Chapter 4: Atoms and Elements

Atoms are EXTREMELY SMALL particles out of which all known matter is made.

- They are the smallest particle of a chemical element that still have the properties of that element.

How small is a typical atom?

- A typical atom is about one MILLIONTH of a millimeter across. (A million of them laid in a line would measure 1 mm across!)

Historical Development of Atomic Structure

- Early Greek philosophers (Leucippus, Democritus) proposed small, indivisible particles called "atomos"
- 1808 - JOHN DALTON PROPOSES ATOMIC THEORY
  (theory soon widely accepted)

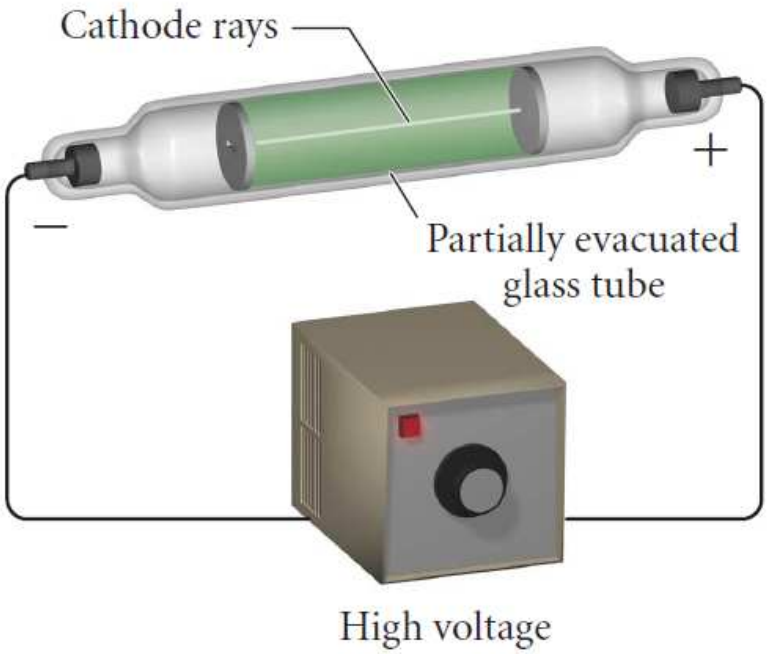
Atomic Theory

1) Each element is made of tiny indestructible particles called "Atoms".
2) All atoms of an element are the same.
3) Atoms combine in simple, whole number ratios to make compounds.

Discovery of the Electron

(J. J. Thomson, late 1800s)

- Used a cathode ray tube which produces a beam of electrons



Cathode rays could be deflected by magnetic fields and charged plates.

- Thomsen concluded that since the cathode rays were deflected by the negatively charged plate and attracted to the positively charged plate that cathode rays consisted of negative particles called **ELECTRONS**

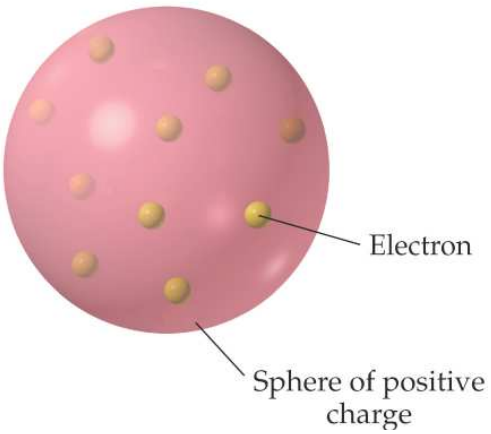
Plum Pudding Model

J.J. Thomsen determined that electrons are :

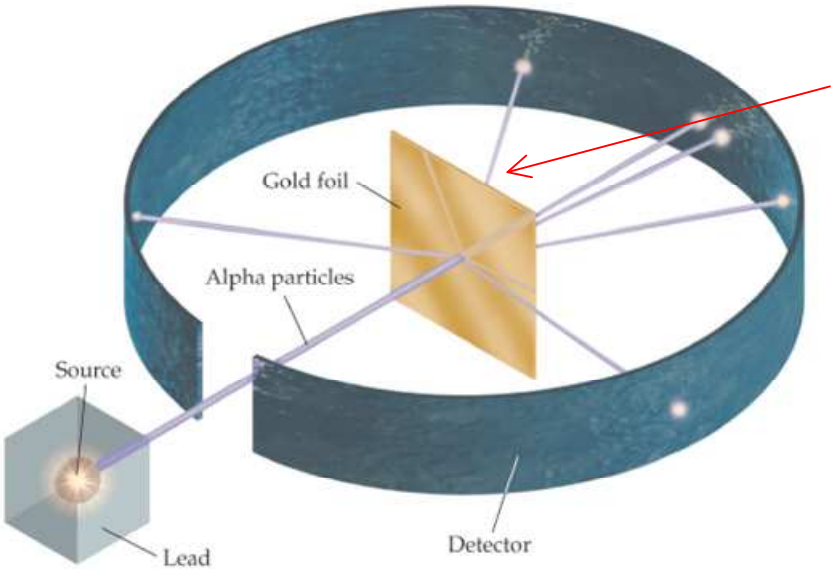
- Negatively charged
- Smaller than atoms
- Fundamental particle in all matter

Since atoms are neutral, Thomsen proposed "Plum Pudding" model for atomic structure

- electrons held within positively charged sphere.



In 1909 Rutherford performed the GOLD FOIL EXPERIMENT to test the plum pudding model

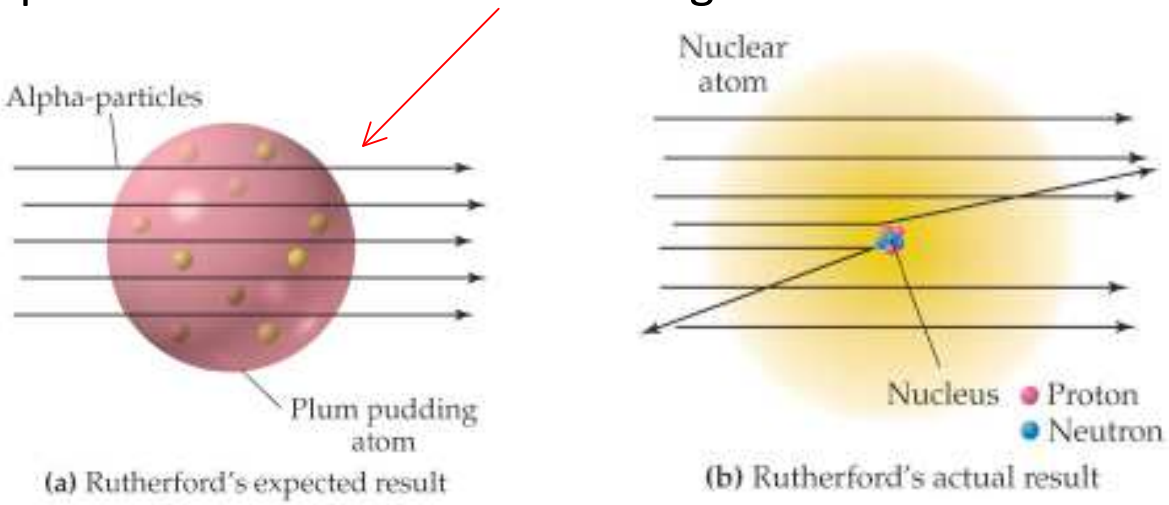


Gold foil was hammered so that is was only a few atoms thick

Positively charged particles shot at the foil - most went straight through, while some were **strongly** deflected

Discovery of the Nucleus

If the Plum Pudding model was correct the positive particles should've flown through the foil.



But this wasn't the case!

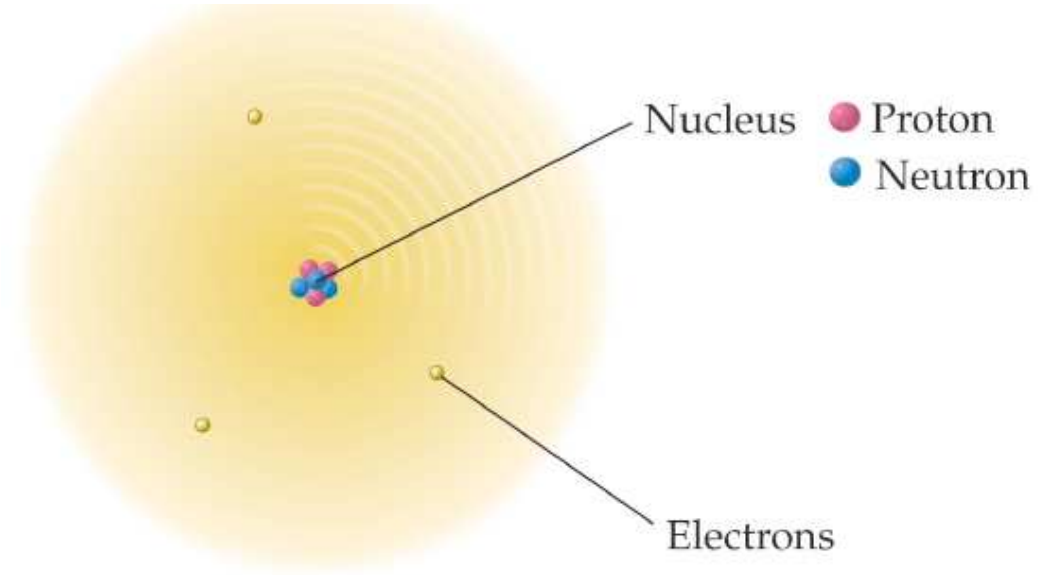
Rutherford's result supported the

Nuclear model of the atom

- All the positive charge and most of the mass of the atom is concentrated in a very small volume, the **nucleus**.
- Electrons occupy the rest of the space in the atom which is approximately 100,000 times larger than the nucleus.
  - If the nucleus were the size of a baseball, then the diameter of the electron cloud would be approx. 2.5 miles!

ATOMS ARE MOSTLY EMPTY SPACE

Modern Model of the Atom



Subatomic Particles: the building blocks from which all atoms are made

Particle	Symbol	Charge
Proton	p^+	+1
Neutron	n^o	0
Electron	e^-	-1

- The nucleus consists of protons and neutrons
- 99.9% of the mass of an atom is in the nucleus
  (p & n mass almost equivalent)
- Electrons are approx. 1/2000 the mass of a proton or neutron
- Electrons are dispersed in a region around the nucleus that is very large (compared to the small, compact nucleus) called the **ELECTRON CLOUD**
- **The number of electrons is equal to the number of protons in a neutral atom.**

Electrical Charge

- Positive and negatively charged objects ATTRACT each other (p^+ and e^- attracted to one another).
- Like charges repel each other.
- When a proton and electron are paired they are charge-neutral.

Elements

Every atom has a characteristic number of protons in it's nucleus which determines the identity of the atom.

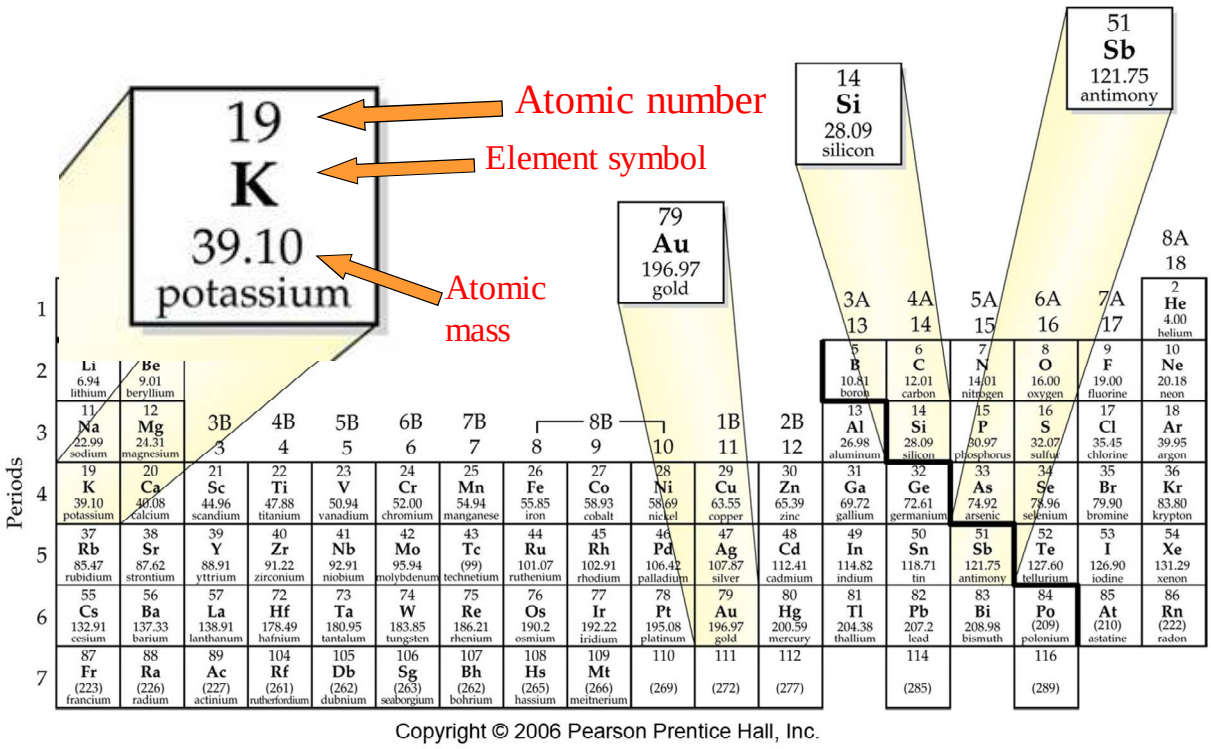
- If 2 atoms differ in the number of protons present, they MUST be 2 different elements. If the two atoms possess the same # of protons, they must be the SAME ELEMENT.

Atomic Number (Z) = number of protons in the nucleus of an atom

# of protons = # of electrons in a neutral atom of that element

The elements are arranged on the Periodic Table in order of increasing atomic number

The Periodic Table of Elements

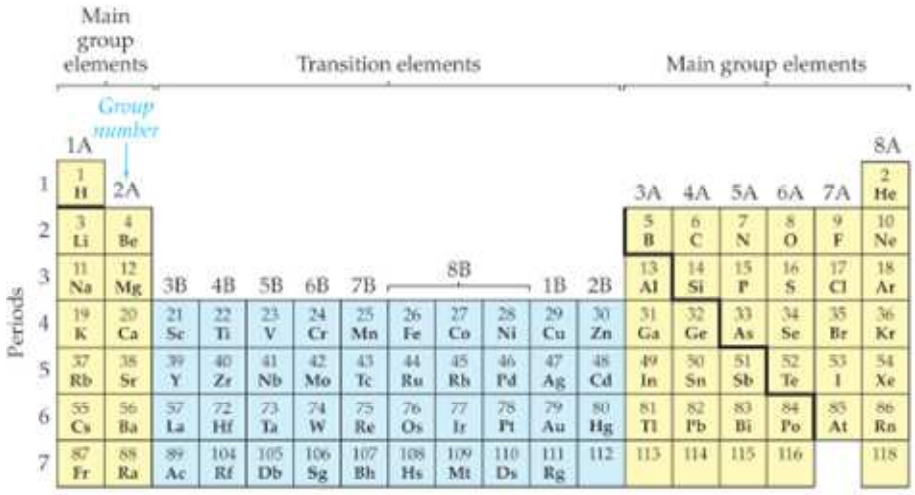


- ALL silicon atoms contain _____ protons
- ALL gold atoms contain _____ protons
- How many electrons does a neutral oxygen atom contain?
- Will a Fe atoms with 24 electrons be electrically neutral?

- In 1869 Dimitri Mendeleev noticed a repeating pattern of properties every 8 elements when elements arranged in order of relative mass.
- Exceptions: Te & I
- Predicted undiscovered elements
- Modern Periodic Table - ordered by increasing atomic number

Dimitri Mendelev (Russian)

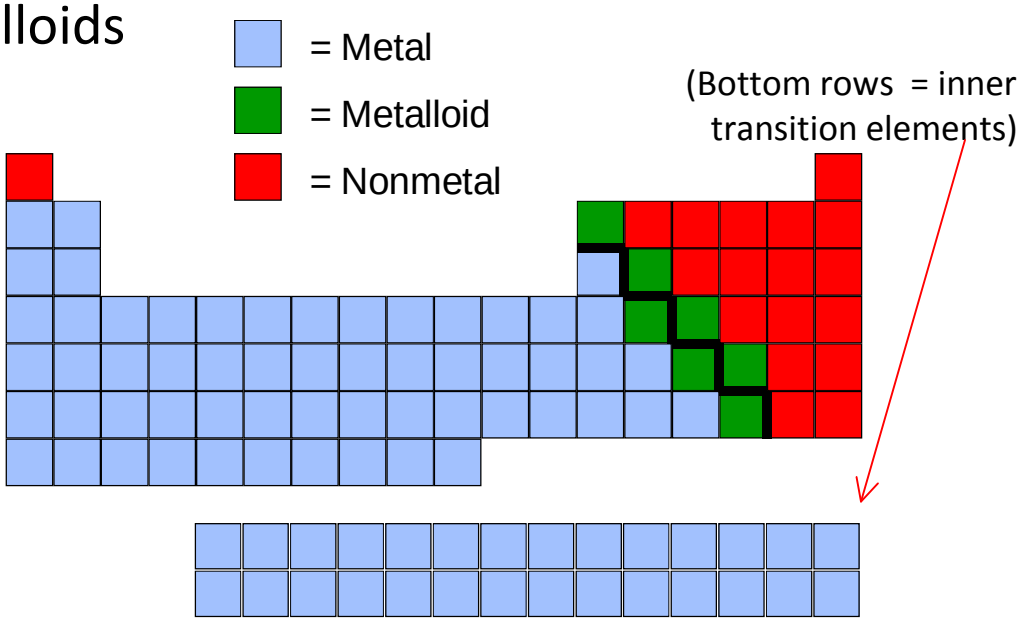
Periodic Table Sections



Vertical Column = Group
Horzontal Row = Period

Elements with similar chemical and physical properties are in the same column (group).

Elements are classified as metals, nonmetals or metalloids



Metals	**Nonmetals**	**Metalloids**
High luster	No luster	Have characteristics
Thermally and electrically conductive	Poor thermal and electrical conductivity	intermediate between metals and nonmetals
Malleable	Not malleable	
Solids (except Hg)	May be solid, liquid or gas	SEMICONDUCTORS

Classify the following elements as a metal, nonmetal or metalloid:

Xenon, Xe	Tungsten, W	Chlorine, Cl
Arsenic,As	Hydrogen, H	Uranium, U

Which is a element above is a main group element? A transition element? An inner transition element?

Recall: Elements with similar chemical and physical properties are in the same group.

= Alkali metals

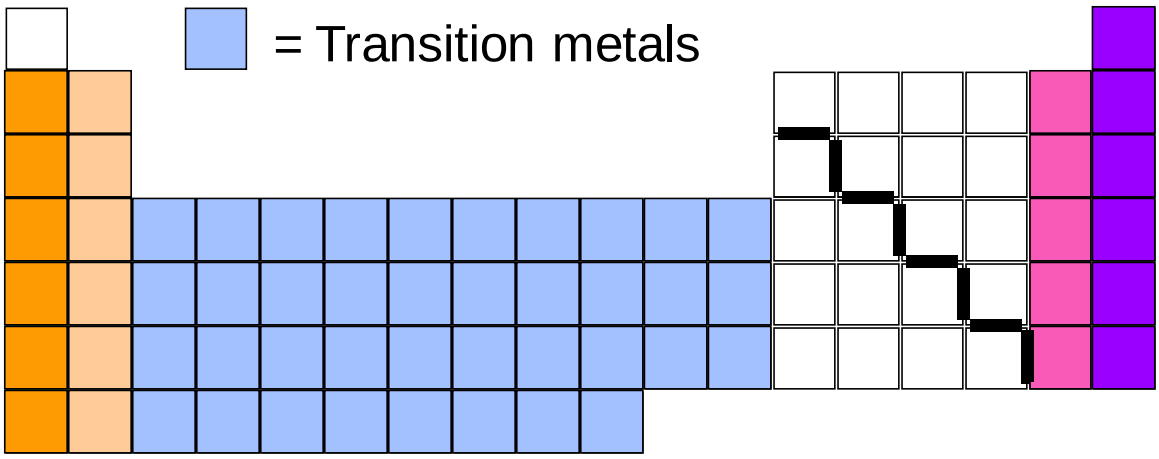
= Alkali earth metals

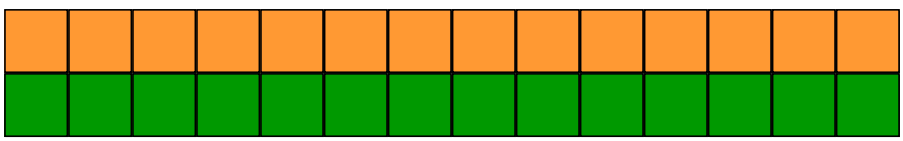
= Noble gases

= Halogens

= Lanthanides

= Actinides





Ions

A neutral atom becomes charged by either gaining or losing 1 or more electrons to become an ION

- CATIONS - ions with a positive charge
  formed by losing electrons
- ANIONS - ions with a negative charge
  formed by gaining electrons

Ion charge = # protons – # electrons

Nonmetals form ANIONS

Cl atom = 17 p^+ & 17 e^-; Cl^- ion = 17 p^+ & 18 e^-

N atom = 7 p^+ & 7 e^-; N^{3-} ion = 7 p^+ & 10 e^-

(**Gained** 3 electrons)

Metals form CATIONS

Na atom = 11 p^+ & 11 e^-; Na^+ ion = 11 p^+ & 10 e^-

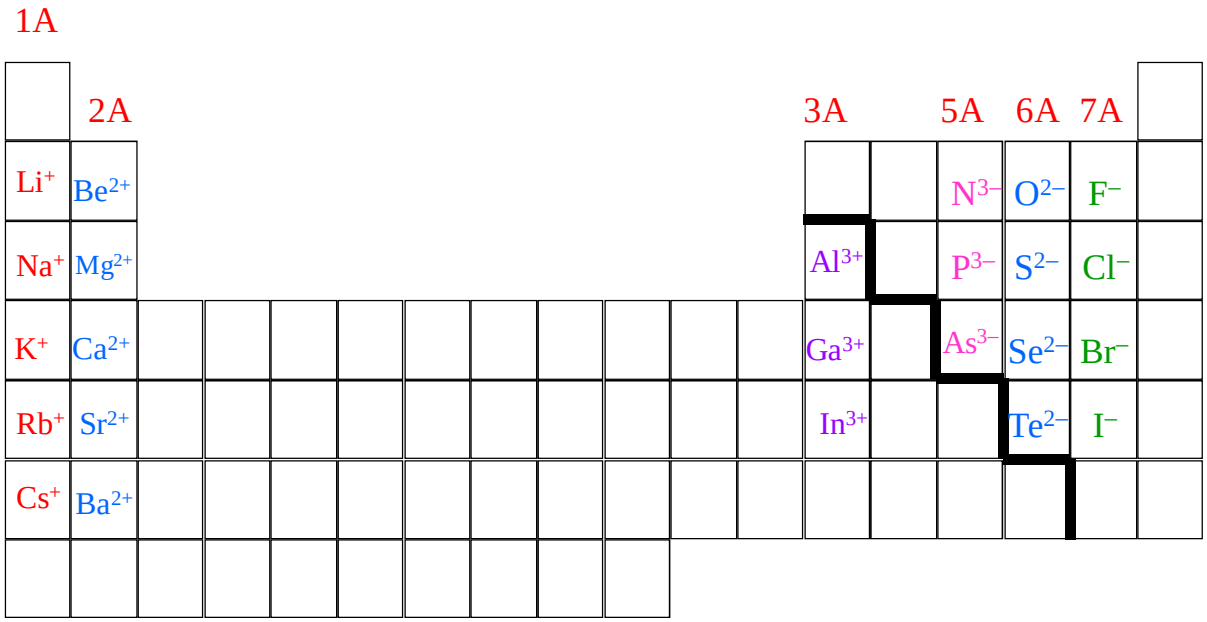
Ca atom = 20 p^+ & 20 e^-; Ca^{2+} ion = 20 p^+ & 18 e^-

(**Lost** 2 electrons)

Valence Electrons

⇒ highest energy electrons in an atom

> The number above each main group column gives the number of valence electrons for elements in that group



- Metals of group IA, IIA and IIIA lose one or more electrons to get the same number of valence electrons as the previous noble gas.
- Nonmetals of groups VA, VIA, and VIIA gain one or more electrons to get the same number of valence electrons as the nearest noble gas.

Note:

- Metallic elements are neutral atoms
- Metals in compounds are cations

Isotopes

Atoms of the same element MUST have the same number of protons. However, they often vary in the number of neutrons.

Mass number (A) = # of protons and # of neutrons in a given nucleus

ISOTOPES

Atoms with the same atomic number (# of protons) but different mass numbers (# of neutrons)

Symbol:

$${}^{A}_{Z}X$$

A = Mass number
Z = Atomic number
X= Element symbol

Ex. 3 naturally-occurring isotopes of carbon:

$${}^{12}_{6}C$$ → Isotope of carbon that has 6 protons and 6 neutrons; carbon-12

$${}^{13}_{6}C$$ → Isotope of carbon that has 6 protons and 7 neutrons; carbon-13

$${}^{14}_{6}C$$ → Isotope of carbon that has 6 protons and 8 neutrons; carbon-14

How can we determine the number of neutrons in an isotope of a particular element?

Isotopes

Complete the following table:

	Atomic Number	Mass Number	Number of protons	Number of electrons	Number of neutrons
Calcium-40					
Carbon-13					
Aluminum-27^{+3}					

An atom has 12 protons and 13 neutrons:

Atomic # = Isotope symbol =

Mass number = #e^- if neutral =

Element name = #e^- if stable ion=

Different isotopes of an element have differing natural abundances:

- Ex. Boron-10 20.0% natural abundance
  Boron-11 80.0% natural abundance

Atomic Mass

Weighted average of the masses of all naturally occurring isotopes of an element

Atomic Mass

(amu = atomic mass units)

Atom	Mass number	Atomic mass
copper-63	63	62.9396 amu
copper-65	65	64.9278 amu

(Atomic Mass and Mass number are NOT THE SAME THING)

A sample of natural copper contains…

69.17% copper-63

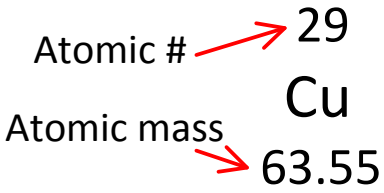
30.83% copper-65

Atomic Mass = (Fraction of isotope 1) x (Mass of Isotope 1)
+ (Fraction of isotope 2) x (Mass of Isotope 2)
+ etc…

where fraction of isotope = % abundance/100

Calculate the atomic mass of copper:

On periodic table:



Mass number is not found on the periodic table