Chapter 2
Section 2
PARTICLES

Dalton's Atomic Theory

Dalton proposed a theory of matter based on it having ultimate, indivisible particles to explain these laws

- Each element is composed of tiny, indestructible particles called atoms
- All atoms of a given element has the same mass and other properties that distinguish them from atoms of other elements
- Atoms combine in simple, whole-number ratios to form molecules of compounds
- In a chemical reaction, atoms of one element cannot change into atoms of another element
  - ✓ they simply rearrange the way they are attached

Reacting Atoms

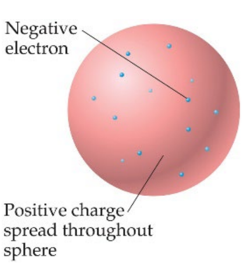
- when elements undergo chemical reactions, the reacting elements do not turn into other elements
  - ✓ Statement 4 of Dalton's Atomic Theory
- this requires that all the atoms present when you start the reaction will still be there after the reaction
- since the number of protons determines the kind of element, the number of protons in the atom does not change in a chemical reaction
- however, many reactions involve transferring electrons from one atom to another

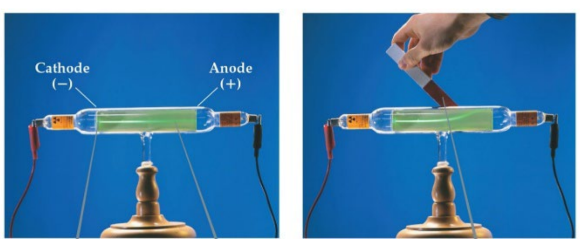
Discovery of Subatomic Particles

In Dalton's view, the atom was the smallest particle possible. Many discoveries led to the fact that the atom itself was made up of smaller particles.

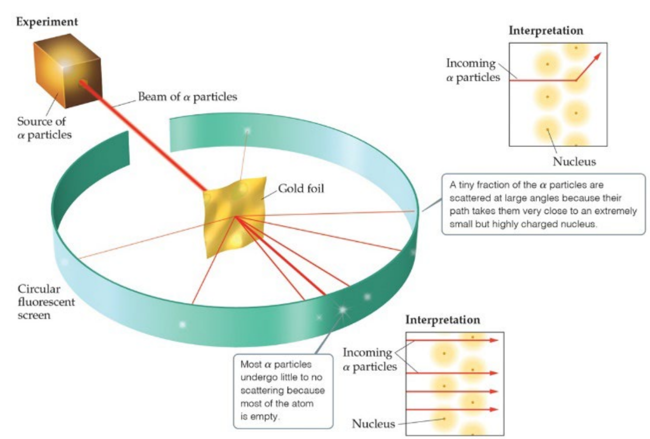
- Electrons and cathode rays
- Radioactivity
- Nucleus, protons, and neutrons

J. J. Thomson.
1990'S (e-)





Ernest Rutherford



Radioactivity

Radioactivity is the spontaneous emission of high-energy radiation by an atom.

It was first observed by Henri Becquerel in the late 1800s.

Marie and Pierre Curie also studied it.

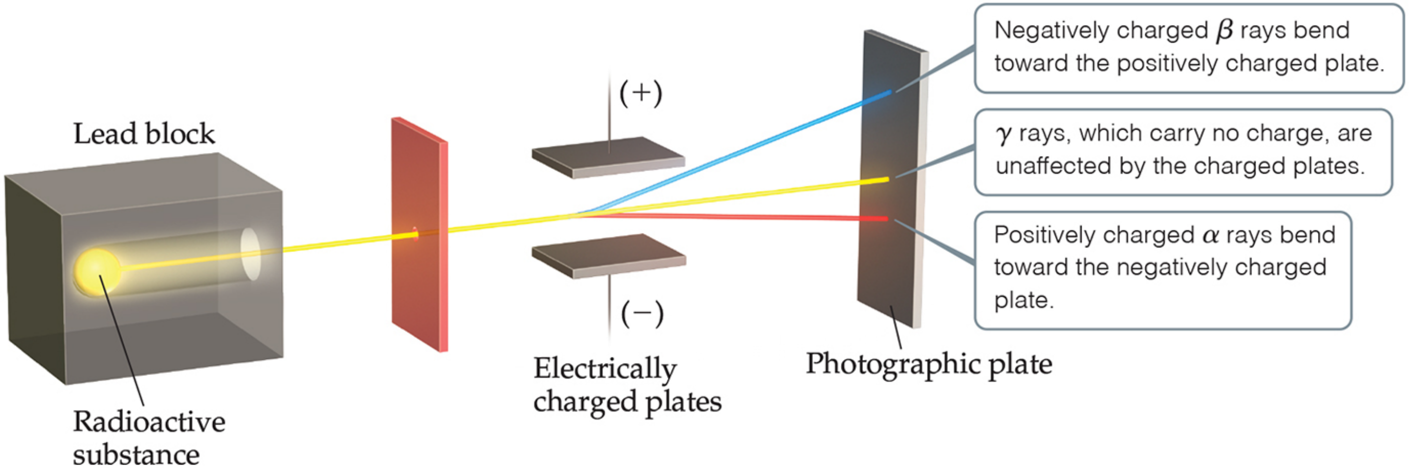
Its discovery showed that the atom had more subatomic particles and energy associated with it and these energetic particles could penetrate matter

Three types of radiation were discovered by Ernest Rutherford:

α particles (positively charged)

β particles (negatively charged, like electrons)

γ rays (uncharged)



ATOMIC THEORY OF MATTER

THE ATOM

NUCLEUS

PROTONS

p

"positively charged"

mass = 1 amu

NEUTRONS

n

"neutral"

mass = 1 amu

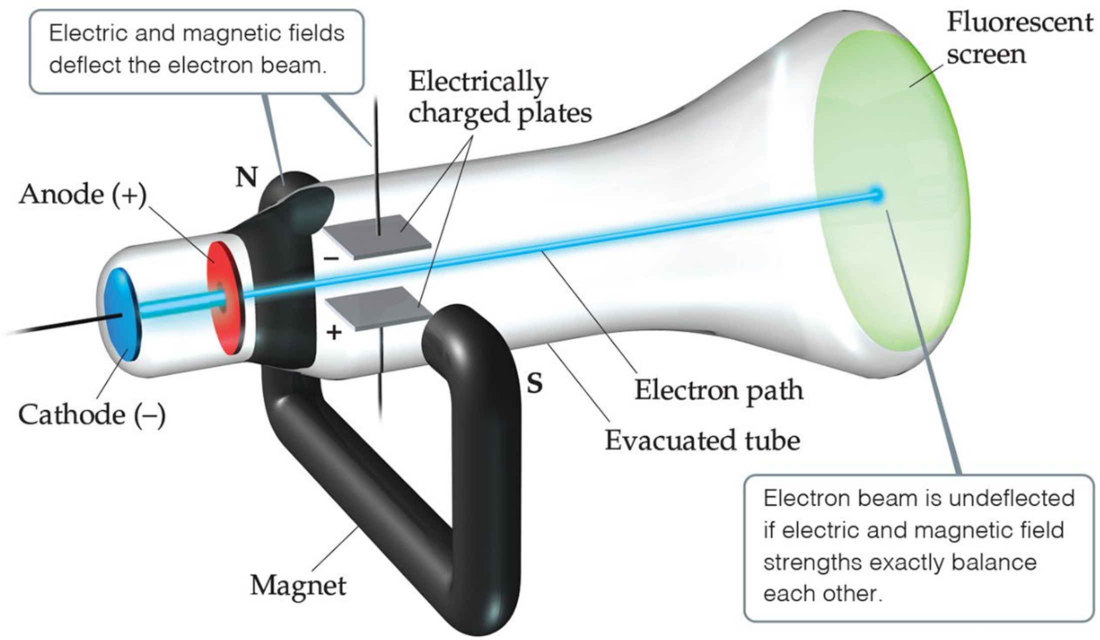
ELECTRONS

e -

"negatively charged"

mass = 1/1837 amu

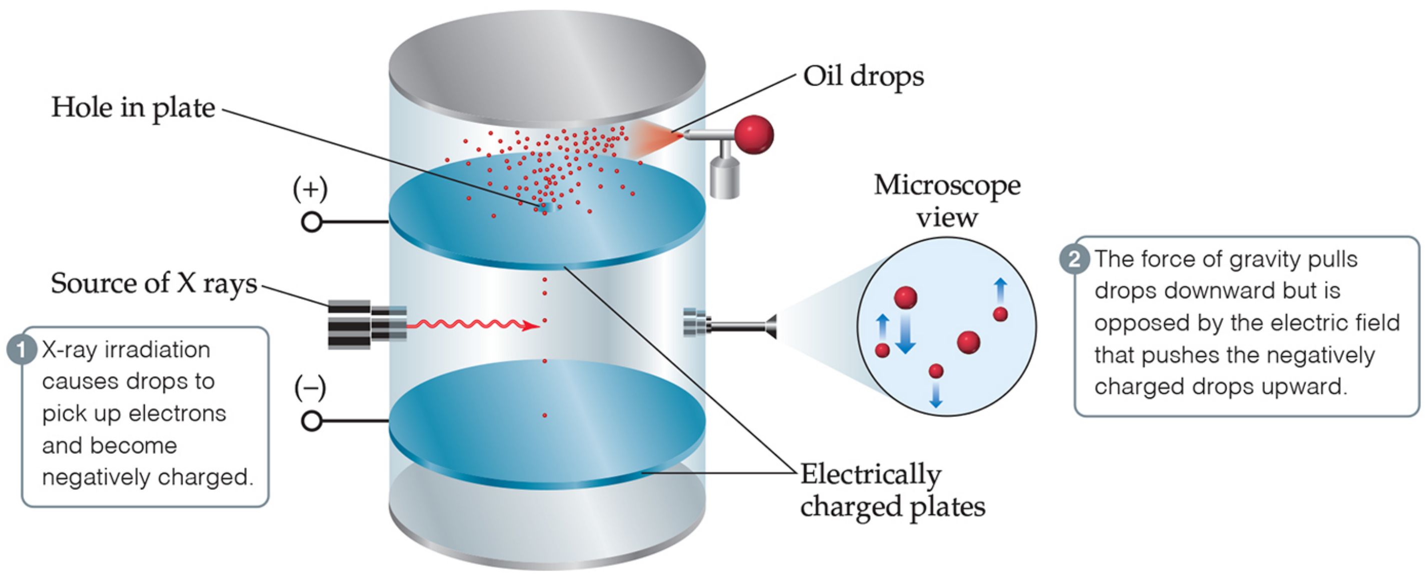
The Electron



Thomson measured the charge/mass ratio of the electron to be 1.76×10^8 coulombs/gram (C/g).

Millikan Oil-Drop Experiment (Electrons)

- Once the charge/mass ratio of the electron was known, determination of either the charge or the mass of an electron would yield the other.
- Robert Millikan determined the charge on the electron in 1909.



Subatomic Particles

Subatomic Particle	Mass g	Mass amu	Location in atom	Charge	Symbol
Proton	1.67262 x 10^{-24}	1.00727	nucleus	+1	p, p^+, H^+
Electron	0.00091 x 10^{-24}	0.00055	empty space	-1	e, e^-
Neutron	1.67493 x 10^{-24}	1.00866	nucleus	0	n, n^0

Table of the subatomic particles in an atom

	symbol	charge	Mass
Proton	p or p+	+1	1 amu
Electron	e-	-1	$^{1}/_{1837}$ amu
Neutron	n	0	1 amu

THE ATOM

may come in one of three forms:

ELEMENTS

\# of p^+ = # of e^-

a neutral atom

IONS

\# of $p^+ \neq$ # of e^-

a charged atom

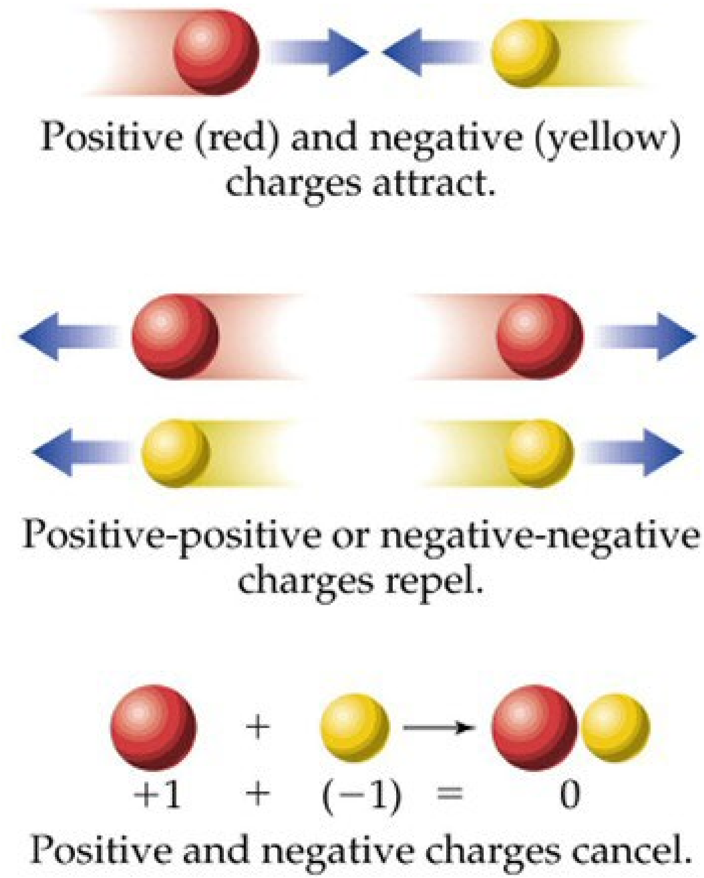
ISOTOPES

\# of neutrons vary

changes the mass of the atom

Some Notes on Charge

- Two kinds of charge called + and –
- Opposite charges attract
  - ✓ + attracted to –
- Like charges repel
  - ✓ + repels +
  - ✓ – repels –
- To be neutral, something must have no charge or equal amounts of opposite charges

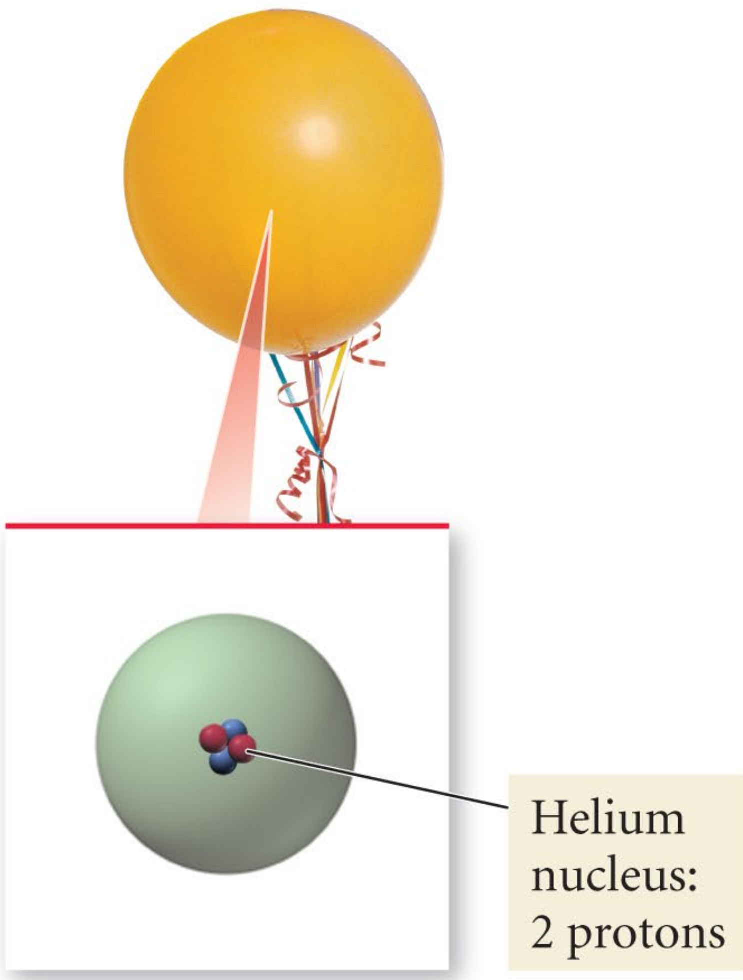


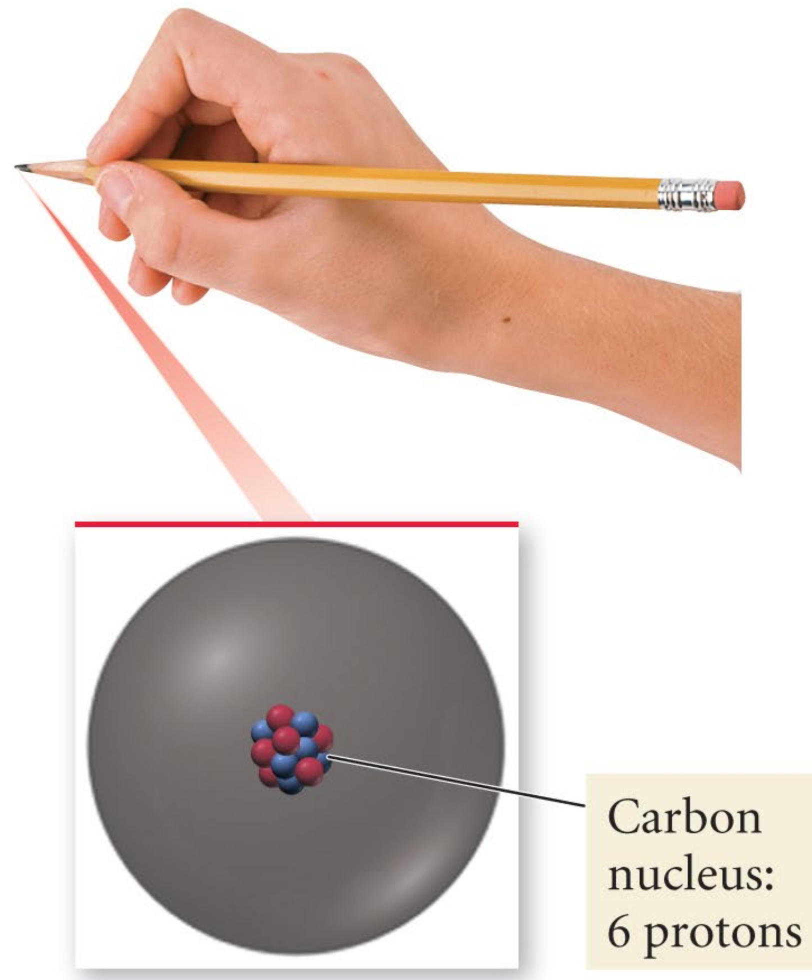
Charged Atoms

- when atoms gain or lose electrons, they acquire a charge
- charged particles are called **ions**
- when atoms gain electrons, they become negatively charged ions, called **anions**
- when atoms lose electrons, they become positively charged ions, called **cations**
- ions behave much differently than the neutral atom
  - ✓ e.g., The metal sodium, made of neutral Na atoms, is highly reactive and quite unstable. However, the sodium cations, Na^+, found in table salt are very nonreactive and stable
- since materials like table salt are neutral, there must be equal amounts of charge from cations and anions in them

Chapter 2
Section 3
ISOTOPES

The Number of Protons Defines the Element





QUICK QUIZ #5A

1. The element with an atomic number 53 on the periodic table contains how many protons and electrons?

Structure of the Nucleus

- Soddy discovered that the same element could have atoms with different masses, which he called **isotopes**
  - ✓ there are 2 isotopes of chlorine found in nature, one that has a mass of about 35 amu and another that weighs about 37 amu
- The observed mass is a weighted average of the weights of all the naturally occurring atoms
  - ✓ the percentage of an element that is 1 isotope is called the isotope's **natural abundance**
  - ✓ the atomic mass of chlorine is 35.45 amu

Isotopes

Isotopes are atoms of the same element with different masses.

Isotopes have different numbers of neutrons, but the same number of protons.

The table below lists four isotopes for carbon.

Table 2.2 Some Isotopes of Carbon[a]

Symbol	Number of Protons	Number of Electrons	Number of Neutrons
^{11}C	6	6	5
^{12}C	6	6	6
^{13}C	6	6	7
^{14}C	6	6	8

[a] Almost 99% of the carbon found in nature is ^{12}C.

ISOTOPIC NOTATION

isotopes are atoms with the same number of protons but different number of neutrons

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

A = mass number

(the total number of protons + neutrons)

Z = atomic number

(the total number of protons)

X = element symbol

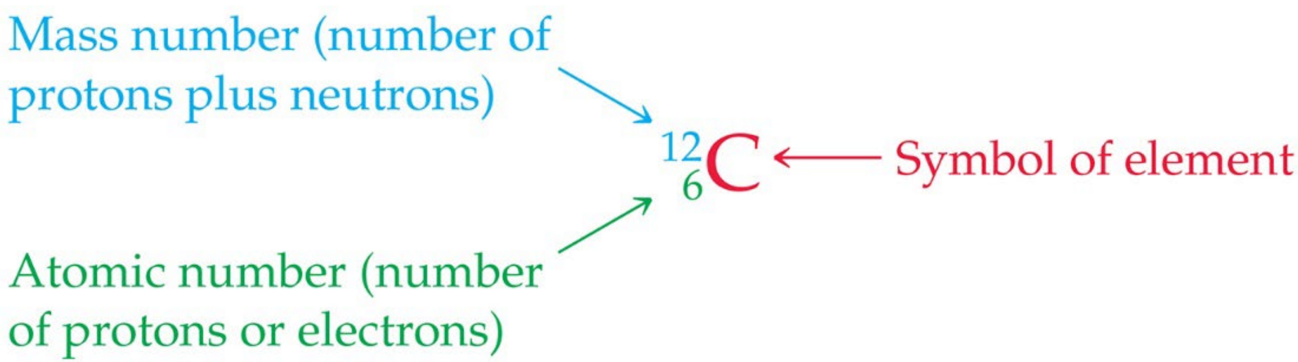
***The number of protons in an atom identifies that atom

*** For neutral atoms, the number of protons equals the number of electrons

Isotopes

- all isotopes of an element are chemically identical
  - ✓undergo the exact same chemical reactions
- all isotopes of an element have the same number of protons
- isotopes of an element have different masses
- isotopes of an element have different numbers of neutrons
- isotopes are identified by their **mass numbers**
  - ✓protons + neutrons

Atoms of an Element



- Elements are represented by a one or two letter **symbol**, for which the first letter is always capitalized. **C** is the **symbol** for carbon.
- All atoms of the same element have the same number of protons, which is called the **atomic number**. It is written as a **subscript Before** the symbol. **6** is the atomic number for carbon.
- The **mass number** is the total number of protons and neutrons in the nucleus of an atom. It is written as a **superscript Before** the symbol.

An Example: Neon

Symbol	Number of Protons	Number of Neutrons	A, Mass Number	Percent Natural Abundance
Ne-20 or $^{20}_{10}\mathrm{N}$	10	10	20	90.48%
Ne-21 or $^{21}_{10}\mathrm{N}$	10	11	21	0.27%
Ne-22 or $^{22}_{10}\mathrm{N}$	10	12	22	9.25%

Atomic Structures of Ions

- Metals form cations
- For each positive charge, the ion has 1 less electron than the neutral atom
  - ✓ Na atom = 11 p^+ and 11 e^-, Na^+ ion = 11 p^+ and 10 e^-
  - ✓ Ca atom = 20 p^+ and 20 e^-, Ca^{2+} ion = 20 p^+ and 18 e^-
- Cations are named the same as the metal

sodium	$Na \rightarrow Na^+ + 1e^-$	sodium ion
calcium	$Ca \rightarrow Ca^{2+} + 2e^-$	calcium ion

Atomic Structures of Ions

- Nonmetals form anions
- For each negative charge, the ion has 1 more electron than the neutral atom
  - ✓ $F = 9\ p^+$ and $9\ e^-$, $F^- = 9\ p^+$ and $10\ e^-$
  - ✓ $P = 15\ p^+$ and $15\ e^-$, $P^{3-} = 15\ p^+$ and $18\ e^-$
- Anions are named by changing the ending of the name to ***-ide***

fluorine	$F + 1e^- \rightarrow F^-$	fluoride ion
oxygen	$O + 2e^- \rightarrow O^{2-}$	oxide ion

GROUP QUIZ #5B for isotopes

Complete the following table:

Symbol	Atomic #	Charge	Mass number	# of proton	# of neutrons	# of electrons
H	1	0	3	1	2	1
Li					7	2
Al		0	27			
______		+2	58	28		
______	78	+4			120	

Atomic Mass

17
Cl
35.45
chlorine

- we previously learned that not all atoms of an element have the same mass
  - ✓ isotopes
- we generally use the average mass of all an element's atoms found in a sample in calculations
  - ✓ however the average must take into account the abundance of each isotope in the sample
- we call the average mass the **atomic mass**

$$\text{Atomic Mass} = \sum (\text{fractional abundance of isotope})_n \times (\text{mass of isotope})_n$$

Generally the formula used is:

% X + % Y + % Z… = atomic mass.

An instrument called the mass spectrometer is generally used to determine the percentages and individual masses of each isotope.

Lecture Questions on Isotopes

A
T
O
M
I
C

M
A
S
S

1. An element consists of 90.51% of an isotope with a mass of 19.992 amu, 0.27% of an isotope with a mass of 20.994 amu, and 9.22% of an isotope with a mass of 21.990 amu. Calculate the average atomic mass and identify the element.

$$(.9051)19.992\text{amu} + (.0027)20.994\text{amu} + (.0922)21.990\text{amu} =$$

$$20.1789 \text{ amu}$$

2. The average atomic weight of lithium is 6.941 amu. The two naturally occurring isotopes of lithium have the following masses: ^{6}Li, 6.01512 amu; ^{7}Li, 7.01600 amu. Calculate the percent abundance of ^{6}Li and ^{7}Li in naturally occurring lithium.

$$X(6.01512) + Y(7.0160) = 6.941 \text{ amu}$$

$$X + Y = 1$$

$$(1-y)\ (6.01512) + y(7.0160)= 6.941 \text{ amu}$$

$Y = 0.9259$ or **92.59%** $\qquad X = 100 – 92.59\% =$ **7.50%**

Atomic Mass Unit (amu)

Atoms have extremely small masses.

The heaviest known atoms have a mass of approximately

$$4 \times 10^{-22} \text{ g.}$$

A mass scale on the atomic level is used, where an atomic mass unit (amu) is the base unit.

❖ $1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g}$

More Isotope problems

1. The mass of one atom of an isotope is 9.746 x 10^{-23} g. One atomic mass unit has the mass of 1.6606 x 10^{-24} g. The atomic mass of this isotope is?

$$9.746\times10^{-23}\ \cancel{g}/_{atom}\left({}^{1\ amu}/_{1.6606\times10^{-24}\ \cancel{g}}\right) =$$

$$58.6896\ {}^{amu}/_{atom}$$

2. The element silver has two naturally occurring isotopes: ^{109}Ag and ^{107}Ag with an average mass of 106.905 amu. Silver consists of 51.82% ^{107}Ag and has an average atomic mass of 107.868 amu. Calculate the mass of ^{109}Ag.

$$X(Ag^{109}) + (51.82\%)\ 106.905\ amu = 107.868\ amu$$

BUT!!!

100% - 51.82% = 48.18% since only two isotopes exist.

$$0.4818X + (0.5182)\ 106.905\ amu = 107.868\ amu$$

$$X = 108.904\ amu$$

GROUP QUIZ #5C

1. Complete the following table:

ION	# p	# n	# e	*ION*	# p	# n	# e
$^{8}Li^{+}$				$^{18}F^{-}$			
$^{40}Ca^{2+}$				$^{18}O^{2-}$			
$^{31}P^{-3}$				$^{124}Sn^{4+}$			

2. Element X has three naturally occurring isotopes, 24X (isotopic mass 23.9850 amu, abundance 78.99%), 25X (isotopic mass 24.9858 amu, abundance 10.00%), and 26X (isotopic mass 25.9826 amu, abundance 11.01%). Calculate the average atomic mass.

ANNOUNCEMENT

I WILL NOT BE COVERING THE PERIODIC TABLE SECTION IN CHAPTER 2 IN LECTURE. (1) THERE IS A LECTURE VIDEO IN CANVAS FOR YOUR VIEWING & (2) YOU CAN WATCH THE MOVIE “HUNTING THE ELEMENTS” ALSO FOR THE INFORMATION.

TOMORROW I WILL BE COVERING NOMENCLATURE