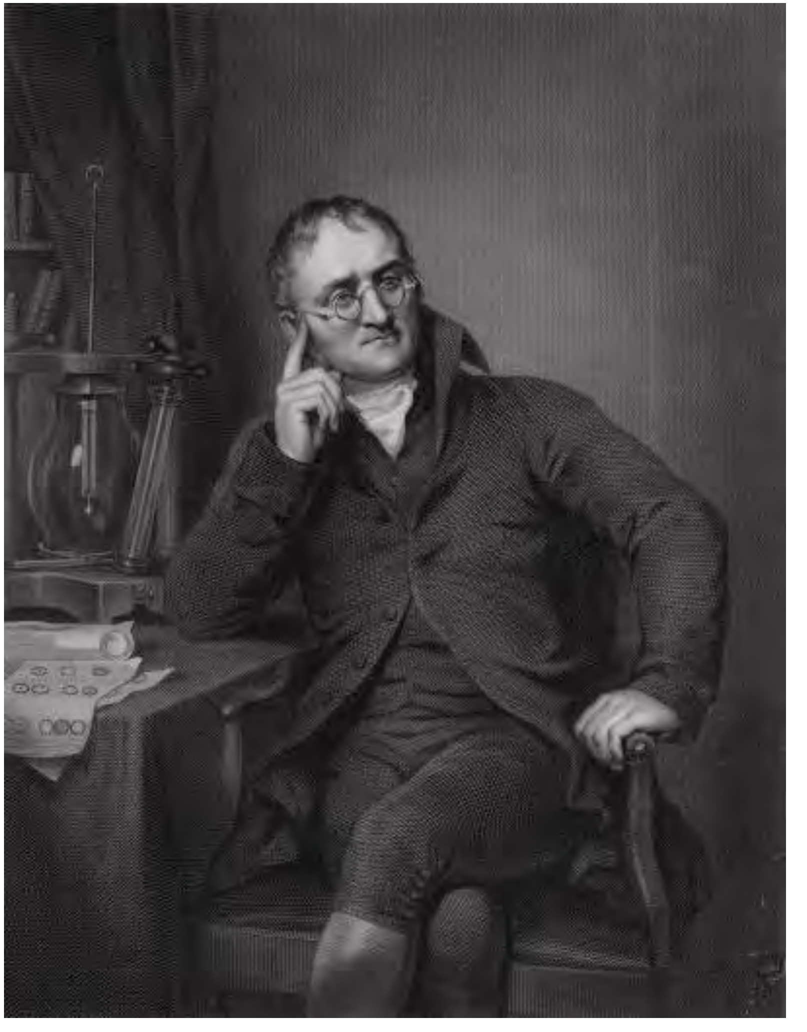
An Introduction to Atoms

Matter (stuff) is made of ***atoms***.



John Dalton (1776-1884)

Check your current model:

Draw a **carbon atom**

Model of the Atom

Atoms are made of ***subatomic particles***.

There are *three* types of subatomic particles that will make up our atomic model:

protons
neutrons
electrons

Protons and neutrons are compacted together in what we call the ***nucleus*** of an atom.

Electrons are distributed in space around the nucleus.

- They are moving very fast in a volume surrounding the nucleus.

Atoms are mostly empty space.

Electrical Charge

There are a few fundamental properties of nature.

- Examples: Gravity, magnetism, and mass.

Another fundamental property in nature is ***electrical charge***.

Particles ***may or may not*** have electrical charge.

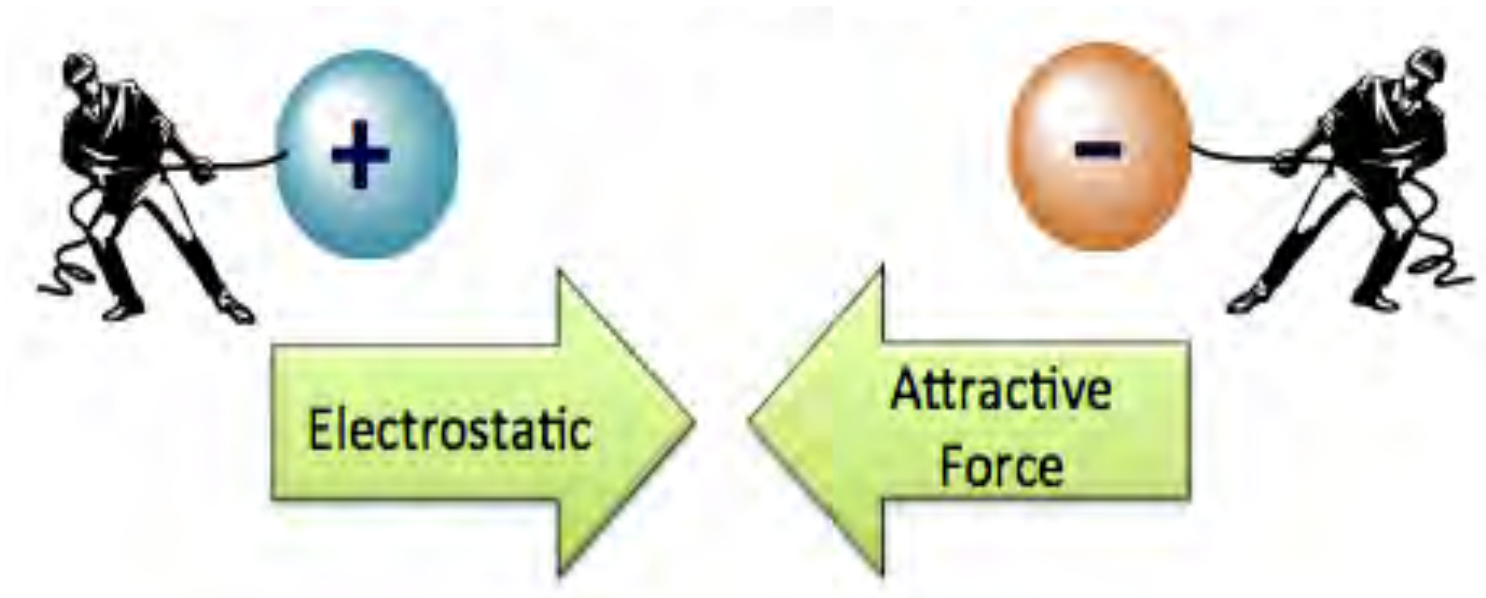
There are two types of electrical charge; we arbitrarily call one type ***positive*** and the other type ***negative***.

Every thing we discuss in this course ultimately occurs because of the interaction of these two types of charges.

Electrical Charge

Particles with ***opposite charges attract*** each other.

The natural attraction is called ***electrostatic attractive* force**.

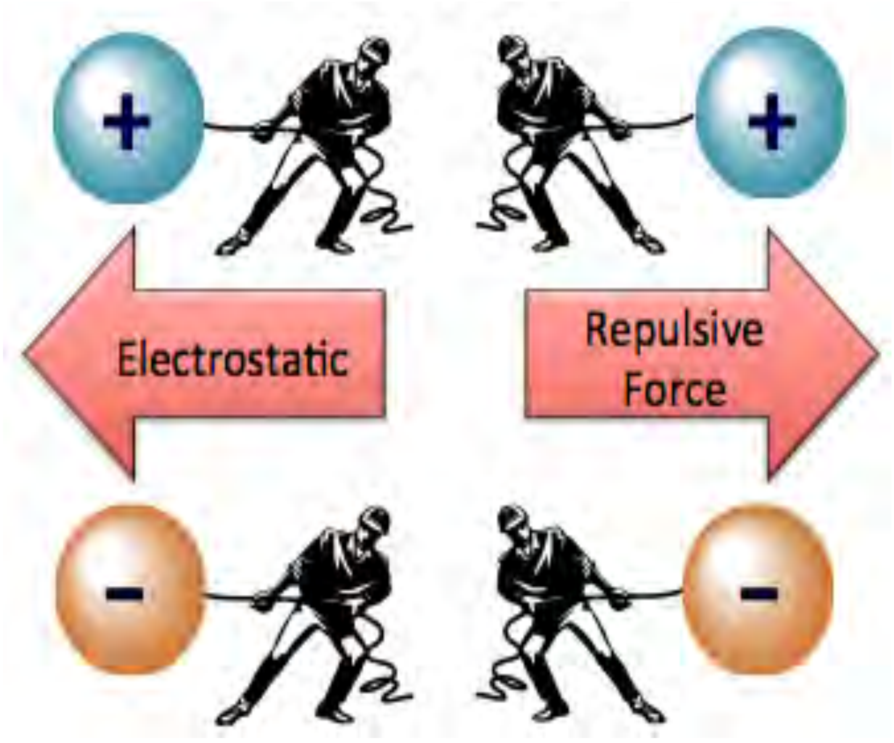


Oppositely charged particles will accelerate **toward** one another if not held apart.

Electrical Charge

Particles with ***like charges repel*** each other.

The natural repulsion is called ***<u>electrostatic</u>*** ***<u>repulsive</u>*** **force**.



Like charged particles will accelerate **away** from one another if not held together.

Subatomic Particles

1) Protons

Protons are ***positively*** ***charged*** particles located in the ***nucleus*** of an atom.

- The number of protons a particular atom contains determines that atom’s identity.

- For example:

  An atom that contains just one proton is called *hydrogen*.

  An atom with two protons is called *helium*.

  An atom with six protons is called *carbon*.

Historically, matter with different numbers of protons, such as hydrogen, helium, and carbon were called the ***elements***.

Antoine Lavoisier (1743-1794) and his wife, Marie-Anne Pierette Paulze (1758-1836)

Periodic Table of the Elements

I Alkali Metals	II Alkaline Earth Metals											III	IV	V	VI	VII Halogens	VIII Noble Gases
1 **H** Hydrogen 1.0079																	**2** **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012183											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.0067	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.998403	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.9815	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973762	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955908	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938044	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933194	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.971	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90584	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90637	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.414	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.90545	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96657	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90766	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93033	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93422	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0377	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Note that each element is represented by its ***atomic symbol*** (a one- or two-letter name abbreviation) and occupies a box in the table.

Above each element's symbol is the ***atomic number***.

The **atomic number** tells us the ***number of protons*** in an atom of that particular element.

Atomic number can be abbreviated using "**Z**." For example, with carbon, **Z** = 6, with hydrogen, **Z** = 1.

Elements are ordered in the periodic table by *increasing* atomic number.

2) Electrons

Electrons are ***negatively charged*** subatomic particles.

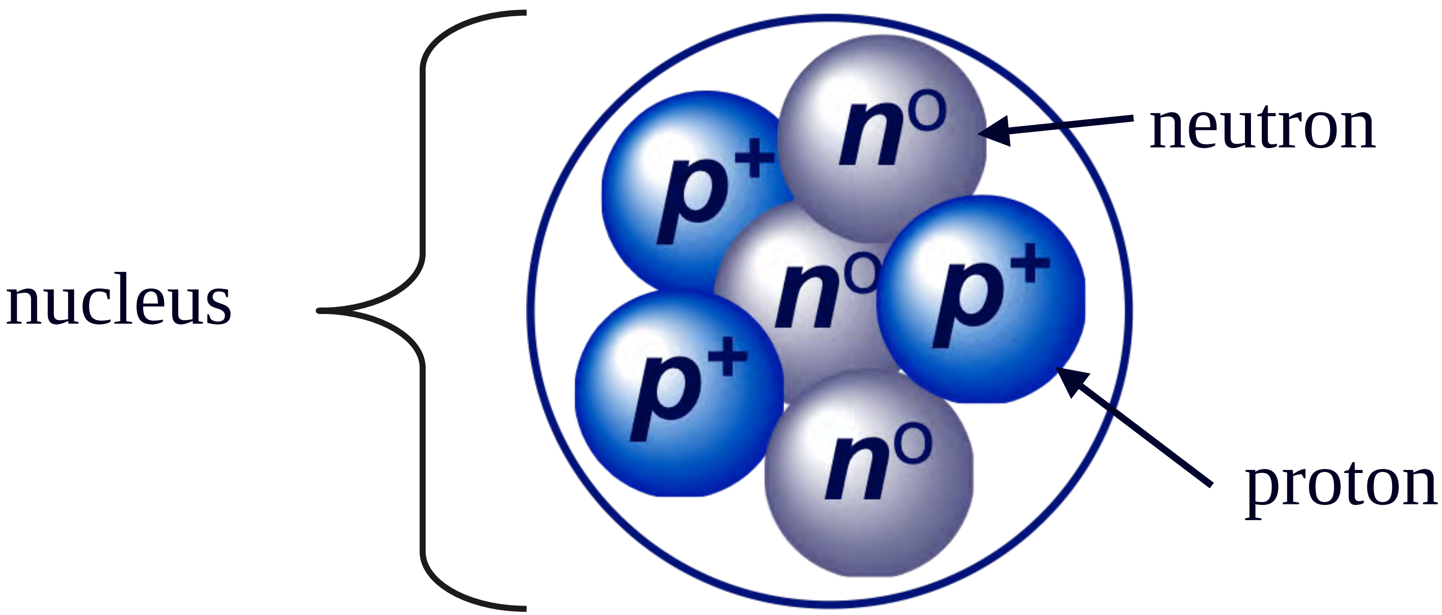
They are light-weight particles that move extremely fast.

Protons and neutrons are about 2000 times **heavier** than electrons and therefore compose most of an atom’s mass.

3) Neutrons

Neutrons are located in the ***nucleus*** (with the protons).

Neutrons **do not** have electrical charge; we say they are ***electrically neutral***.



Names, charges, and symbols for the three types of subatomic particles.

SUBATOMIC PARTICLE	SYMBOL	CHARGE
PROTON	*p*	positive (1+)
NEUTRON	*n*	none
ELECTRON	*e* or e^-	negative (1-)

How many neutrons are in an atom?

We ***cannot determine*** the number of neutrons in an atom based on the number of protons.

- This is because atoms of a particular element ***do not all have the same number of neutrons***.

Example: Some carbon atoms have *six neutrons*, some have *seven neutrons*, and some have *eight neutrons*.

- These three different forms of carbon are called ***<u>isotopes</u>*** of carbon.

Isotopes are defined as atoms with the *same* number of protons (same element), but a *different* number of neutrons.

You learned that an atom's ***"atomic number* (Z)"** is the *number of protons* it contains.

When considering the number of neutrons in an isotope of a particular atom, it is useful to learn a new term called **"mass number."**

The ***mass number*** of an atom is defined as *the number of protons* ***plus*** *the number of neutrons*.

mass number* =** *number of* ***protons **+** *number of* ***neutrons***

Mass number can be abbreviated using "**A**."

	SYMBOL	DEFINITION
ATOMIC NUMBER	Z	number of protons
MASS NUMBER	A	number of protons + number of neutrons

number of ***neutrons*** **=** ***mass number*** **-** *number of* ***protons***

mass number **=** *number of* ***protons*** **+** *number of* ***neutrons***

Example:

How many neutrons are in a sodium (Na) atom that has a ***mass number*** of **23**?

Take notes here:

Understanding Check:

How many neutrons are in a carbon (C) atom that has a ***mass number*** of **14**?

You will often see one of two "shorthand notation" methods used to differentiate the various isotopes:

Method 1: Write the *element symbol*, a dash, then the *mass number* (A)

Let's use our three isotopes of carbon for examples:

NUMBER OF NEUTRONS IN THE CARBON ATOM	SHORTHAND NOTATION
6	C-12
7	C-13
8	C-14

Method 2: Write the *element symbol*, we superscript the *mass number* (A) to the left of the symbol.

NUMBER OF NEUTRONS IN THE CARBON ATOM	SHORTHAND NOTATION
6	^{12}C
7	^{13}C
8	^{14}C

the symbol.

- Sometimes the atomic number (Z) is also subscripted to the left of the symbol.
  - For example:

$$^{12}_{6}C$$

Understanding Check

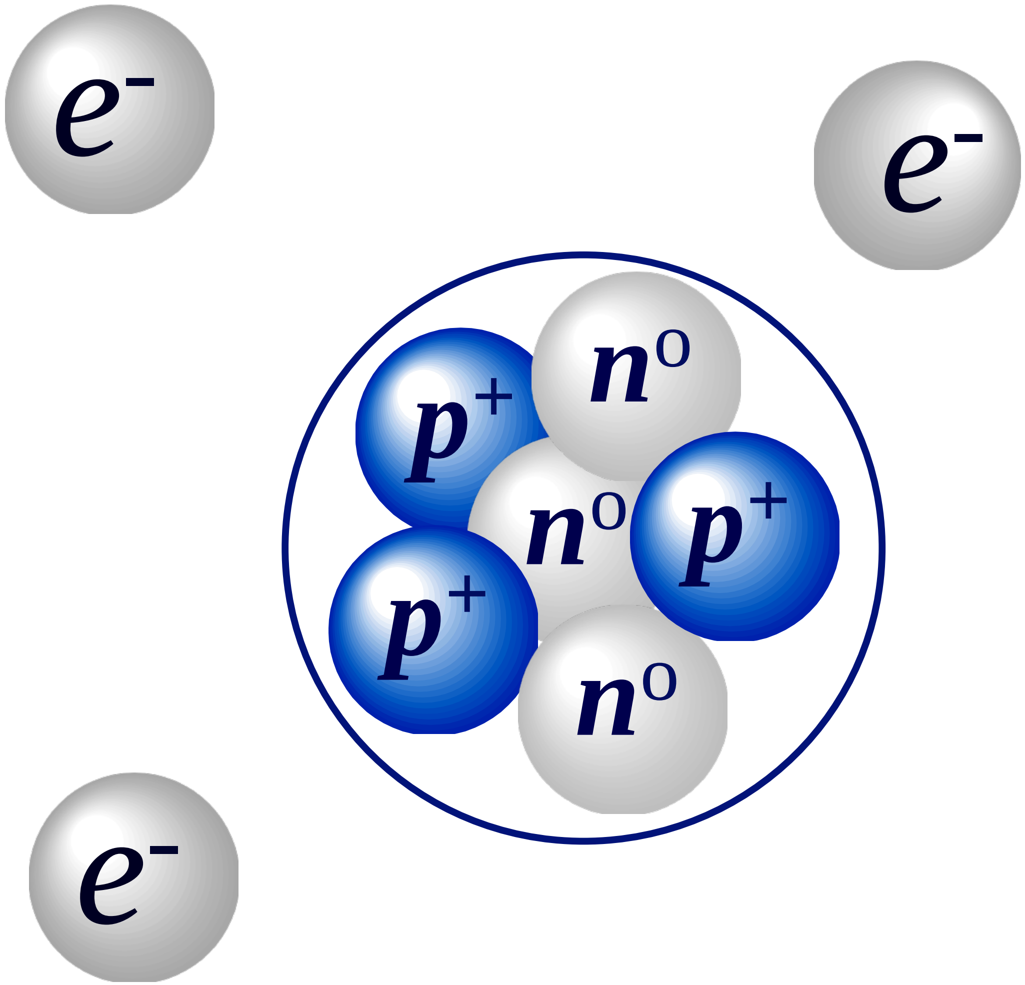
Fill in the blanks for the following isotopes:

a. ^{14}**N** number of protons ___ number of neutrons ___ atomic number ___ mass number ___

b. ^{15}**N** number of protons ___ number of neutrons ___ atomic number ___ mass number ___

c. ^{42}**Ca** number of protons ___ number of neutrons ___ atomic number ___ mass number ___

d. ^{1}**H** number of protons ___ number of neutrons ___ atomic number ___ mass number ___



Atoms are ***electrically neutral***; their **total charge** is equal to **zero**.

They have the same number of electrons (-) as protons (+), so the positive and negative charges add up to zero (cancel).

A ***mole*** is a counting unit used for atoms and molecules.

- A ***counting unit*** is any term that refers to a specific number of things.
  - a couple = 2 items (e.g. people)
  - a dozen = 12 items (e.g. eggs, donuts)
  - **a mole** = 6.022×10^{23} (e.g. atoms, molecules)

Avogadro’s number

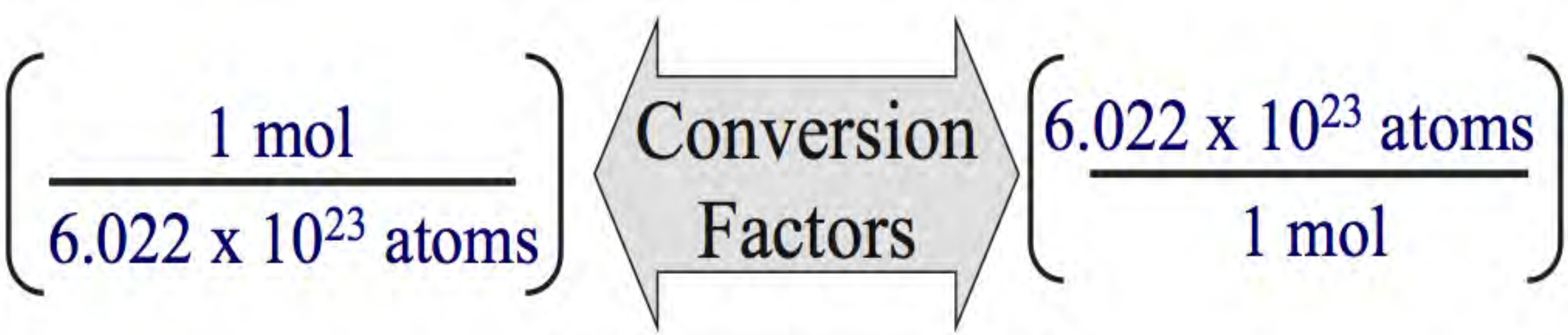
The Chemist's Mole

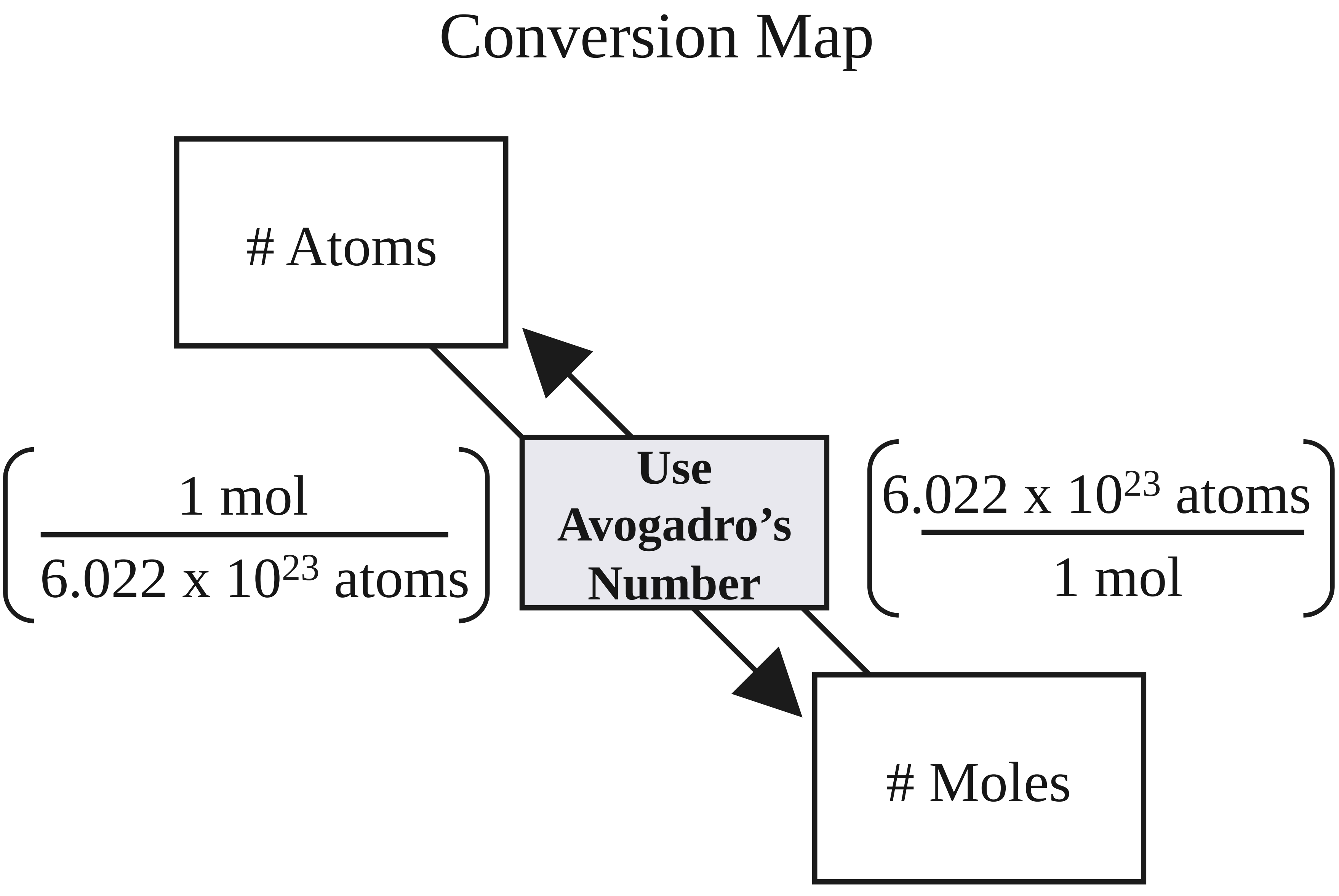
- **One mole** of anything represents 6.022×10^{23} of the things.
- This is referred to as **Avogadro's number**.
- 1 mole $= 6.022 \times 10^{23}$

Understanding Check: How many atoms are in ***1 mole*** of helium (He)? ___________________________

Because the mole is the standard counting unit used to indicate the number of atoms present in a sample, it is useful to **convert** back and forth from ***moles*** to ***atoms***.

- Use our ***conversion factor*** method.
- The ***relationship*** between # of atoms and moles is:
  - 1 mole = 6.022×10^{23}





Conversion Map
Atoms
1 mol
6.022 x 10^23 atoms
Use Avogadro's Number
6.022 x 10^23 atoms
1 mol
Moles

Example:

What is the mass of 0.770 moles of carbon?

$$\frac{0.770\ \cancel{\text{mol C}}}{} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = \textbf{9.25 g carbon}$$

You try one: How many moles are 2.9×10^{12} F atoms?

The Mole and Mass

The ***molar mass*** of an element is equivalent to the mass (in grams) of one mole of the element.

- Molar mass is given in the periodic table ***under*** the symbol of the element
  - Molar mass units: ***grams/mole***
  - Example: Carbon – molar mass is ***12.01* g/*mole***

- Examples:
  - 1 mole of argon (Ar) = 39.95 g
  - Molar mass of argon is 39.95 g/mole

Understanding Check

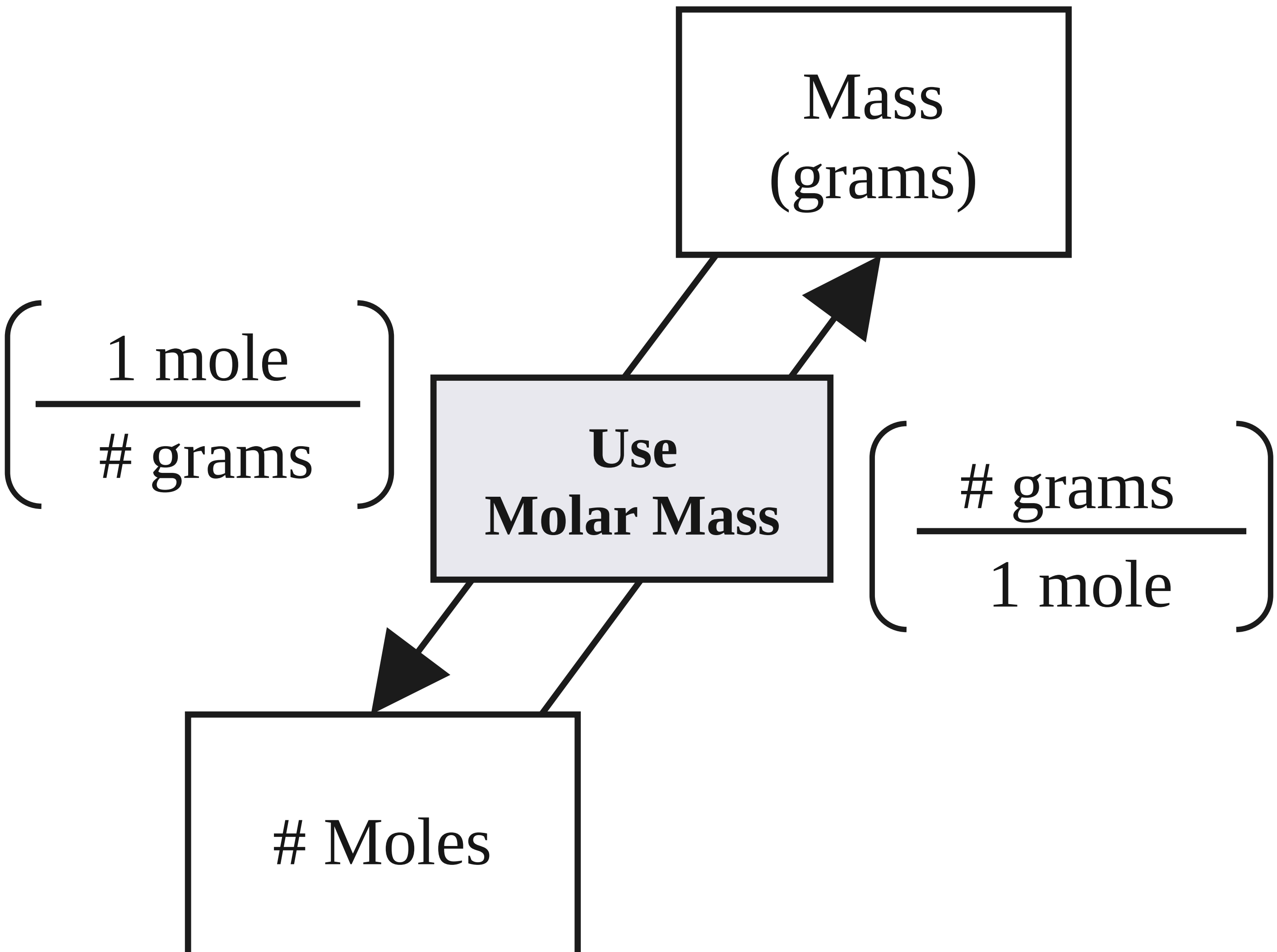
1 mole of C = ______ grams of C = ___________ atoms of C

1 mole of Al = ______grams of Al = __________ atoms of Al

The Mole and Mass

- Because the molar mass gives us the ***relationship*** between the number of moles and the mass of an element, it can be used to ***convert*** back and forth between moles and mass (in grams).
  - Use our conversion factor method.

Conversion Map



The Mole and Mass

Example: Carbon

- The relationship between # of moles of carbon and grams of carbon is:
  - 1 mole Carbon = 12.01 g
- This can be written as conversion factors:

$$\left(\frac{1\ \text{mole C}}{12.01\ \text{grams C}}\right) \quad \text{Conversion Factors} \quad \left(\frac{12.01\ \text{grams C}}{1\ \text{mole C}}\right)$$

Example:

What is the mass of 0.770 moles of carbon?

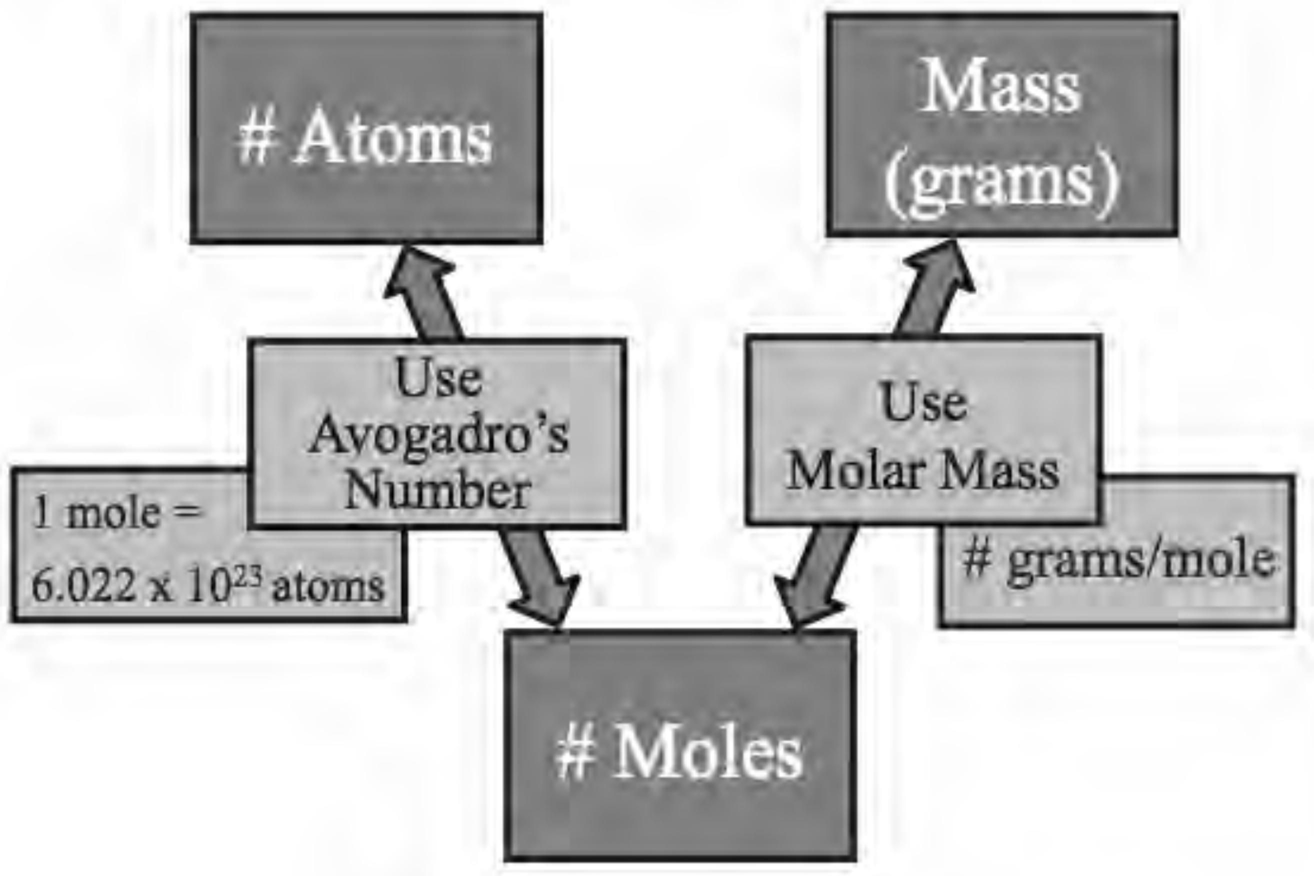
$$\frac{0.770\ \cancel{\text{mol C}}}{} \;\Big|\; \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = \mathbf{9.25\ g\ carbon}$$

You try one:

How many moles are there in 50.0 g of lead?

Lead = Pb

Converting Between the Number of Atoms and Grams



Example: grams to moles

What is the mass of 2.50 x 10^{21} Pb atoms?

2.50 x 10^{21} ~~Pb atoms~~	1 ~~mole Pb~~	207.2 g Pb	= **0.860 g Pb**
	6.022 x 10^{23} ~~atoms Pb~~	~~1 mole Pb~~	

You try one: grams to moles

Compute the number atoms in 10.0 g of Aluminum (Al)?

Classification of Elements Based on Electrical and Heat Conduction

CATEGORY	PROPERTIES
Metals	•Good conductors of heat and electricity •Ductile (can be pulled into wires and pounded flat) •Have a luster
Nonmetals	•Poor conductors of heat and electricity •Brittle (break or shatter if bent or hammered)
Metalloids (sometimes called Semimetals)	Intermediate conductors of heat and electricity

Classification of Elements Based on Electrical and Heat Conduction

1 **H**			Metals (Green)			Nonmetals (Blue)			Metalloids (Red)								2 **He**
3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**	8 **O**	9 **F**	10 **Ne**
11 **Na**	12 **Mg**											13 **Al**	14 **Si**	15 **P**	16 **S**	17 **Cl**	18 **Ar**
19 **K**	20 **Ca**	21 **Sc**	22 **Ti**	23 **V**	24 **Cr**	25 **Mn**	26 **Fe**	27 **Co**	28 **Ni**	29 **Cu**	30 **Zn**	31 **Ga**	32 **Ge**	33 **As**	34 **Se**	35 **Br**	36 **Kr**
37 **Rb**	38 **Sr**	39 **Y**	40 **Zr**	41 **Nb**	42 **Mo**	43 **Tc**	44 **Ru**	45 **Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **Sb**	52 **Te**	53 **I**	54 **Xe**
55 **Cs**	56 **Ba**	57 **La**	72 **Hf**	73 **Ta**	74 **W**	75 **Re**	76 **Os**	77 **Ir**	78 **Pt**	79 **Au**	80 **Hg**	81 **Tl**	82 **Pb**	83 **Bi**	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	89 **Ac**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**									
				58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **Er**	69 **Tm**	70 **Yb**	71 **Lu**
				90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

Elements in the periodic table are arranged in columns called ***Groups*** (sometimes, but much less often, called **Families**).

- Sometimes these groups are shown with **group numbers** in Roman numerals above the column.

s-Block

p-Block

d-Block

f-Block

Transition Metals

	I	II											III	IV	V	VI	VII	VIII
1	1 **H**																	2 **He**
2	3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**	8 **O**	9 **F**	10 **Ne**
3	11 **Na**	12 **Mg**											13 **Al**	14 **Si**	15 **P**	16 **S**	17 **Cl**	18 **Ar**
4	19 **K**	20 **Ca**	21 **Sc**	22 **Ti**	23 **V**	24 **Cr**	25 **Mn**	26 **Fe**	27 **Co**	28 **Ni**	29 **Cu**	30 **Zn**	31 **Ga**	32 **Ge**	33 **As**	34 **Se**	35 **Br**	36 **Kr**
5	37 **Rb**	38 **Sr**	39 **Y**	40 **Zr**	41 **Nb**	42 **Mo**	43 **Tc**	44 **Ru**	45 **Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **Sb**	52 **Te**	53 **I**	54 **Xe**
6	55 **Cs**	56 **Ba**	57 **La**	72 **Hf**	73 **Ta**	74 **W**	75 **Re**	76 **Os**	77 **Ir**	78 **Pt**	79 **Au**	80 **Hg**	81 **Tl**	82 **Pb**	83 **Bi**	84 **Po**	85 **At**	86 **Rn**
7	87 **Fr**	88 **Ra**	89 **Ac**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**									

(Inner) Transition Metals

6	Lanthanides	58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **Er**	69 **Tm**	70 **Yb**	71 **Lu**
7	Actinides	90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

The elements in **Group I** (also called Group 1A) are called the ***alkali metals***.

- Although it is not a metal, note that hydrogen is in this group *for reasons that I will discuss in chapter 3*.

The elements in **Group II** (also called group 2A) are called the ***alkaline earth metals***.

The elements in **Group VII** (also called group 7A) are called the ***halogens***.

The elements in **Group VIII** (also called group 8A) are called the ***noble gases*.**

The elements in Group I and Group II are in what is called the ***s*-Block**.

The elements in Groups III - VIII are in the ***p*-Block**.

The **transition metals**, *located between the s- and p-Blocks*, are in the ***d*-Block.**

The **Inner Transition Metals**, located in the bottom two rows of the periodic table are in the ***f*-Block**.

- They are called ***lanthanides*** (top row of the *f-Block*) and ***actinides*** (bottom row of the *f-Block*).

The ***rows*** in the periodic table are called ***Periods***.

- The periods are often numbered to the left of each row.