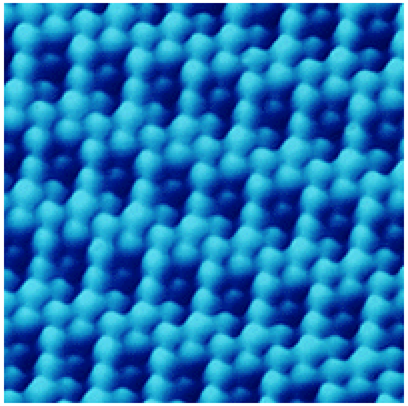
Atoms and Elements

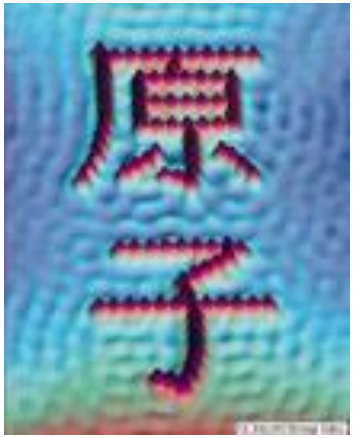
Chapter 2

Imaging Atoms

- March 6, 1981
  - Scanning tunneling microscopy allowed Gerd Binnig and Heinrich Rohrer to "see" the first atoms.



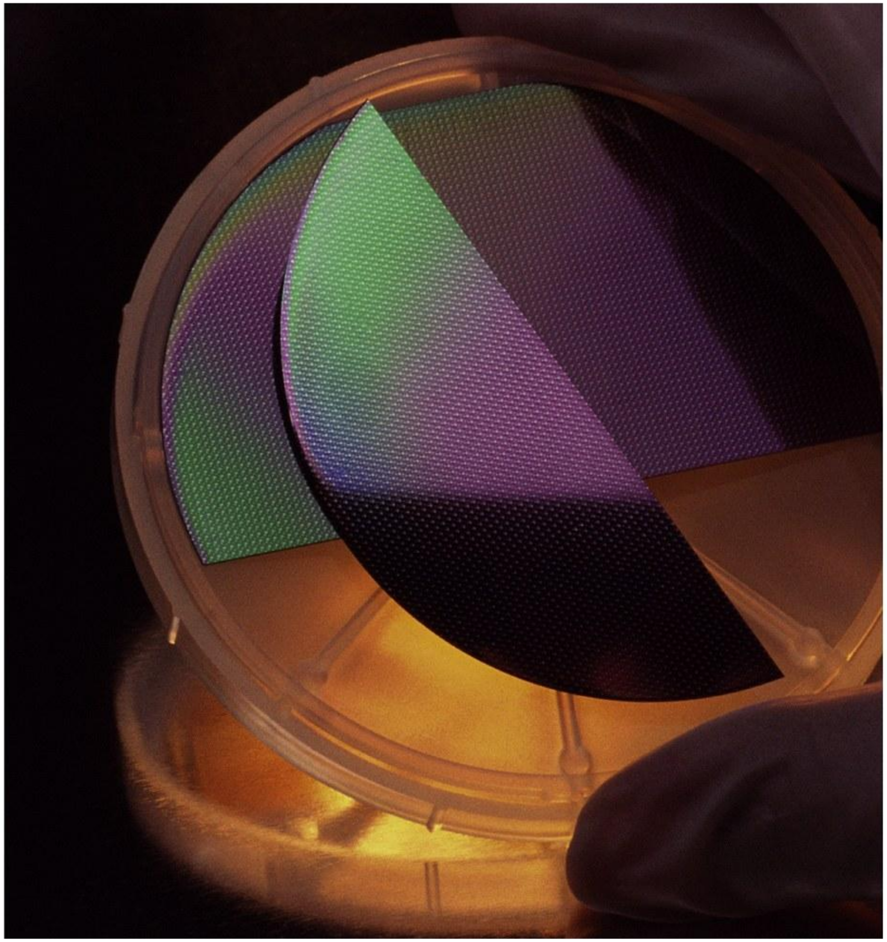
Individual atoms



The word atom written with atoms in Japanese

Heinrich Rohrer

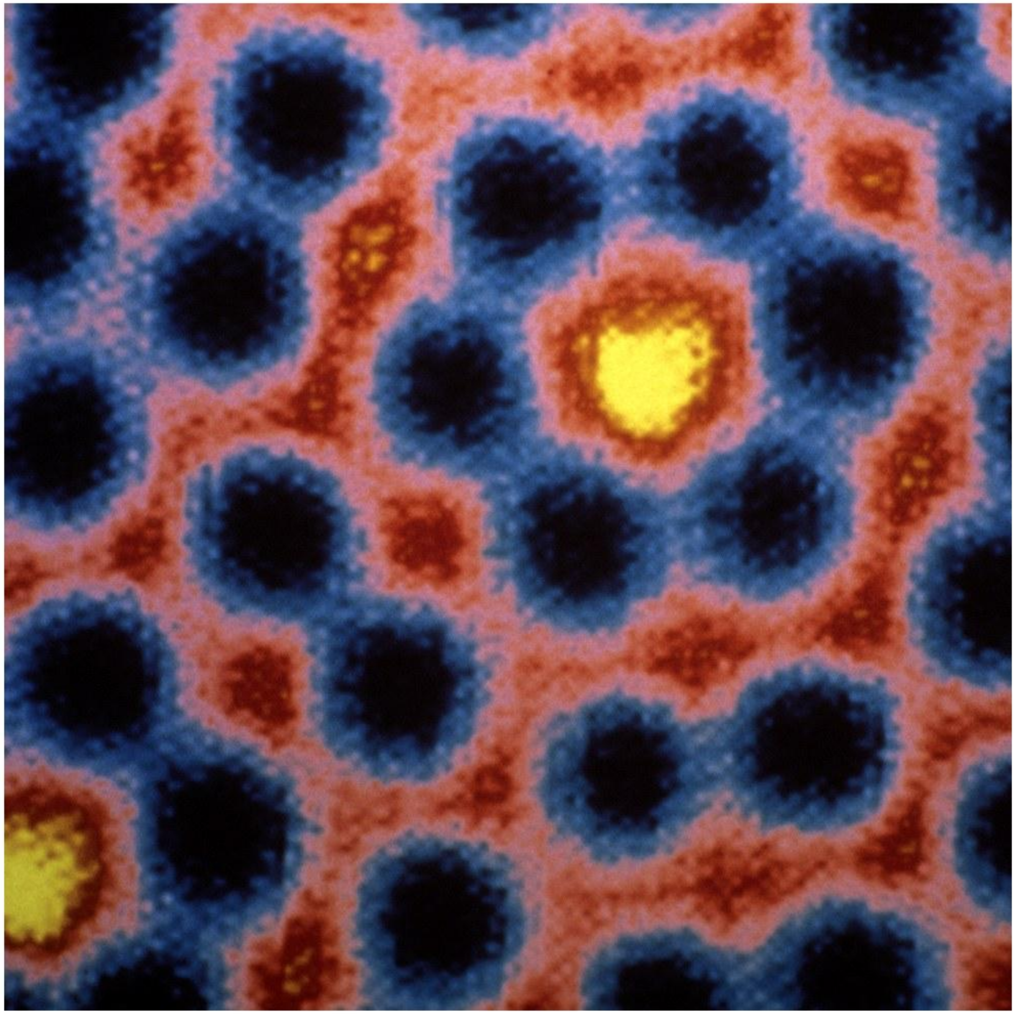
Gerd Binnig



Chemistry: The Science in Context 2/e Figure 1.5a
Mason Morfit/Taxi/Getty Images

Silicon Wafer

Individual Silicon atoms



Law of conservation of mass

- Mass is neither created nor destroyed in a chemical reaction.

- In an ordinary chemical reaction, the total mass of reacting substances is equal to the total mass of products formed.

Practice problems Tro – 2.4, 2.31-2.32, 2.91

Law of Constant composition (Law of Definite Proportions)

- Different samples of a pure chemical substance always contain the same proportion of elements by mass.

- The relative amount of each element in a particular compound is always the same, regardless of the source of the compound or how it was made.

Practice problems Tro – 2.5, 2.33-2.36,

Law of Multiple Proportions

- If two elements combine in different ways to form different substances, the mass ratios are small, whole number multiples of each other.

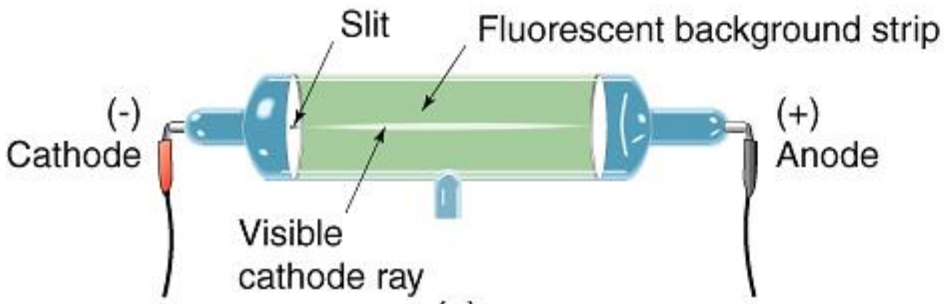
Practice problems Tro – 2.6-2.7, 2.37-2.40, 2.113

Atomic Theory

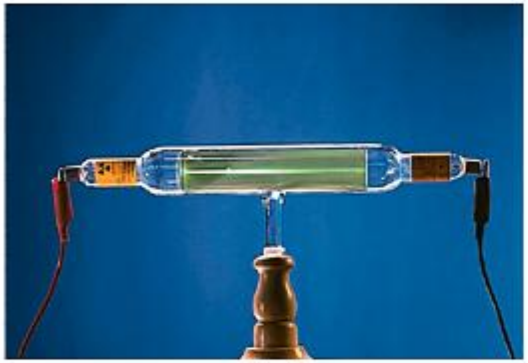
- Elements (matter) is composed of small, indivisible particles called atoms.
- Atoms of a given element are identical in mass and behavior.
- Atoms of different elements differ in mass and behavior.
- Chemical combination of elements to make different substances occurs when atoms join together in small whole number ratios.
- Chemical reactions only rearrange the way the atoms are combined; the atoms themselves are not changed.

Practice problems Tro – 2.8, 2.41-2.42

Sub Atomic Particles

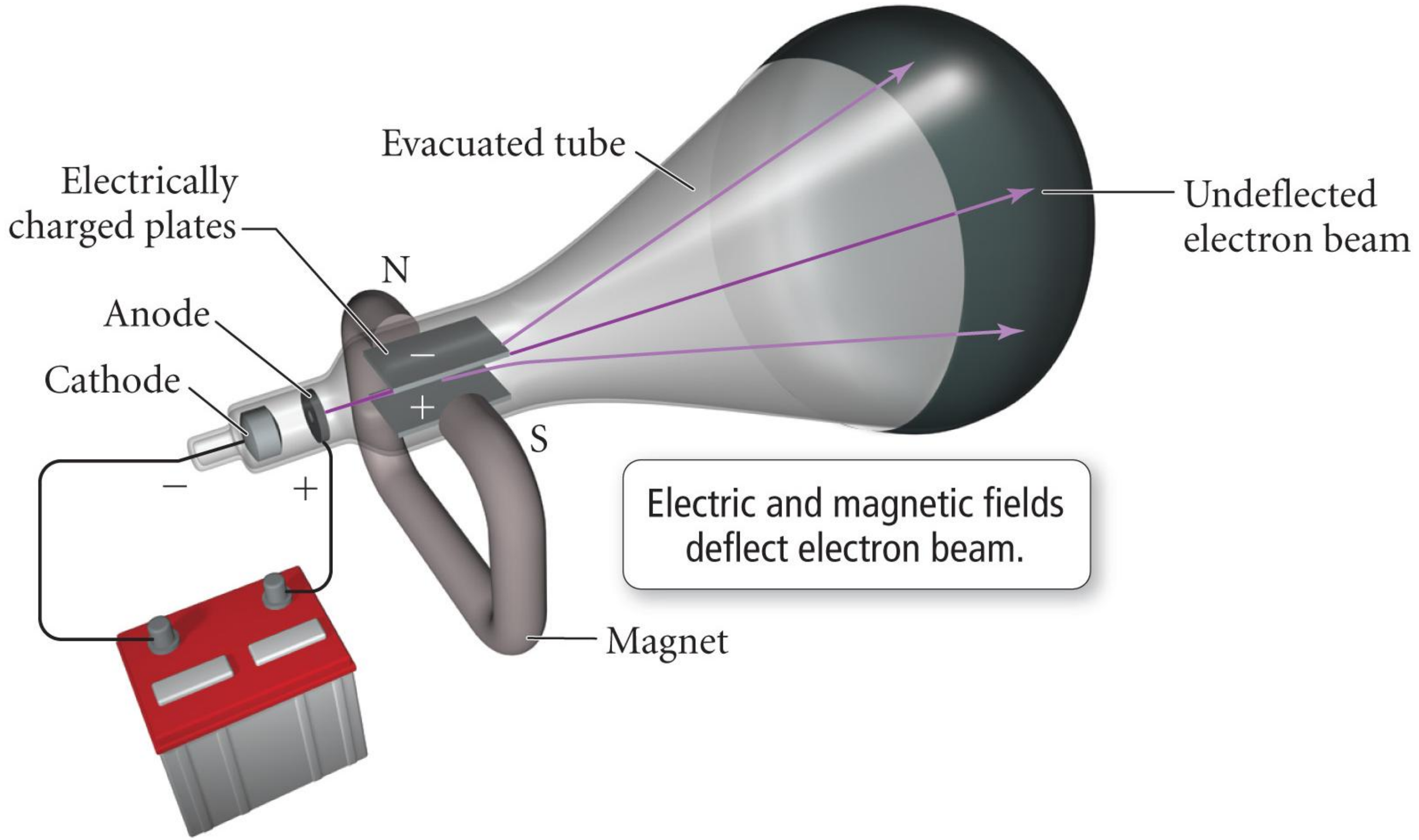


(a)


(b)


(c)

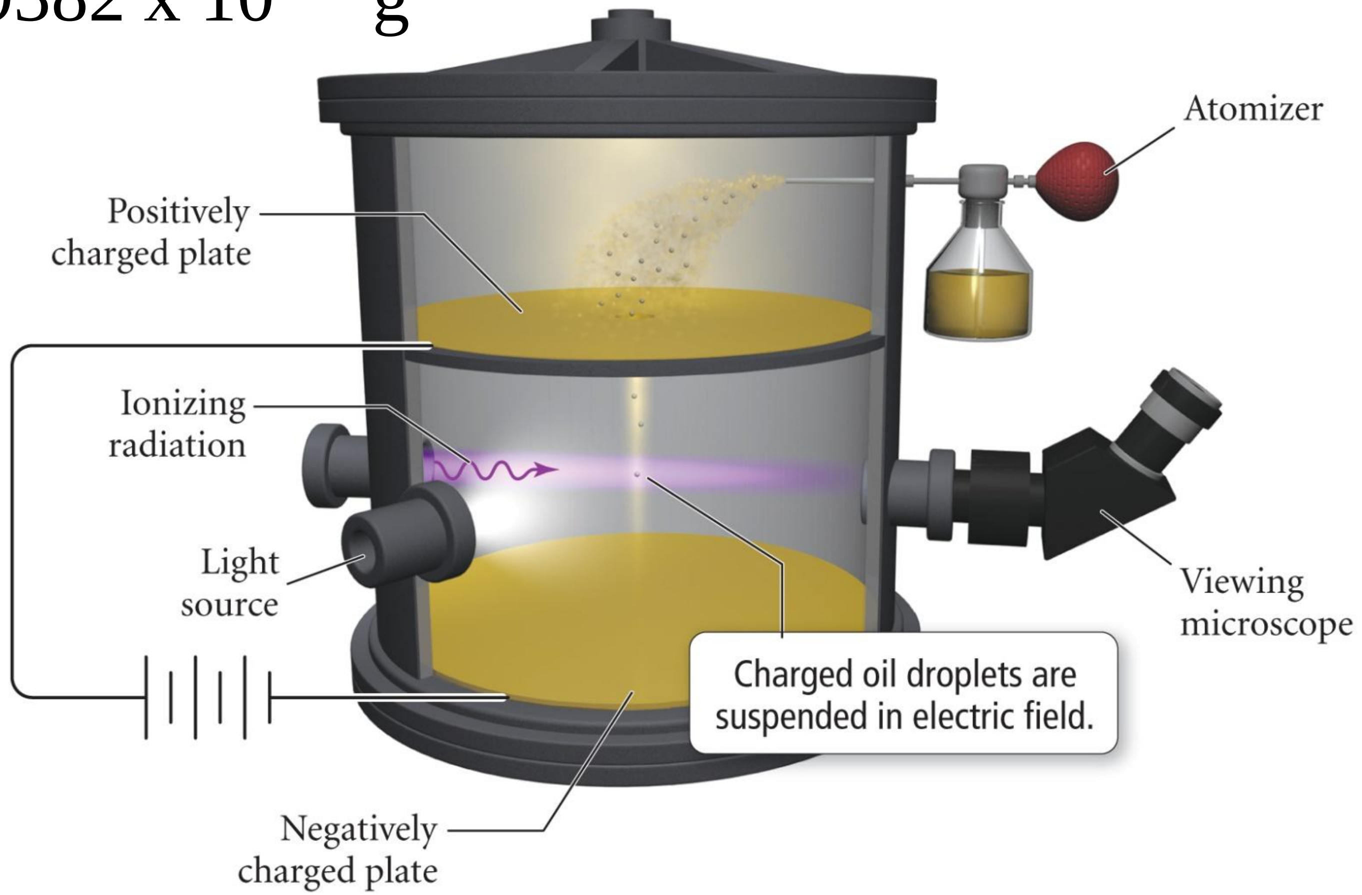
- Thompson – determined charge/mass ratio for an electron.
  - Charge/mass = 1.758820 x 108 C/g



- Millikan – determined the charge on an electron.
  - Charge = 1.602176×10^{-19} C

  Leading to the mass of an electron

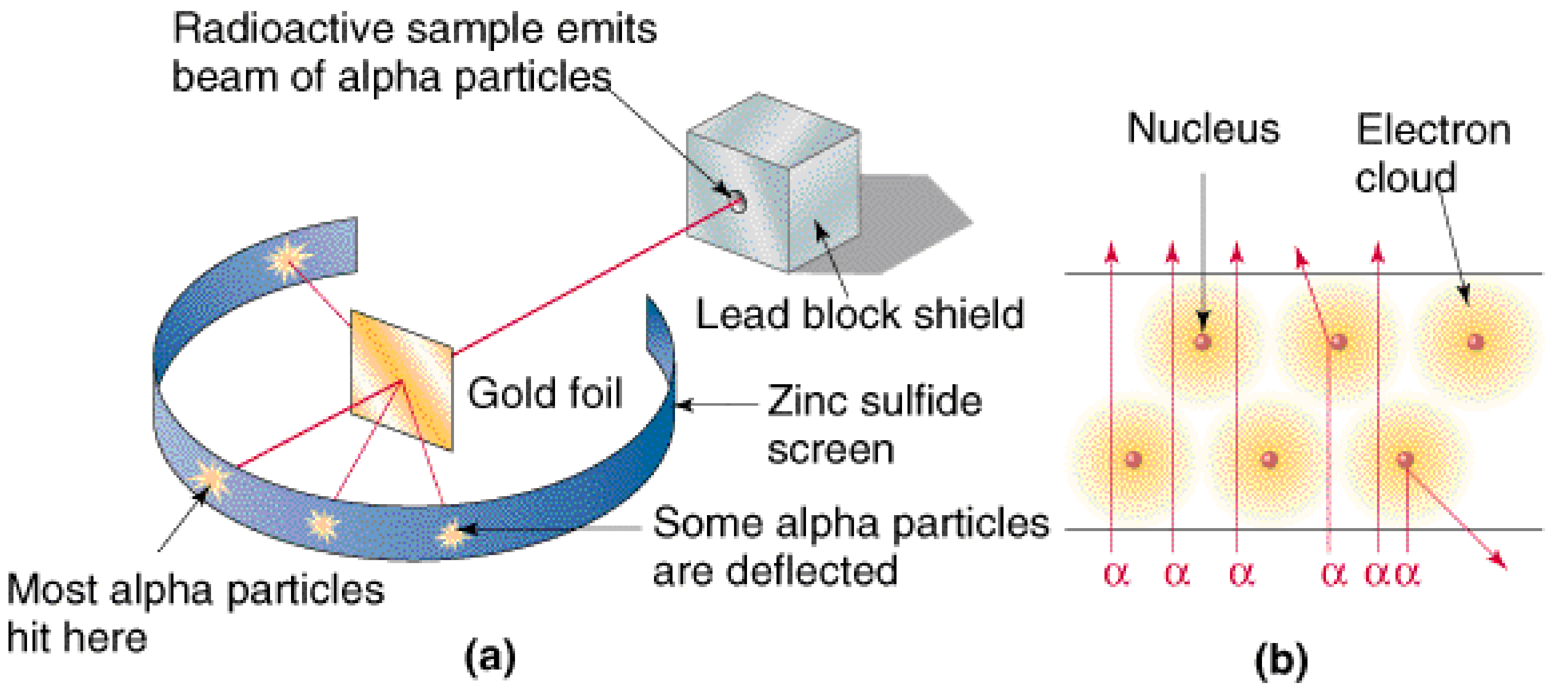
  mass = 9.109382×10^{-29} g



96

Cm

Curium


Radioactive sample emits beam of alpha particles
Lead block shield
Gold foil
Zinc sulfide screen
Some alpha particles are deflected
Most alpha particles hit here
(a)
Nucleus
Electron cloud
α
α
α
α
α
α
(b)

Atoms are composed of

Protons	+ charge	1.67×10^{-24} g	nucleus
Neutrons	no charge	1.67×10^{-24} g	nucleus
Electrons	– charge	9.11×10^{-28} g	Around nucleus

Practice problems Tro – 2.12-2.15, 2.44, 2.49-2.52

If a proton had the mass of a baseball, an electron would have the mass of a rice grain.

Atomic Number

= Z

= number of protons in an atom.

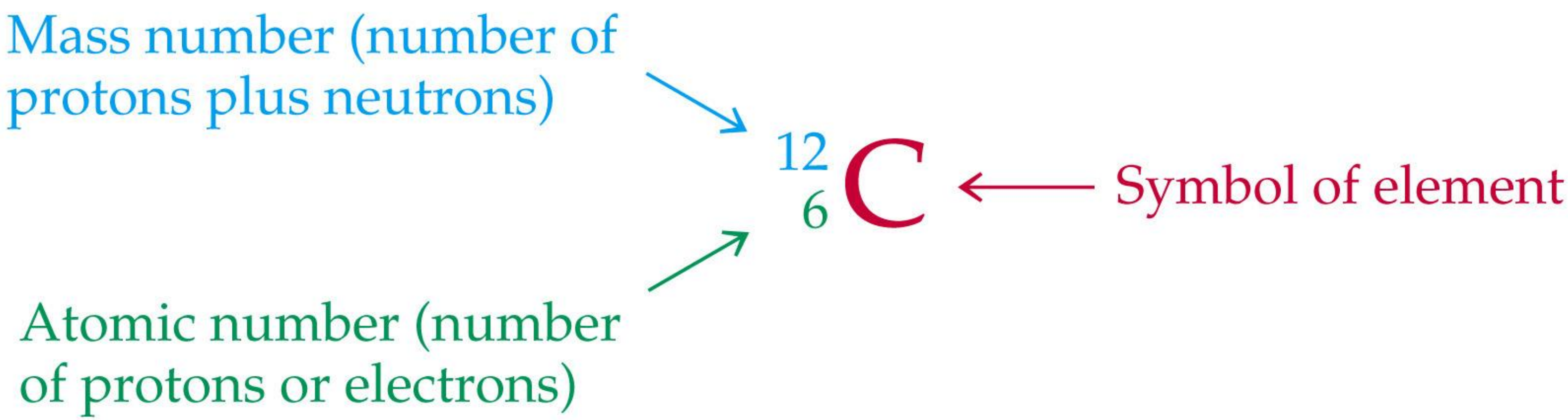
= number of electrons in a neutral atom.

Neutrons

- What do neutrons do?
  - Help keep protons together – buffers charge
  - Generally 1-1.5 neutrons per proton
  - Have little effect on chemistry

Isotopes

- Atoms which differ only in the number of neutrons present in the nucleus.

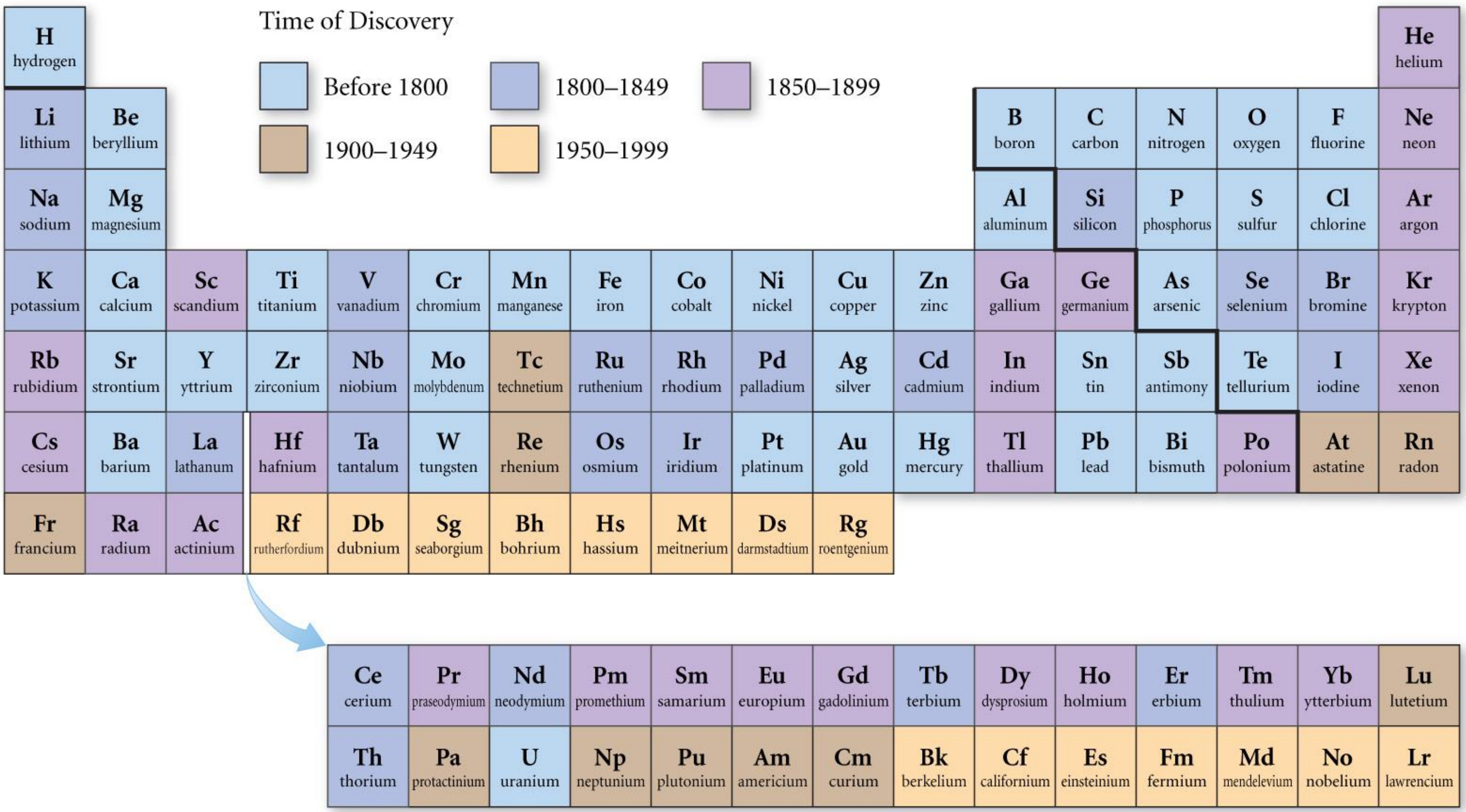


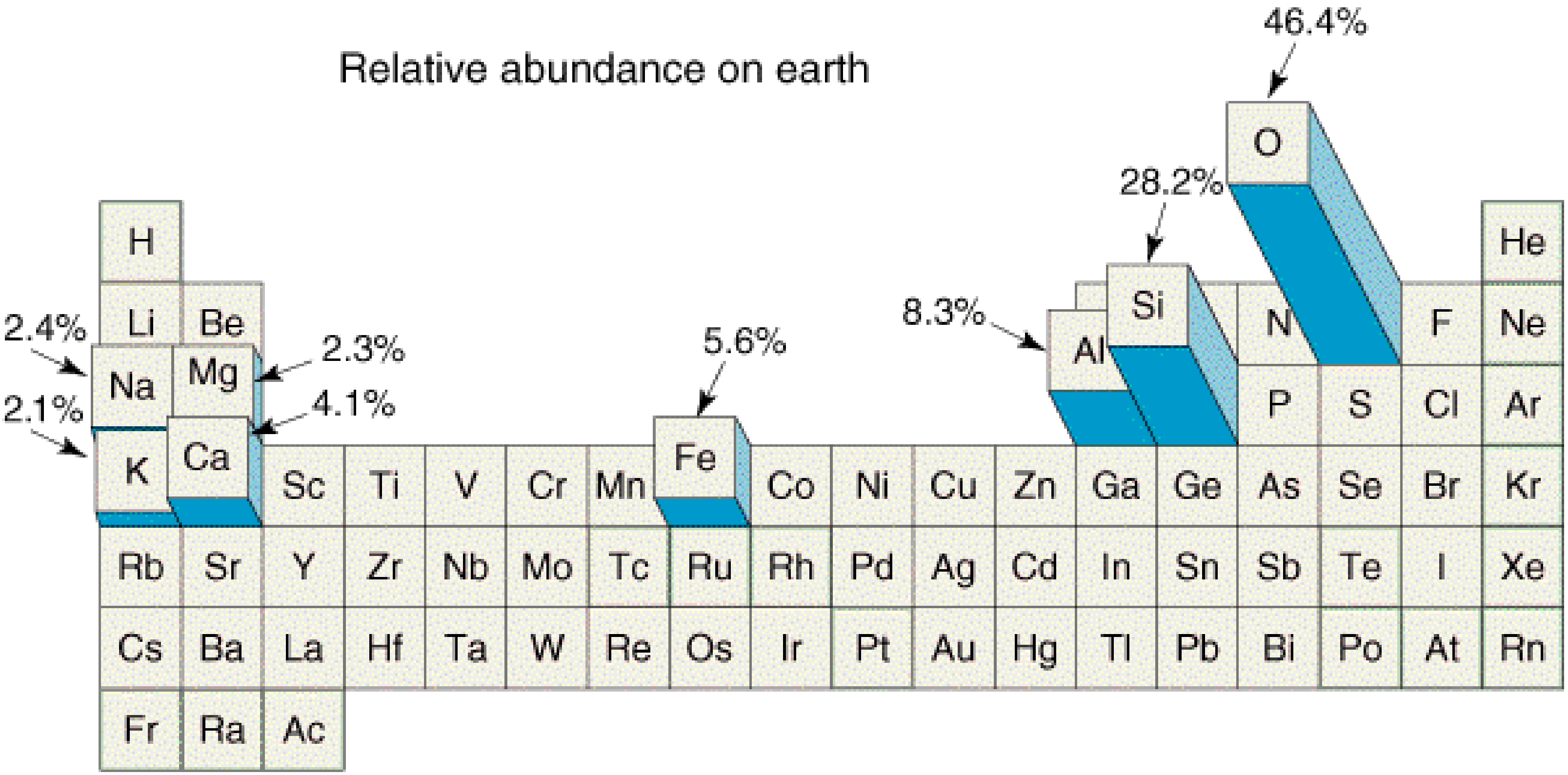
Carbon – 12

Element name

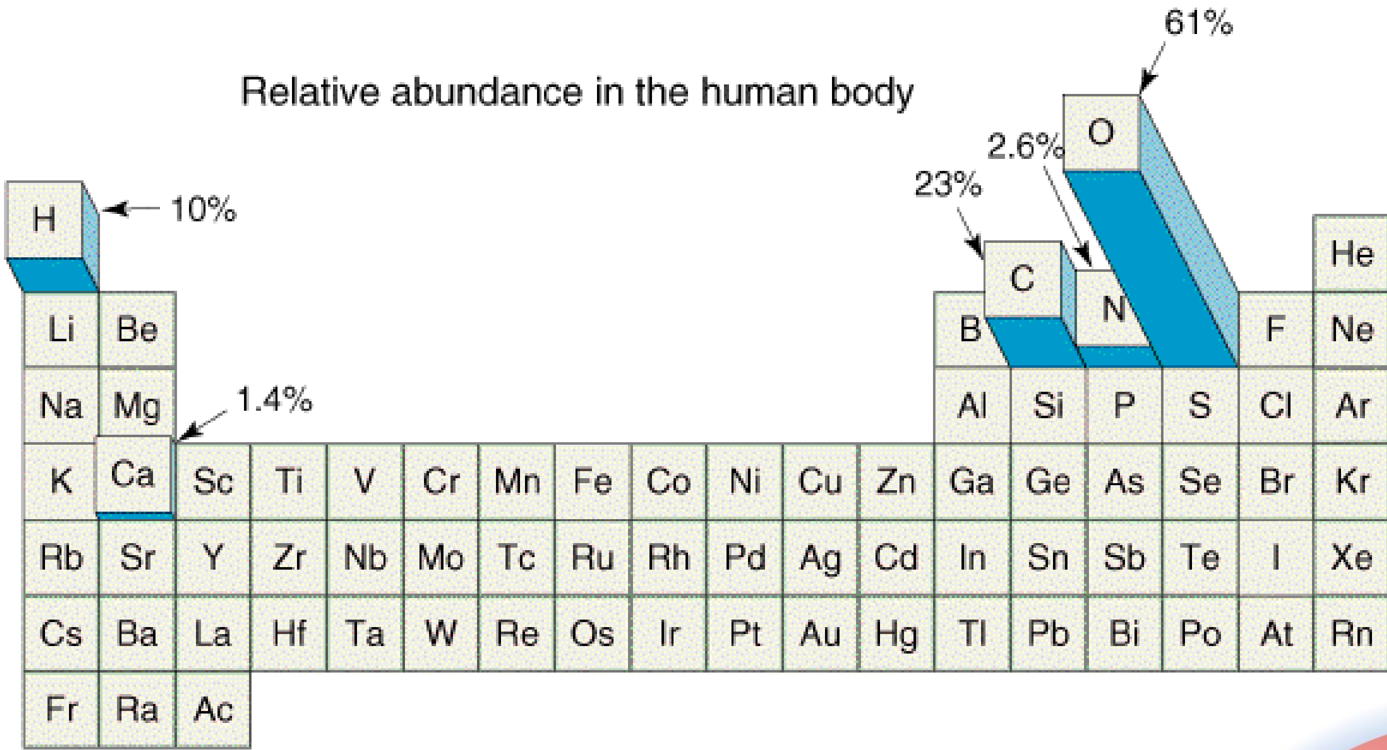
Mass Number

Practice problems Tro – 2.16-2.17, 2.53-2.58

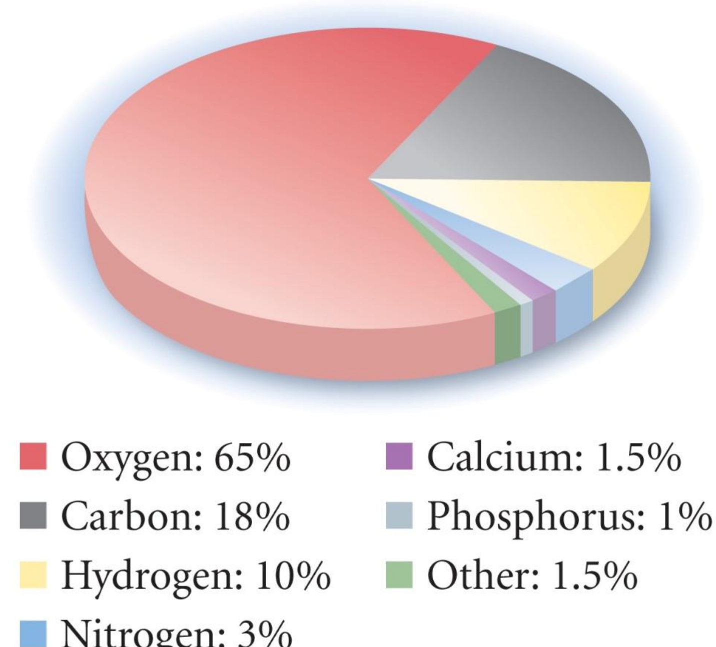

Time of Discovery
Before 1800
1800–1849
1850–1899
1900–1949
1950–1999
H hydrogen
He helium
Li lithium
Be beryllium
B boron
C carbon
N nitrogen
O oxygen
F fluorine
Ne neon
Na sodium
Mg magnesium
Al aluminum
Si silicon
P phosphorus
S sulfur
Cl chlorine
Ar argon
K potassium
Ca calcium
Sc scandium
Ti titanium
V vanadium
Cr chromium
Mn manganese
Fe iron
Co cobalt
Ni nickel
Cu copper
Zn zinc
Ga gallium
Ge germanium
As arsenic
Se selenium
Br bromine
Kr krypton
Rb rubidium
Sr strontium
Y yttrium
Zr zirconium
Nb niobium
Mo molybdenum
Tc technetium
Ru ruthenium
Rh rhodium
Pd palladium
Ag silver
Cd cadmium
In indium
Sn tin
Sb antimony
Te tellurium
I iodine
Xe xenon
Cs cesium
Ba barium
La lathanum
Hf hafnium
Ta tantalum
W tungsten
Re rhenium
Os osmium
Ir iridium
Pt platinum
Au gold
Hg mercury
Tl thallium
Pb lead
Bi bismuth
Po polonium
At astatine
Rn radon
Fr francium
Ra radium
Ac actinium
Rf rutherfordium
Db dubnium
Sg seaborgium
Bh bohrium
Hs hassium
Mt meitnerium
Ds darmstadtium
Rg roentgenium
Ce cerium
Pr praseodymium
Nd neodymium
Pm promethium
Sm samarium
Eu europium
Gd gadolinium
Tb terbium
Dy dysprosium
Ho holmium
Er erbium
Tm thulium
Yb ytterbium
Lu lutetium
Th thorium
Pa protactinium
U uranium
Np neptunium
Pu plutonium
Am americium
Cm curium
Bk berkelium
Cf californium
Es einsteinium
Fm fermium
Md mendelevium
No nobelium
Lr lawrencium


Relative abundance on earth
46.4%
O
28.2%
Si
8.3%
Al
5.6%
Fe
2.4%
Na
2.3%
Mg
4.1%
Ca
2.1%
K
H He
Li Be N F Ne
P S Cl Ar
Sc Ti V Cr Mn Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac

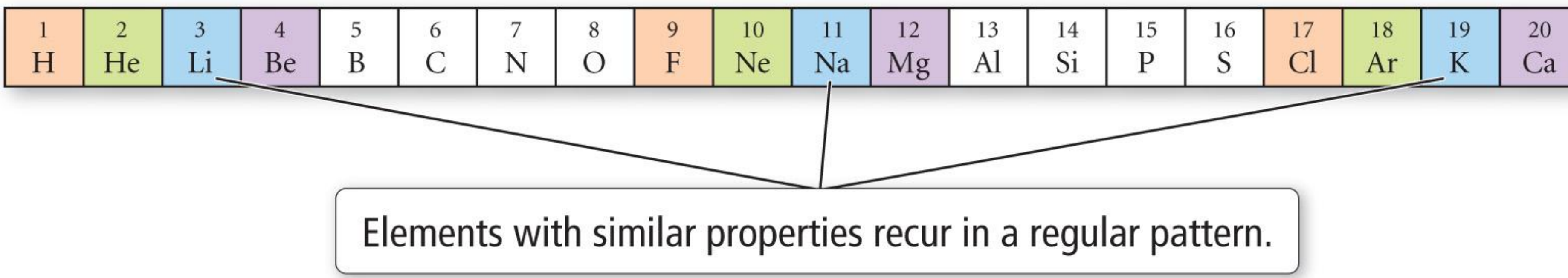
(a)


Relative abundance in the human body
61%
2.6%
23%
10%
1.4%
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac

(b)


Oxygen: 65%
Carbon: 18%
Hydrogen: 10%
Nitrogen: 3%
Calcium: 1.5%
Phosphorus: 1%
Other: 1.5%

The Periodic Law



A Simple Periodic Table

1 H							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						

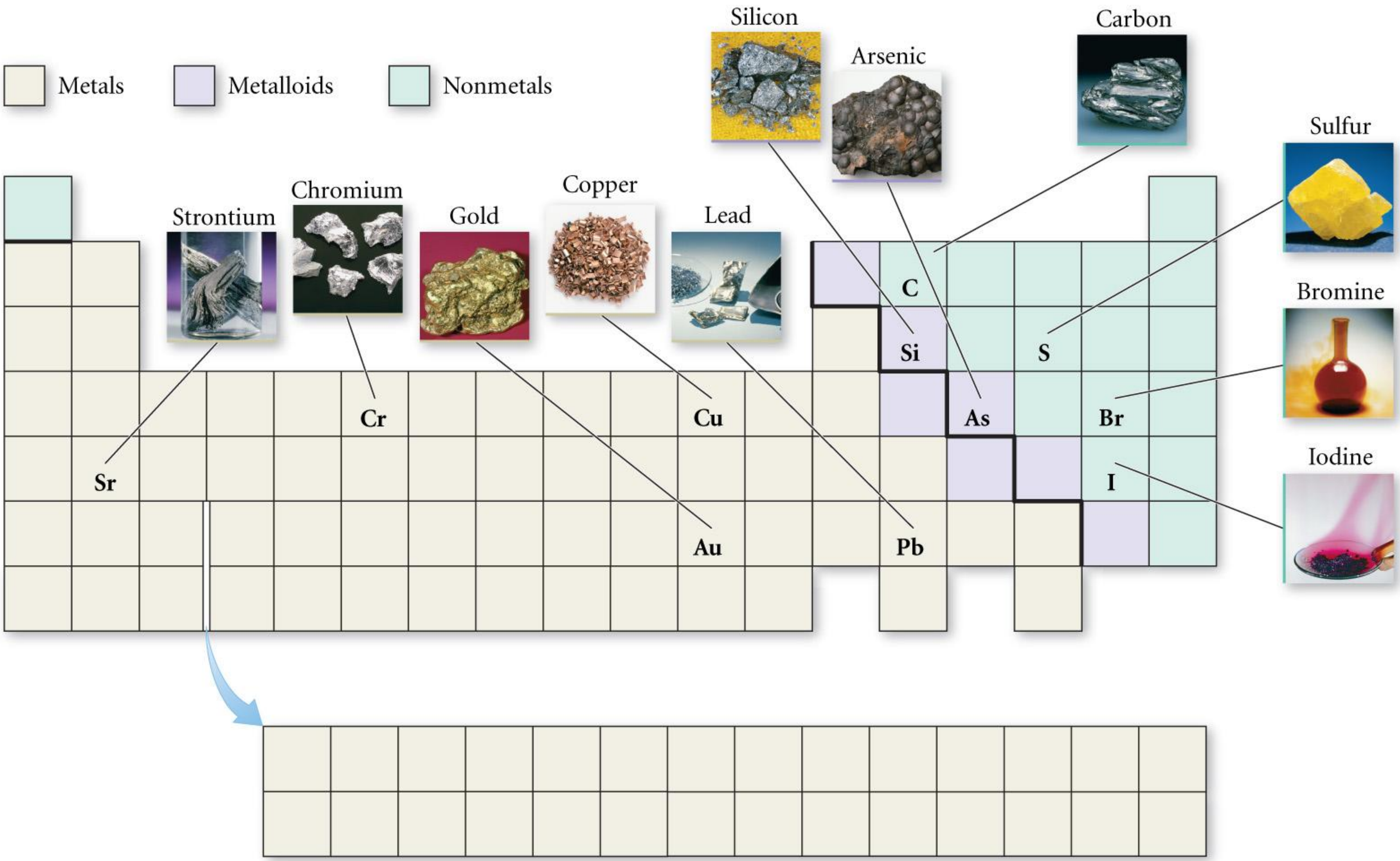
Elements with similar properties fall into columns.

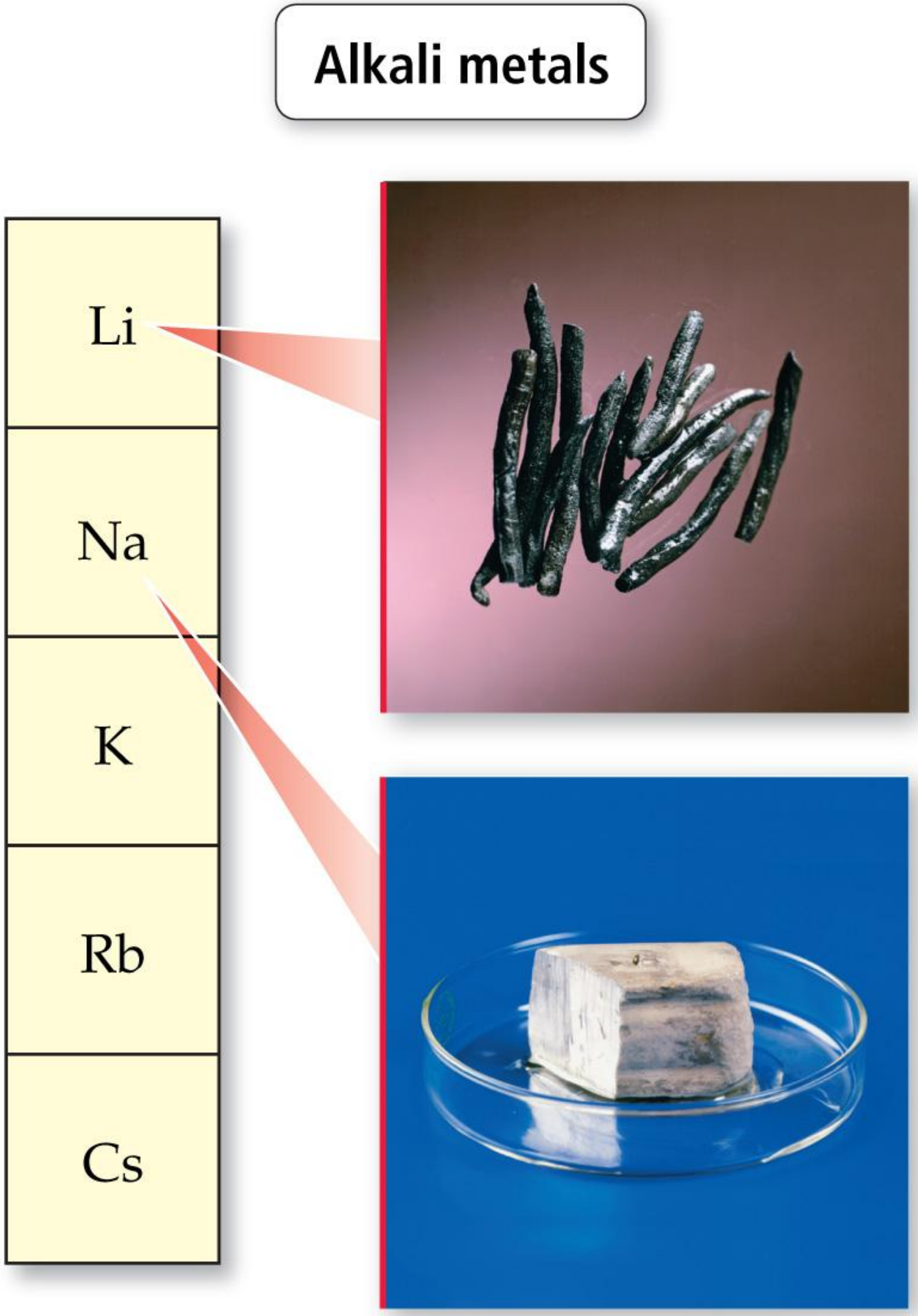
Major Divisions of the Periodic Table

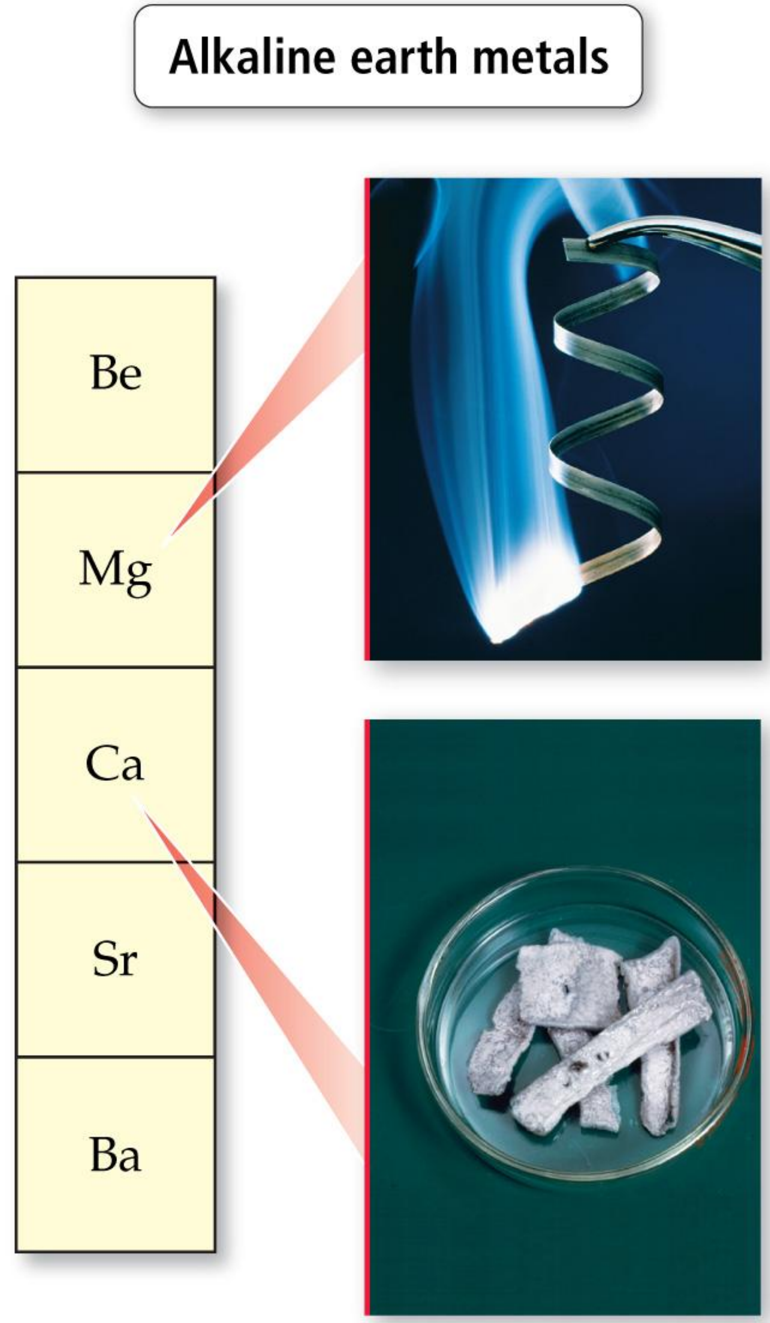
Metals | Metalloids | Nonmetals

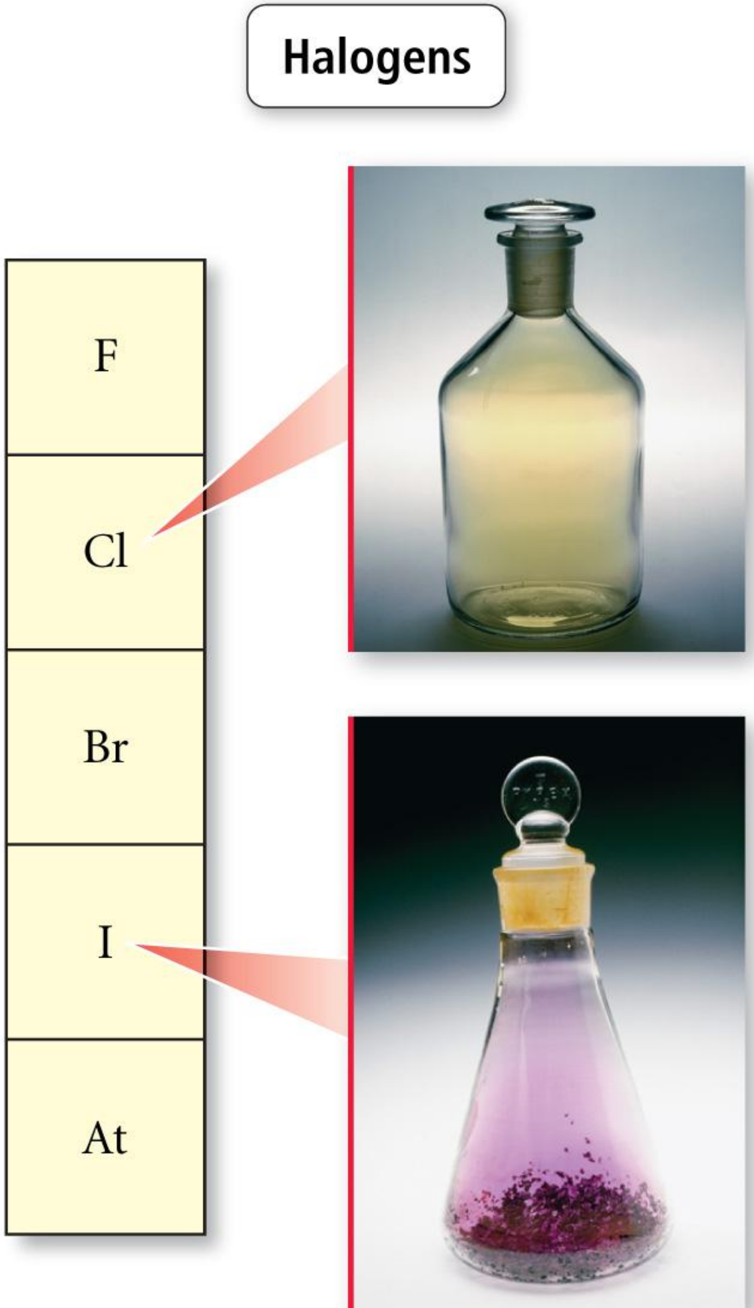
	1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H**																	2 **He**
2	3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**	8 **O**	9 **F**	10 **Ne**
3	11 **Na**	12 **Mg**											13 **Al**	14 **Si**	15 **P**	16 **S**	17 **Cl**	18 **Ar**
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**	110 **Ds**	111 **Rg**	112		114		116		

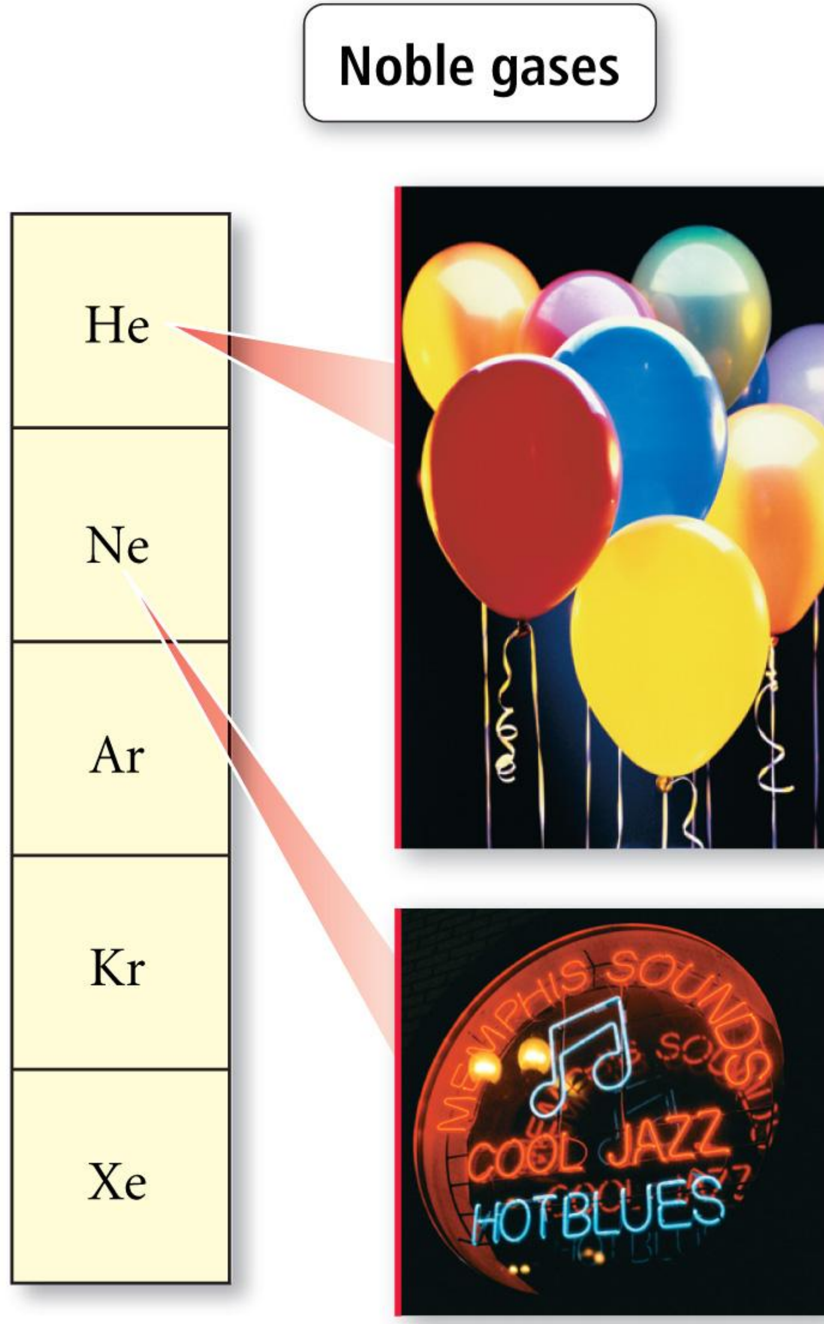
Lanthanides	58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **Er**	69 **Tm**	70 **Yb**	71 **Lu**
Actinides	90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**


Metals
Metalloids
Nonmetals
Silicon
Arsenic
Carbon
Sulfur
Strontium
Chromium
Gold
Copper
Lead
Bromine
Iodine
C
Si
S
Cr
Cu
As
Br
Sr
I
Au
Pb


Alkali metals
Li
Na
K
Rb
Cs


Alkaline earth metals
Be
Mg
Ca
Sr
Ba


Halogens
F
Cl
Br
I
At

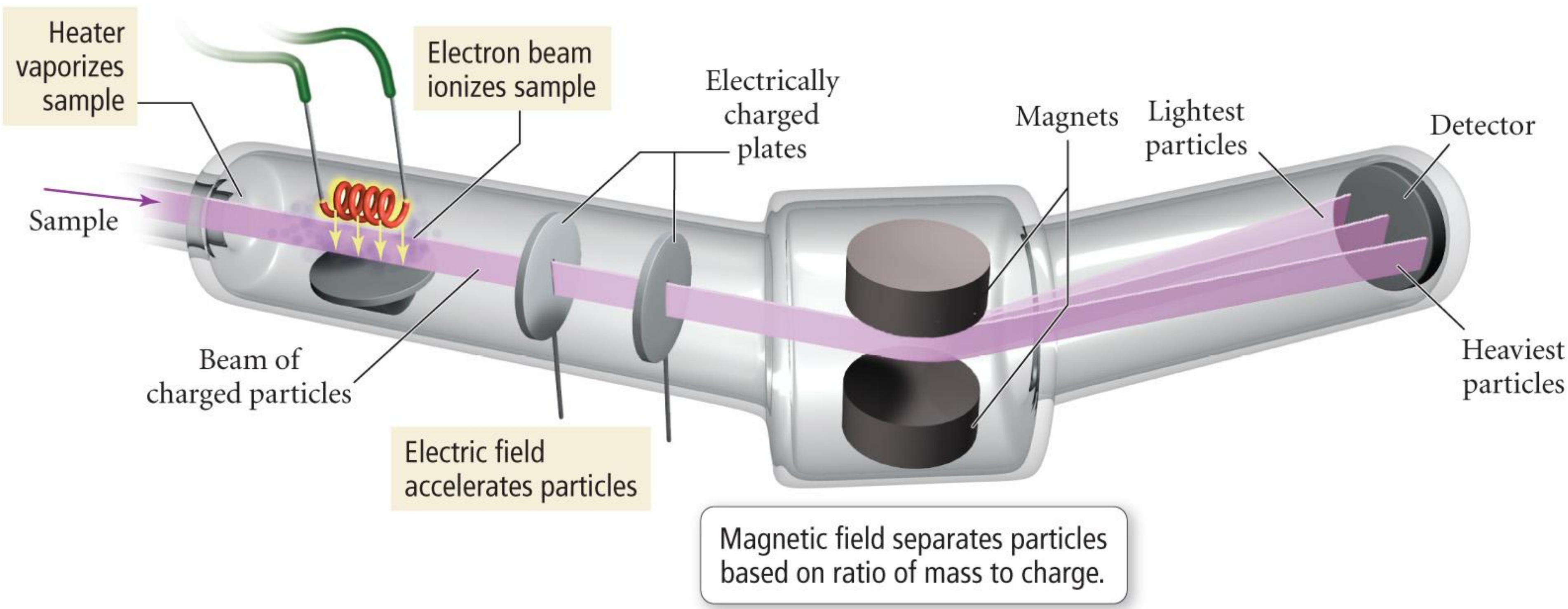

Noble gases
He
Ne
Ar
Kr
Xe
MEMPHIS SOUNDS
COOL JAZZ
HOT BLUES

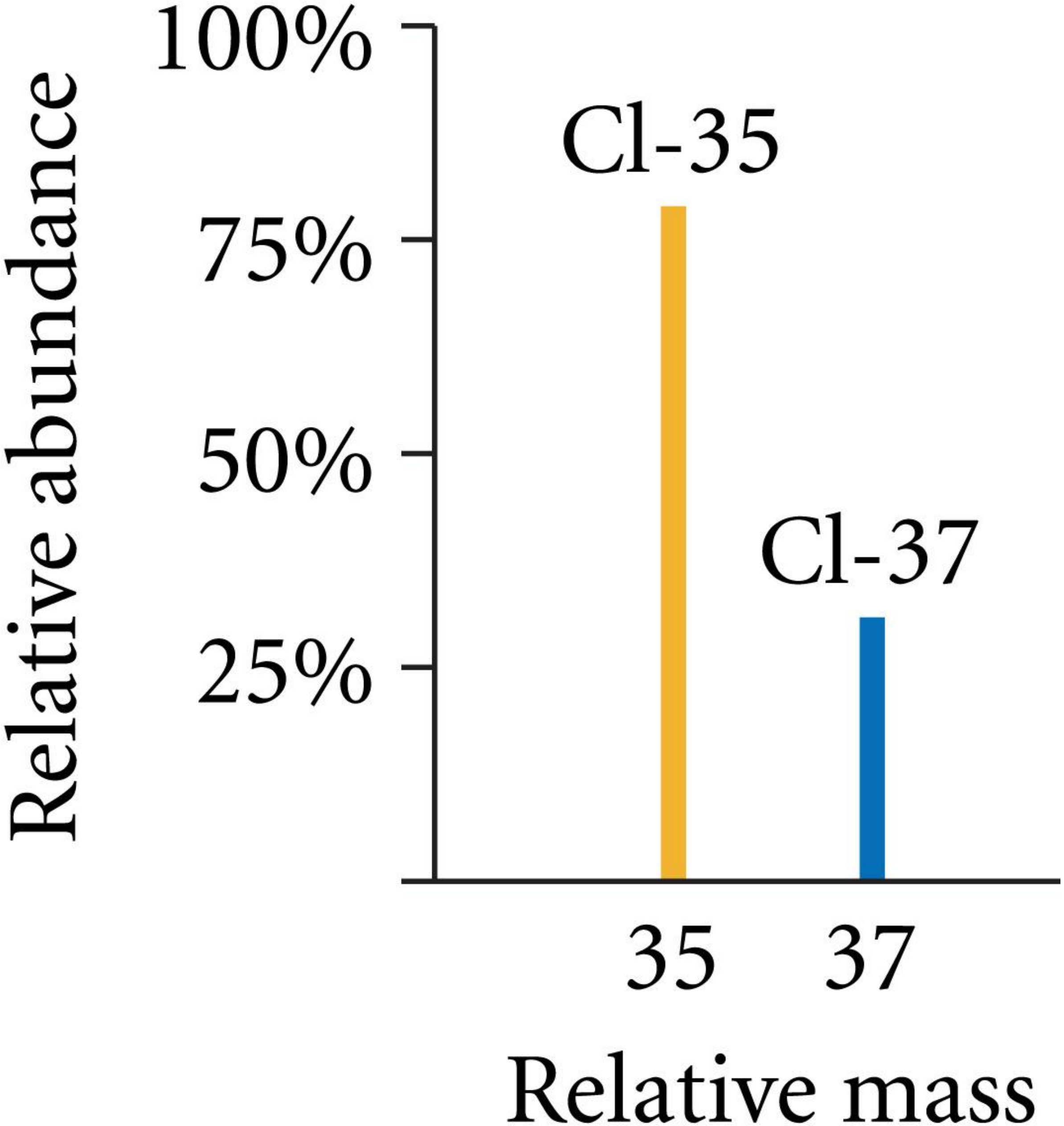
Atomic Mass

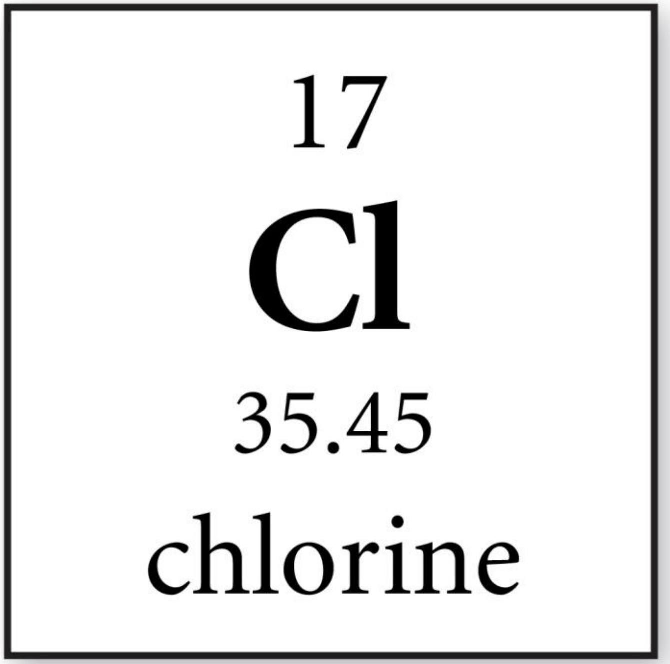
- The weighted average of the isotopic masses of an element’s naturally occurring isotopes.

- Atomic mass unit - amu

Mass Spectrometer







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Isotopes of Neon

isotope	Atomic mass	Natural Abundance
^{20}Ne	19.99	90.51%
^{21}Ne	20.99	0.27%
^{22}Ne	21.99	9.22%

Isotopes of Neon

isotope	Atomic mass	Natural Abundance	Mass of 100 atoms
^{20}Ne	19.99	90.51%	(19.99 amu)(90.51atoms) = 1809 amu
^{21}Ne	20.99	0.27%	(20.99 amu)(.27 atoms) = 6 amu
^{22}Ne	21.99	9.22%	(21.99 amu)(9.22 atoms) = 203 amu
weighted average			1809 + 6 + 203 = 2018 amu/100 atoms or 20.18 amu/atom

Practice problems <u>Tro</u> – 2.73-2.78, 2.108-2.109, 2.112

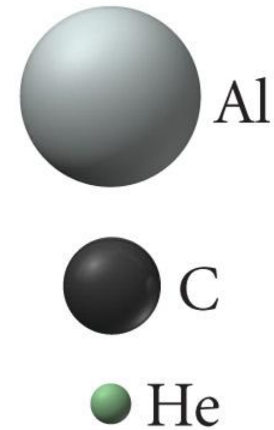
Mole (mol)

- Number of particles in atomic mass in grams of an element.
- Number of molecules/formula units in the molar mass in grams of a compound
- 6.02×10^{23} particles.

26.98 g aluminum = 1 mol aluminum = 6.022×10^{23} Al atoms

12.01 g carbon = 1 mol carbon = 6.022×10^{23} C atoms

4.003 g helium = 1 mol helium = 6.022×10^{23} He atoms



One tablespoon of water contains approximately one mole of water molecules.

Twenty-two copper pennies contain approximately 1 mol of copper atoms.

- How many water molecules are in one drop of water? (One drop of water is 1/20 of a mL, and the density of water is 1.0 g/mL.)

- How many hydrogen atoms are in a drop of water?

Practice problems Tro – 2.79-2.90, 2.102-2.104, 2.106-2.107, 3.59-3.64