. Multiply the element's atomic mass by the molar mass constant by the number of atoms of that element in the compound. Here's how you do it:



- For hyd ent is 1.007 grams per mole for hydrogen and 35.453 grams per mole for chlorine.
- For glucose, $C_6H_{12}O_6$, the molar mass of each element is 12.0107 times 6, or 72.0642 grams per mole for carbon; 1.007 times 12, or 12.084 grams per mole for hydrogen; and 15.9994 times 6, or 95.9964 grams per mole for oxygen.

Molar Mass

- Add the molar masses of each element in the compound. This determines the molar mass for the compou



- For hydrogen chloride, the molar mass is 1.007 + 35.453, or 36.460 grams per mole.
- For glucose, the molar mass is 72.0642 + 12.084 + 95.9964, or 180.1446 grams per mole.

Calculating Percent by Mass

- What is the percent by mass of metal in the compound copper II phosphate? ($Cu_3(PO_4)_2$)
- Find total mass
- Find mass due to the part
- Divide mass of part by total
- Multiply by 100

($Cu_3(PO_4)_2$)

subscript from P.T.

Cu 3 x 63.55 +

P 2 X 30.97 +

O 8 x 16.00 =

Total mass= 380.59 amu

Mass of metal = 190.7 amu

$$\frac{190.7}{380.59} \times 100 = 50.1\%$$

Chemical Quantities-The Mole

1 dozen = 12

1 gross = 144

1 ream = 500

1 mole = 6.02×10^{23}

There are exactly 12 grams of carbon-12 in one mole of carbon-12.

A mole is the atomic mass taken in grams of a substance

Diatomic Elements

In nature these elements exist in pairs.

Therefore the atomic mass is doubled

The SUPER SEVEN- There are seven of them, It starts with element 7- nitrogen- forms a seven and has a superhero hat of hydrogen!

Diatomic elements	
H_2	Hydrogen
N_2	Nitrogen
O_2	Oxygen
F_2	Fluorine
Cl_2	Chlorine
Br_2	Bromine
I_2	Iodine

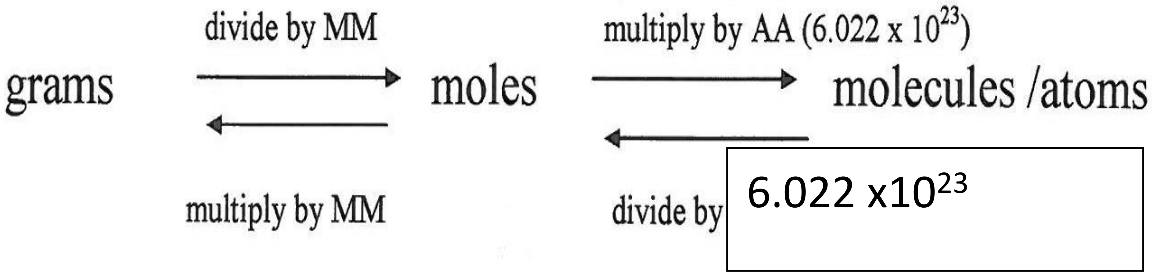
Avogadro's Number

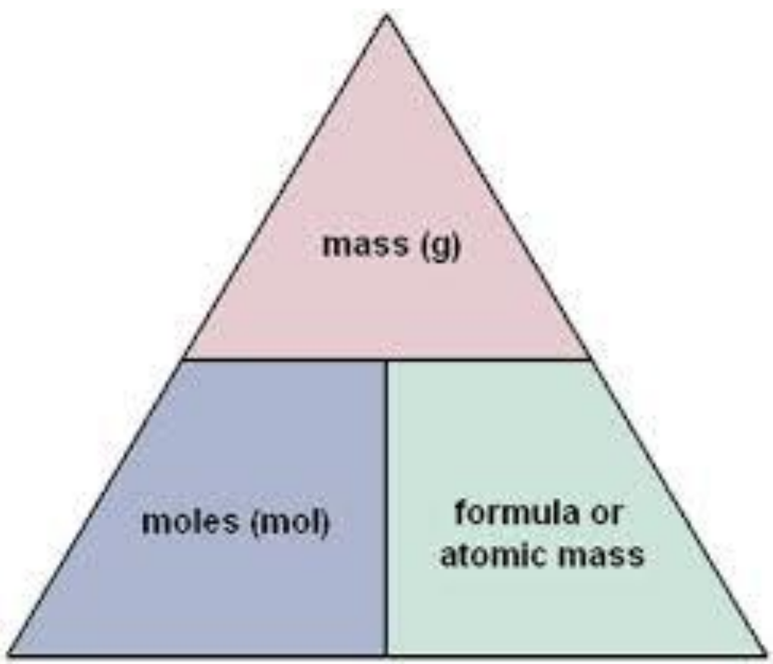
6.02×10^{23} is called "Avogadro's Number" in honor of the Italian chemist Amadeo Avogadro (1776-1855).

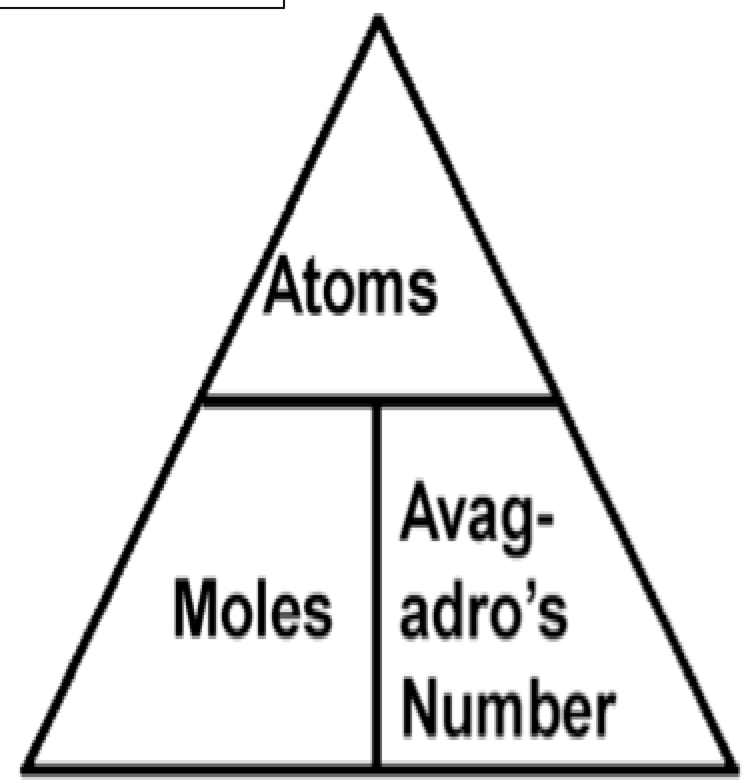
Amadeo Avogadro

I didn't discover it. Its just named after me!

Ways to remember moles



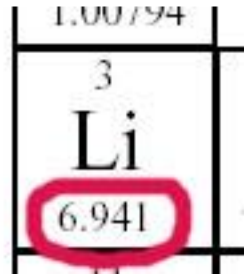




Calculations with Moles:

Converting moles to grams

How many grams of lithium are in 3.50 moles of lithium?

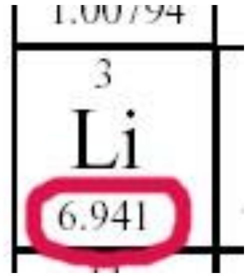


3.50 mol Li	6.94 g Li	= 24.3 g Li
	1 mol Li	

Calculations with Moles:

Converting grams to moles

How many moles of lithium are in 18.2 grams of lithium?



18.2 ~~g~~ Li	1 mol Li
	6.94 ~~g~~ Li

= 2.62 mol Li

Calculations with Moles:

Using Avogadro's Number

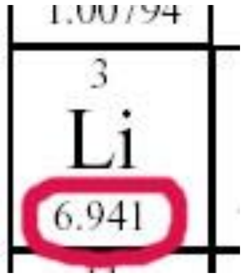
How many atoms of lithium are in 3.50 moles of lithium?

$$\frac{3.50 \text{ mol Li} \times 6.022 \times 10^{23} \text{ atoms Li}}{1 \text{ mol Li}} = 2.11 \times 10^{24} \text{ atoms Li}$$

Calculations with Moles:

Using Avogadro's Number

How many <u>atoms</u> of lithium are in 18.2 g of lithium?



18.2 ~~g~~ Li	1 ~~mol~~ Li	6.022×10^{23} atoms Li
	6.94 ~~g~~ Li	1 ~~mol~~ Li

$(18.2)(6.022 \times 10^{23})/6.94 \quad = 1.58 \times 10^{24}$ atoms Li

Finding Molar Mass of a Compound

- First decide how many of each type of atom you have. (*Remember to multiply a subscript outside a parenthesis to the atoms within)*
- Look up the individual masses on the P.T.
- Multiply the number of atoms by the mass
- Add all parts

What is the molar mass of

copper II phosophate?

($Cu_3(PO_4)_2$)

Cu 3 x 63.55 +

P 2 X 30.97 +

O 8 x 16.00 =

380.59 g/mol

Converting to Moles with a Compound

Cindy masses 205.3 grams of $Cu_3(PO_4)_2$, how many moles does she have?

$$\frac{205.3 \text{ grams} \;|\; 1 \text{ mole } Cu_3(PO_4)_2}{\;|\; 380.59 \text{ grams}} = 0.539 \text{ moles}$$

Using A

- How many moles are used for an experiment if 2.57×10^{23} molecules of $Cu_3(PO_4)_2$ are consumed?
  - (again ignore MM and just divide by A#)

2.57×10^{23} molecules of $Cu_3(PO_4)_2$ | 1 mole / 6.022×10^{23} | = .427 moles $Cu_3(PO_4)_2$

Converting to Grams

- Charlie needs to use 2.50×10^{-4} moles of $Cu_3(PO_4)_2$ for an experiment. How many milligrams should she mass out?

- 2.50×10^{-4} moles | 380.59 grams / 1 mole $Cu_3(PO_4)_2$ | = 9.51×10^{-2} g

$$2.50 \times 10^{-4} \text{ moles} \times \frac{380.59 \text{ grams}}{1 \text{ mole } Cu_3(PO_4)_2} = 9.51 \times 10^{-2} \text{ g}$$

Therefore: 95.1 milligrams

Using A#

- How many kilograms are consumed in a reaction if 2.45×10^{24} molecules of $Cu_3(PO_4)_2$ are used?

$$2.45 \times 10^{24} \text{ molecules of } Cu_3(PO_4)_2 \times \frac{1 \text{ mole}}{6.022 \times 10^{23}} \times \frac{380.59 \text{ grams}}{1 \text{ mole } Cu_3(PO_4)_2} = 1.55 \times 10^{3} \text{ g}$$

Therefore: 1.55 kilograms