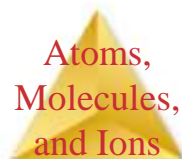


# Chapter 2

# Atoms, Molecules, and Ions

*Chemistry, The Central Science*, 10th edition  
Theodore L. Brown; H. Eugene LeMay, Jr.;  
and Bruce E. Bursten



# Atomic Theory of Matter



The theory that atoms are the fundamental building blocks of matter.

Atoms are neither created nor destroyed in chemical reactions.

# Dalton's Postulates



Each element is composed of extremely small particles called atoms.

Compounds are formed when atoms of more than one element combine;

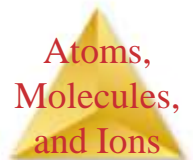
A given compound always has the same relative number and kind of atoms

# Law of Conservation of Mass

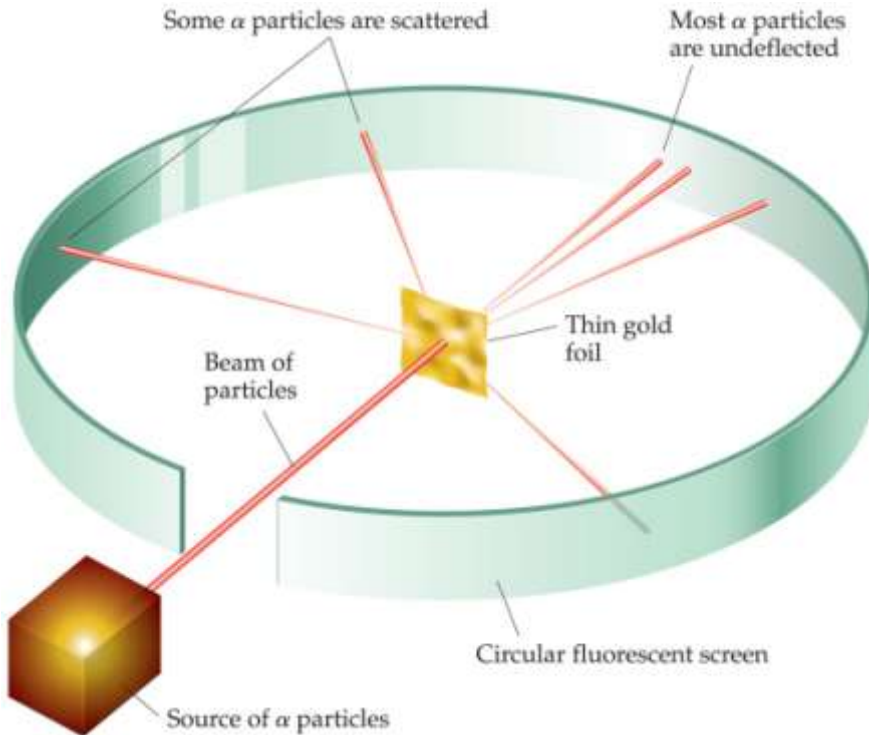
The total mass of substances present  
at the *beginning* of a chemical process

is the SAME as ...

The mass of substances present  
*after* the process took place.



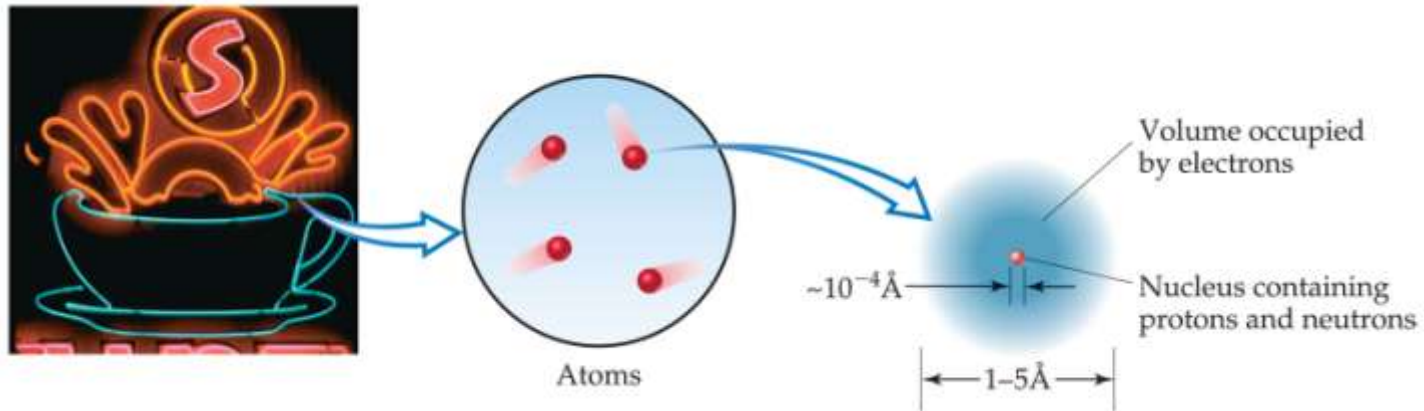
# Discovery of the Nucleus



Ernest Rutherford shot  $\alpha$  particles at a thin sheet of gold foil and observed the pattern of scatter of the particles.

# The Nuclear Atom

- Rutherford postulated a tiny, dense nucleus with most of the mass,
- Most of the atomic volume is empty space with orbiting electrons.



# Other Subatomic Particles

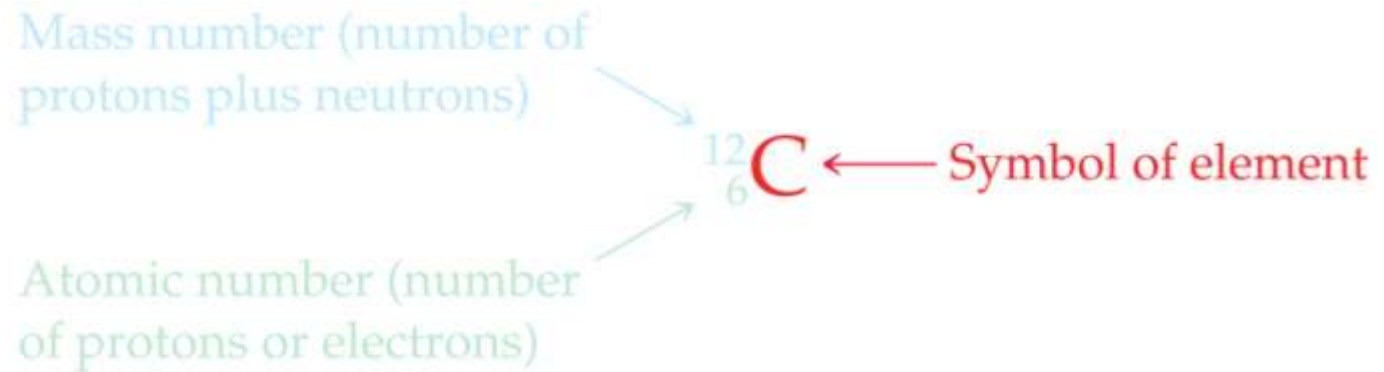
- Protons were discovered by Ernest Rutherford in 1919.
- Neutrons were discovered by James Chadwick in 1932.

# Subatomic Particles

- Protons and electrons are the only particles that have a charge.
- Protons and neutrons have essentially the same mass.
- The mass of an electron is so small we ignore it.

Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1-)	$5.486 \times 10^{-4}$

# Symbols of Elements



Elements are symbolized by one or two letters.

# Atomic Number

Mass number (number of protons plus neutrons)

Atomic number (number of protons or electrons)



← Symbol of element

All atoms of an element,  
have the same number of protons.

The atomic number (Z) – Number of Protons.

# Atomic Mass

Mass number (number of protons plus neutrons)



Symbol of element

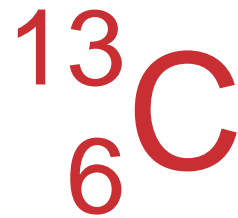
Atomic number (number of protons or electrons)

## Mass Number-

- Mass of an atom,
- In atomic mass units (amu),
- Total # of protons and neutrons in the atom.

# Isotopes:

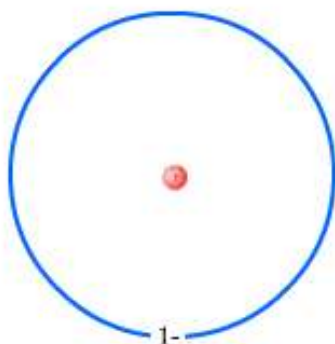
- Atoms of an element may have different masses.
- Isotopes have different numbers of neutrons, making the element's nucleus denser.



# Isotopes of Hydrogen

Hydrogen's atomic number is 1. How many protons?

Click an isotope button.



Hydrogen's atomic mass is 1.008 amu.

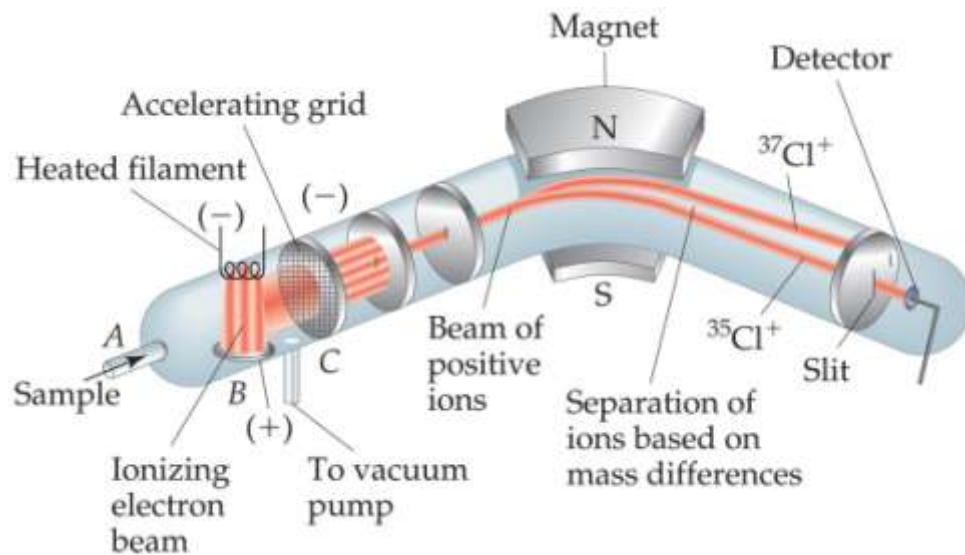
How many neutrons in  $^1\text{H}$ ?

How many neutrons in  $^2\text{H}$ ?

How many neutrons in  $^3\text{H}$ ?



# Atomic Mass



Atomic and molecular masses can be measured with great accuracy with a mass spectrometer.

# Atomic Mass

- Average mass is an average.
- All the isotopes of an element are multiplied by their relative abundance in our universe.
- Usually the atomic mass is a decimal to account for all the isotopes.

# Periodic Table:

1A 1																	8A 18
1 H	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	2 He
2 3 Li	4 4 Be											5 5 B	6 6 C	7 7 N	8 8 O	9 9 F	10 10 Ne
3 11 Na	12 12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10			1B 11	2B 12	13 13 Al	14 14 Si	15 15 P	16 16 S	17 17 Cl	18 18 Ar
4 19 K	20 20 Ca	21 21 Sc	22 22 Ti	23 23 V	24 24 Cr	25 25 Mn	26 26 Fe	27 27 Co	28 28 Ni	29 29 Cu	30 30 Zn	31 31 Ga	32 32 Ge	33 33 As	34 34 Se	35 35 Br	36 36 Kr
5 37 Rb	38 38 Sr	39 39 Y	40 40 Zr	41 41 Nb	42 42 Mo	43 43 Tc	44 44 Ru	45 45 Rh	46 46 Pd	47 47 Ag	48 48 Cd	49 49 In	50 50 Sn	51 51 Sb	52 52 Te	53 53 I	54 54 Xe
6 55 Cs	56 56 Ba	71 71 Lu	72 72 Hf	73 73 Ta	74 74 W	75 75 Re	76 76 Os	77 77 Ir	78 78 Pt	79 79 Au	80 80 Hg	81 81 Tl	82 82 Pb	83 83 Bi	84 84 Po	85 85 At	86 86 Rn
7 87 Fr	88 88 Ra	103 103 Lr	104 104 Rf	105 105 Db	106 106 Sg	107 107 Bh	108 108 Hs	109 109 Mt	110	111	112	113	114	115	116		

Metals	57 La	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
Metalloids	89 Ac	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
Nonmetals														

- A systematic catalog of elements.
- Elements are arranged by atomic number.

# Periodicity

Atomic number	1	2	3	4	9	10	11	12	17	18	19	20
Symbol	H	He	Li	Be	F	Ne	Na	Mg	Cl	Ar	K	Ca
		Nonreactive gas	Soft, reactive metal		Nonreactive gas	Soft, reactive metal		Nonreactive gas	Soft, reactive metal			

When one looks at the chemical properties of elements, one notices a repeating pattern of reactivities.



# Groups

Group	Name	Elements
1A	Alkali metals	Li, Na, K, Rb, Cs, Fr
2A	Alkaline earth metals	Be, Mg, Ca, Sr, Ba, Ra
6A	Chalcogens	O, S, Se, Te, Po
7A	Halogens	F, Cl, Br, I, At
8A	Noble gases (or rare gases)	He, Ne, Ar, Kr, Xe, Rn

- Groups 3B to 2B are Transition Metals.
- Group A reveals the number of Valance Electrons available for bonding.
- Valance Electrons are located in the outermost shell.

# Periodic Table

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4 19 K	20 20 Ca	21 21 Sc	22 22 Ti	23 23 V	24 24 Cr	25 25 Mn	26 26 Fe	27 27 Co	28 28 Ni	29 29 Cu	30 30 Zn	31 31 Ga	32 32 Ge	33 33 As	34 34 Se	35 35 Br	36 36 Kr
5 37 Rb	38 38 Sr	39 39 Y	40 40 Zr	41 41 Nb	42 42 Mo	43 43 Tc	44 44 Ru	45 45 Rh	46 46 Pd	47 47 Ag	48 48 Cd	49 49 In	50 50 Sn	51 51 Sb	52 52 Te	53 53 I	54 54 Xe
6 55 Cs	56 56 Ba	71 71 Lu	72 72 Hf	73 73 Ta	74 74 W	75 75 Re	76 76 Os	77 77 Ir	78 78 Pt	79 79 Au	80 80 Hg	81 81 Tl	82 82 Pb	83 83 Bi	84 84 Po	85 85 At	86 86 Rn
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Nonmetals														

Nonmetals are on the right side of the periodic table (with the exception of H).



# Periodic Table

1A 1																	8A 18
1 H	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	2 He
2 3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
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Metalloids	89 Ac	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
Nonmetals														

Metals are on the left side of the chart.

# Chemical Formulas



Water, H<sub>2</sub>O



Carbon dioxide, CO<sub>2</sub>



Carbon monoxide, CO



Methane, CH<sub>4</sub>



Hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>



Oxygen, O<sub>2</sub>

The subscript (right of the symbol)

- tells the number of atoms
- of that element
- in one molecule
- of the compound.

# Molecular Compounds



Water, H<sub>2</sub>O



Carbon dioxide, CO<sub>2</sub>



Carbon monoxide, CO



Methane, CH<sub>4</sub>



Hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>

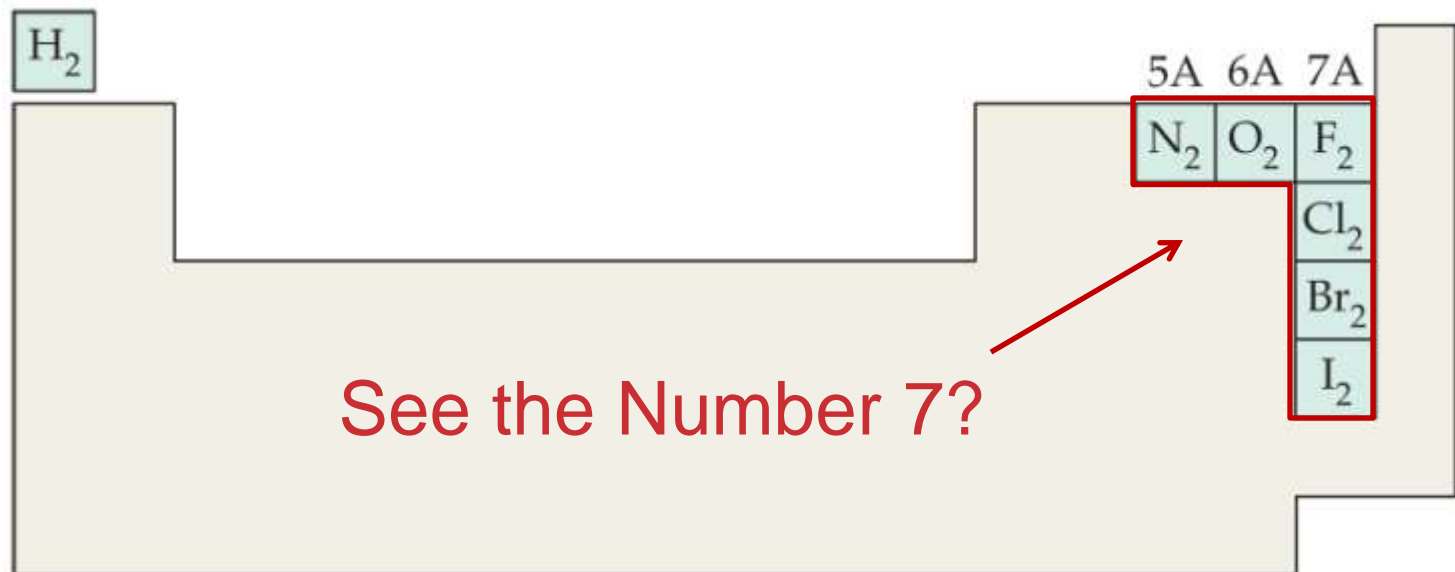


Oxygen, O<sub>2</sub>

Molecular compounds

- composed of molecules
- contains only nonmetals.

# Diatomic Molecules



These *seven* elements occur in nature as molecules containing two atoms.

*Another way to remember these seven atoms is to recall that they are the GEN-u-INE elements (end in -gen or -ine).*