Coulomb's Law: fundamental relationship between electrostatic attraction and repulsion.

- It applies to charged particles, magnets, gravitation, etc.
- In chemistry, we are most interested in energy of attraction or repulsion between subatomic particles

$$\textbf{Coulomb's Law: } E \propto \frac{Q_1Q_2}{r}$$

E= energy of attraction or repulsion between particles
Q_1 = charge of first particle
Q_2 = charge of second particle
r = distance between charged particles

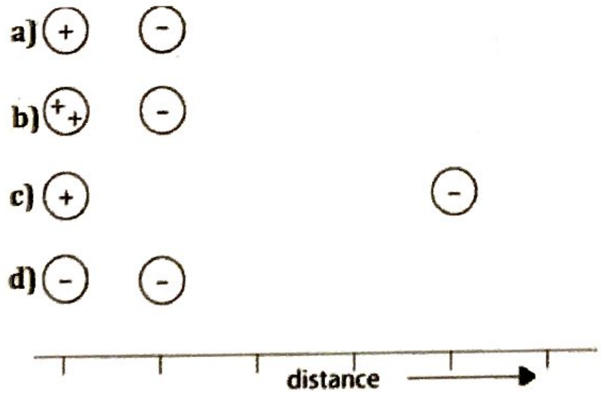
In short:

- Energy of attraction/repulsion ↑ as the magnitudes (sizes) of the charges ↑
- Energy of attraction/repulsion ↓ as the distance between the charges ↑

Thought question: will an electron be more attracted to the nucleus of a hydrogen atom or a helium atom, and why?

Helium! He has $2p^+$ while H has only $1p^+$, more positive charge means negative e^- will be more attracted.

Coulomb's Law Practice



1. Which set of particles shown the left will experience:
   a. the greatest attraction to each other? b.
   b. the greatest repulsion from each other? d.
2. The particles in (a) will experience ______ attraction to each other than the particles in (c) because:
   (a) greater, the distance between them is less.
   b. smaller, the distance between them is less.
   c. the same, distance is irrelevant to force of attraction.
3. The particles shown above in (a) will experience ______ attraction to each other than the particles in (b) because:
   a. greater, the nucleus has one proton instead of two.
   (b.) smaller, the nucleus has one proton instead of two.
   c. the same, charge is irrelevant to force of attraction.
4. An electron (in the lowest energy level) would be most attracted to the nucleus of which element? (assuming same distance apart)
   a. lithium ($3p^+$)
   b. sodium ($11p^+$)
   c. potassium ($19p^+$)
   (d.) rubidium ($37p^+$)
5. A proton would be least repulsed by the nucleus of which element?
   (a.) helium ($2p^+$)
   b. neon ($10p^+$)
   c. argon ($18p^+$)
   d. krypton ($36p^+$)

Atomic Structure

The atom can be divided into two regions:

- Nucleus: a very small region near the center of an atom that has a positive charge. It contains:
  - Protons: charge: +1, mass: 1 amu; the number of protons is known as the atomic number and distinguishes one element from another.
  - Neutrons: charge: Ø, mass: 1 amu

***Note**: the unit of mass for atomic particles is the atomic mass unit (amu)

→ 1 amu = one-twelfth the mass of a carbon atom containing six protons and six neutrons.

- Electron cloud: a very large region surrounding the nucleus that is negatively charged. It contains:
  - Electrons: charge: -1, mass: ~Ø; atoms that are electrically neutral (they have no charge) must contain the equal number of protons and electrons.
  - It consists mostly of empty space.
  - Electrons exist in complex regions of space known as orbitals, which are organized in various energy levels.

Isotopes

What are **isotopes**? Atoms of the same element, but different mass

This means the number of protons is the same, and the number of neutrons is different.

→ **Mass of an isotope = # protons + # neutrons**

Two ways to write isotopes:

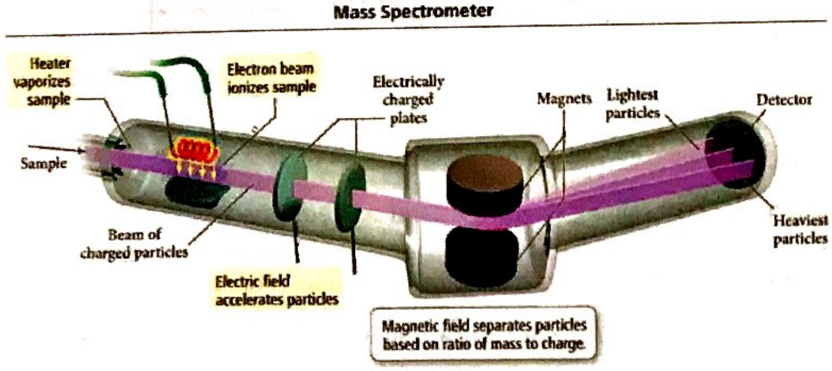
Type	hyphen-notation		isotope notation/ nuclide symbol
Definition	name-mass	vs	$^{\text{mass \#}}_{\text{atomic \#}}\text{Symbol}$
Example	carbon-12		$^{12}_{6}C$

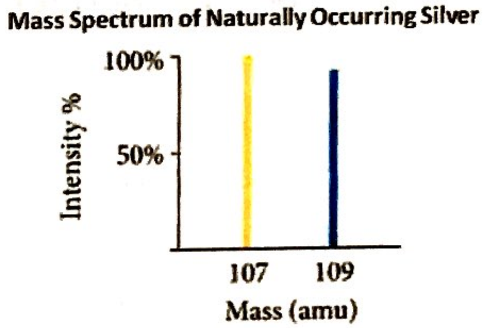
Let's Practice with Tasty Isotopes! Complete the chart below.

Hyphen notation	Isotope Notation	Mass #	Atomic #	Protons	Neutrons	Electrons
carbon-13	$^{13}_{6}C$	13	6	6	7	6
phosphorus–32	$^{32}_{15}P$	32	15	15	17	15
Zinc-66	$^{66}_{30}Zn$	66	30	30	36	30

Mass Spectrometry and Average Atomic Mass

The masses of elements and their percent abundances of isotopes of elements are measured using mass spectrometry: a technique that separates particles according to their mass, producing a mass spectrum.





a. The position (location) of each peak on the x-axis indicates the mass of the isotope.

b. The intensity (indicated by the height of the peak) indicates the relative abundance (how common that isotope is in nature).

Average Atomic Mass: the weighted average mass of an element's isotopes and is the mass found on the periodic table.

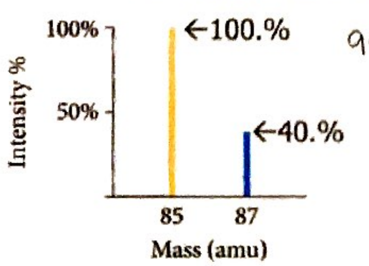
$$Average\ atomic\ mass = mass_1\left(\frac{\%\ Abundance}{100}\right) + mass_2\left(\frac{\%\ Abundance}{100}\right) + \cdots$$

- The average atomic mass will be between the mass of the largest and the mass of the smallest isotope.
- The average atomic mass will generally be closest to the most abundant isotope.
- Note: It is important to understand that the masses of a proton and neutron are ***approximately*** 1 amu, but the actual mass of each isotope is NOT a whole number (mmm, nuclear binding energy). When specific, non-whole number masses are provided for each isotope, use the specific masses!

Free Response Practice:

1. Consider the mass spectrum shown below.

   a. Determine the average atomic mass of the element using the mass spec shown below.



$aam = (85)\left(\frac{100.}{100.+40.}\right) + (87)\left(\frac{40.}{100.+40.}\right)$

$= (85)(0.714) + (87)(0.29)$

$= 85.5714$ (86 w/ s.f., sigh)

   b. Which element is most likely shown here? Rb

   c. How did you identify the element? On P.T., Rb's average atomic mass is 85.47 amu

$\% Ab\ ^{40}Ca + \% Ab\ ^{46}Ca = 100$

$\therefore\ x + y = 1$

Let $x = \frac{(\% Ab. \text{ of } ^{40}Ca)}{100}$, $y = \frac{\% Ab.\ ^{46}Ca}{100}$

2. There are two stable isotopes of calcium: Ca-40 (39.96) and Ca-46 (45.95).

a. Using the average atomic mass of calcium from the periodic table, calculate the % abundance of each isotope of calcium.

(40.078 from P.T.)

$39.96x + 45.95(1-x) = 40.078$

$39.96x + 45.95 - 45.95x = 40.078$

$\Rightarrow 5.99x = 5.872$

$\Rightarrow x = 0.980 \Rightarrow$ $\boxed{\% Ab.\ ^{40}Ca = 98.0\%,\ \% Ab.\ ^{46}Ca = 100 - 98.0 = 2.0\%}$

b. How many atoms of Ca-46 would be found in a 25.0 g sample of naturally occurring calcium?

$$25.0 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.078 \text{ g Ca}} \times \frac{6.022E23 \text{ atoms Ca}}{1 \text{ mol Ca}} \times \underbrace{0.020}_{2.0\%} = \boxed{7.5 \times 10^{21} \text{ atoms } ^{46}Ca}$$

3. The mass reported on the periodic table for chlorine is 35.45 amu. Why, when a sample of chlorine is examined with a mass spectrometer, is there no peak in the spectrum with a mass of 35.45 amu?

Mass on P.T. is the weighted average of mass of all the Cl isotopes, ∴ it is not the mass of any actual Cl atom.

4. Silver consists of two stable isotopes, one with a mass of 106.905 and an abundance of 51.84%.

a. What is the abundance and mass of the other isotope? $\% Ab = 100\% - 51.84\% = 48.16\%$

(from P.T.)

$107.87 = (106.905)(0.5184) + x(0.4816)$

$= 55.42 + 0.4816x$

$52.45 = 0.4816x$ $\Rightarrow x =$ $\boxed{108.9 \text{ am},\ 48.16\% \text{ Ab}}$

b. How many silver-107 atoms are present in a 2.00 gram sample of pure silver?

$$2.00 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{107.87 \text{ g Ag}} \times \frac{6.022E23 \text{ atoms Ag}}{1 \text{ mol Ag}} \times \underbrace{0.5184}_{51.84\%} = \boxed{5.79 \times 10^{21} \text{ Ag-107 atoms}}$$

5. Sulfur has four isotopes: ^{32}S, ^{33}S, ^{34}S, and ^{36}S.

a. Which isotope would you predict to be the most abundant and why? (No math needed! ☺)

^{32}S must be the most abundant, b/c the average atomic mass of S on the P.T. is 32.07 amu, so the isotope w/ the closest mass to the average is usually the most abundant.

b. What is the difference between these four isotopes?

# of neutrons! (thus mass)