Chem 30A

Ch 4. Atoms and Elements

Early View of Atomic Structure

In the Beginning…

Greeks (~400 BC)

- Four elements – fire, earth, water, air
- Is matter continuous or made of discrete particles (atomos)?

Alchemists (next 2000 years)

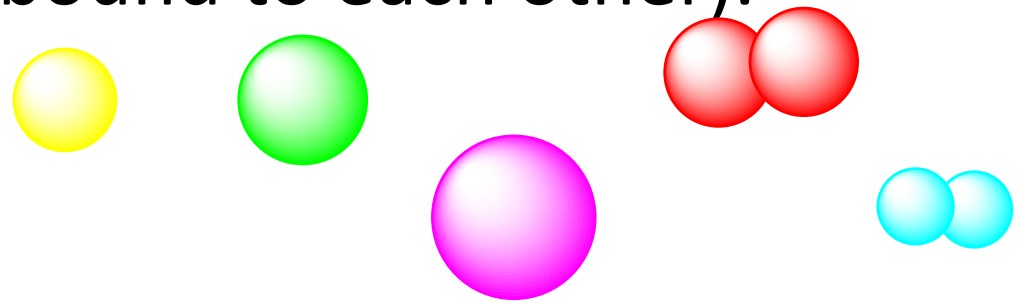
- First chemists
- Discovered elements; acid preparation

Robert Boyle (1627-1691)

- Science should be grounded in experiments.
- Elements are substances that cannot be broken down into simpler substances.

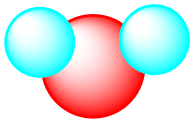
Dalton's Atomic Theory (1808)

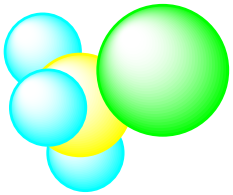
1. Each element is made of tiny indivisible particles called atoms that cannot be created nor destroyed (law of conservation of matter).
2. Atoms of an element cannot be converted to atoms of another element. In chemical reactions, atoms re-combine to form different substances (change the way they are bound to each other).



Dalton's Atomic Theory, continued

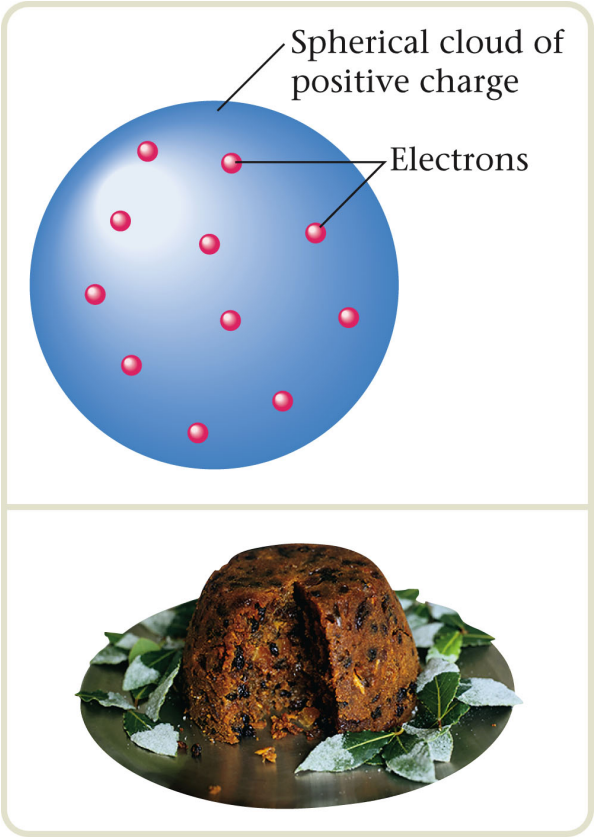
4. The atoms of a given element are identical, and different from those of any other element.
5. Atoms of one element can combine with atoms of other elements to form compounds. A given compound always has the same relative numbers and types of atoms.





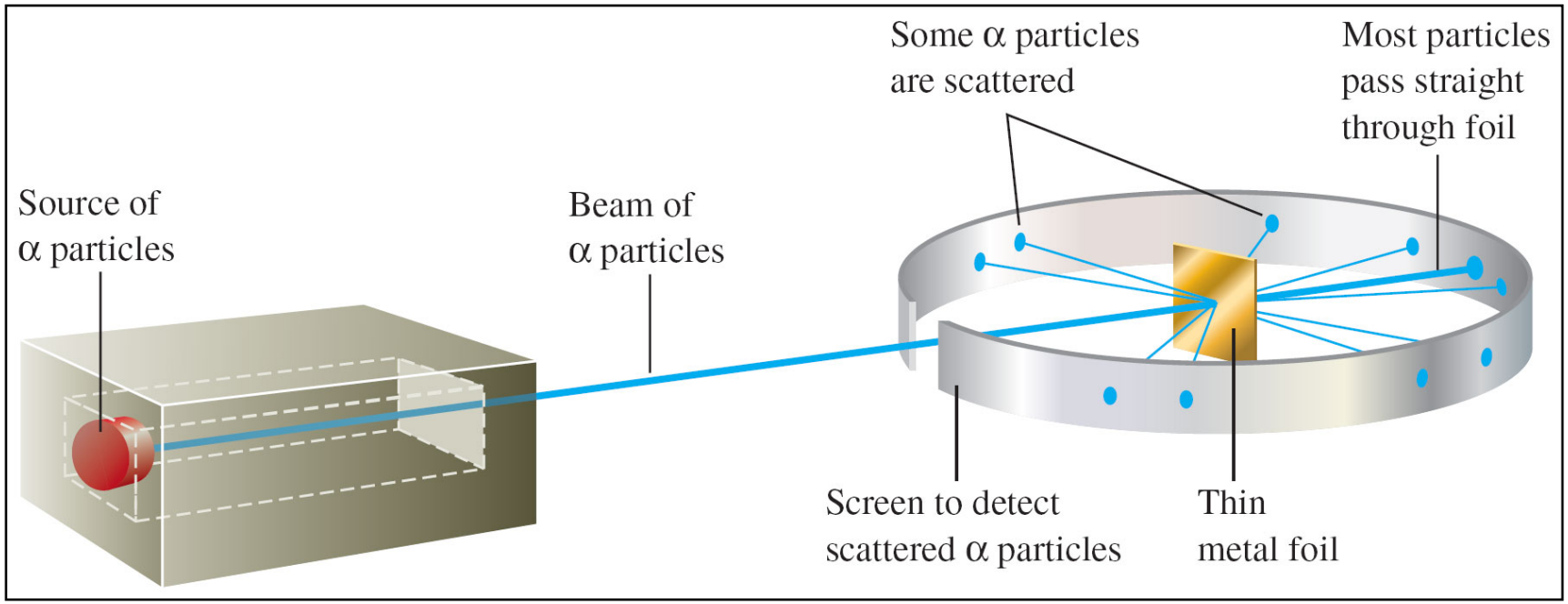
Hypothesized Atomic Structure, 1910

- Lord Kelvin, 1910
  - Plum pudding model

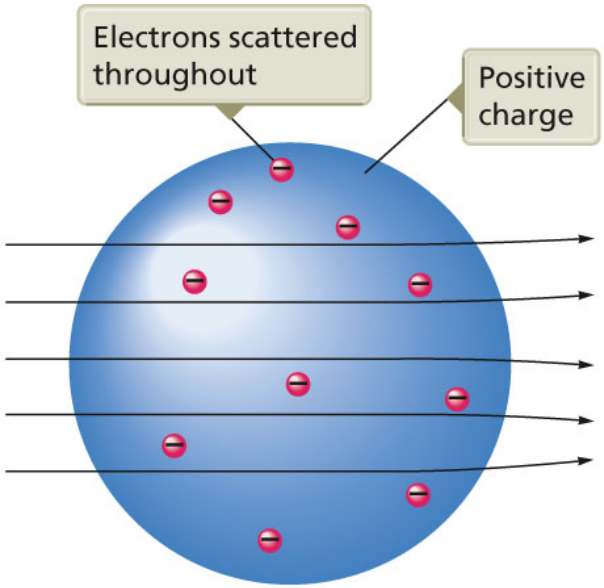


Rutherford's Gold Foil Experiment

- 1911: Ernest Rutherford shot α-particles (positively charged particles with mass 7300x that of electron) through gold foil.



Rutherford's Gold Foil Experiment



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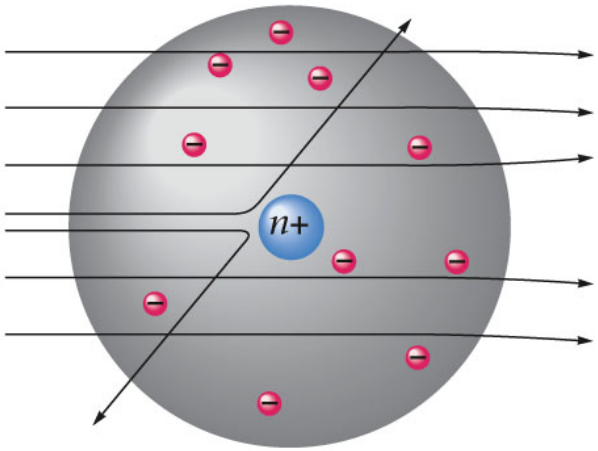


Observed

The Nuclear Atom

Earnest Rutherford concluded the nuclear atom: (1911-1919)

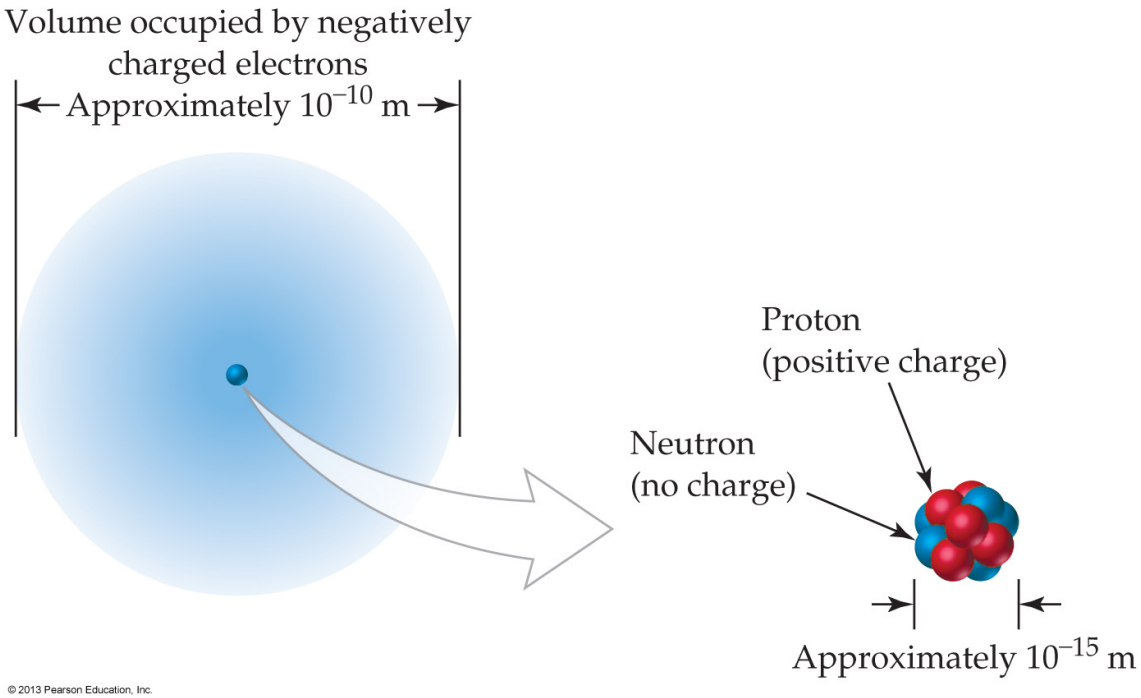
- An atom is mostly empty space that is occupied by electrons.
- Atom has a tiny, dense center of positive charge: nucleus.
- The nucleus contains particles called protons, which have charge of same magnitude as electrons but are positive.
- Most nuclei also contain a neutral particle: neutron. (with Chadwick, 1932)

The Nuclear Atom

- *Protons:* Found in the nucleus; has positive charge equal in magnitude to the electron's negative charge.
- *Neutrons*: Found in the nucleus; no charge; virtually same mass as a proton.
- *Electrons*: Found outside the nucleus, relatively far from the nucleus; negatively charged.

Modern Atomic Theory

Modern View of Atomic Structure



- Small, dense nucleus (nucleus diameter ~10^{-15} m). Nucleus accounts for almost all of atom's mass.
- Electron moving far from nucleus (atom diameter ~10^{-10} m). Electron accounts for atom's size.

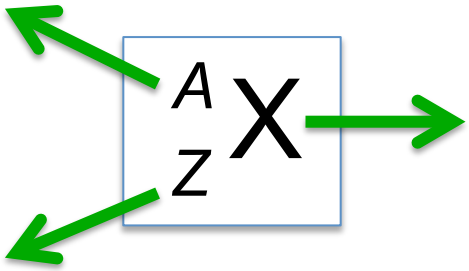
Modern View of Atomic Structure

TABLE 4.1 Subatomic Particles

	Mass (kg)	Mass (amu)	Charge
proton	1.67262×10^{-27}	1.0073	1+
neutron	1.67493×10^{-27}	1.0087	0
electron	0.00091×10^{-27}	0.00055	1−

Symbols for Atoms (Isotope Symbols)

Mass Number
(number of protons + neutrons



Element Symbol
unique one- or two-letter symbol

Atomic Number
(number of protons)

No. of protons = atomic number Z = IDENTIFIES ELEMENT!

No. of neutrons = Mass number A – Atomic number Z

No. of electrons = No. of protons (since atoms are neutral)

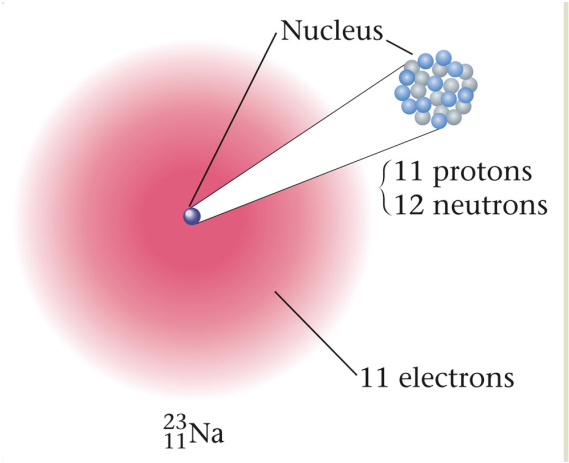
Ex Probs

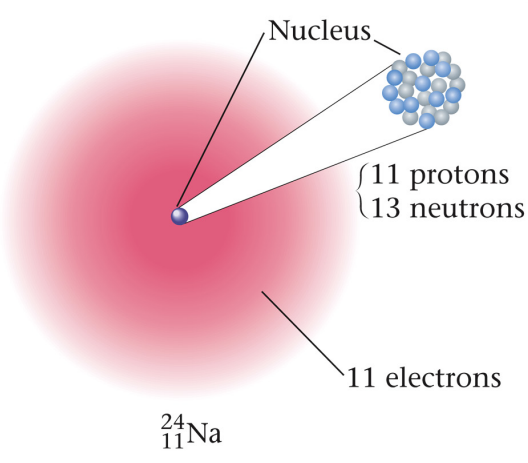
Isotopes

Isotopes: Atoms with same number of protons, but different numbers of neutrons

→ So, isotopes have same atomic number (same element), but different mass numbers

Sodium Isotopes





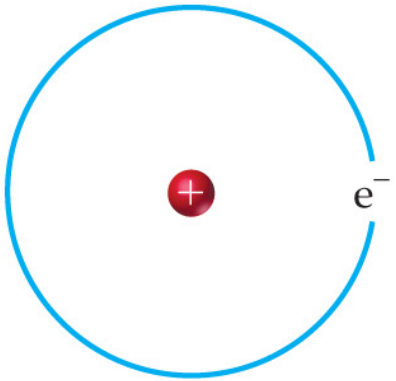
"Sodium-23" $^{23}_{11}Na$

- 11 = Atomic number Z (11 protons)
- 23 = Mass number A
- A - Z = 12 neutrons

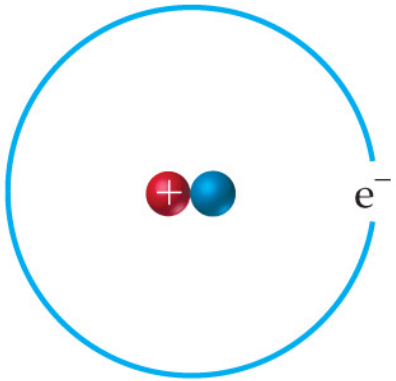
"Sodium-24" $^{24}_{11}Na$

- 11 = Atomic number Z (11 protons)
- 24 = Mass number A
- A - Z = 13 neutrons

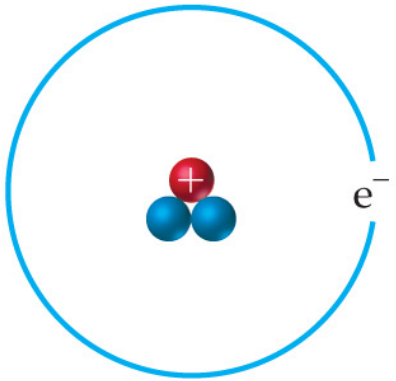
Hydrogen Isotopes



$^{1}_{1}H$ Protium



$^{2}_{1}H$ Deuterium



$^{3}_{1}H$ Tritium

Isotopes

- Show almost identical chemical properties (The chemistry of atom is due to its electrons!).
- In nature, most elements contain mixture of isotopes.

Carbon Isotope	Natural Abundance
^{12}C	98.89%
^{13}C	1.11%

Ex Probs

Atomic Mass

- Atoms have very tiny masses, so scientists made a unit for atomic mass to avoid using very small numbers.

1 atomic mass unit (amu) = 1.660539×10^{-24} g

Atomic Mass Unit

- Definition of atomic mass unit is based on ^{12}C:

  One atom of ^{12}C has a mass of exactly 12 amu.

So, 1 amu = 1/12 the mass of ^{12}C atom

$= 1.660539 \times 10^{-24}$ g

- Masses of all other atoms are relative to this ^{12}C standard.

Atomic Mass

- On the periodic table, why does C have a mass of 12.01 amu, NOT 12 amu?

The atomic mass on the periodic table is an average atomic mass– weighted average of masses of all the isotopes of an element.

Finding Atomic Mass of an Element

Carbon Isotope	Natural Abundance
^{12}C	98.89%
^{13}C	1.11%

Atomic weight of element =

Σ[fractional abundance$_i$ x isotopic mass$_i$]

For C: (0.9889)(12amu) + (0.01110)(13.0034 amu) =

12.01 amu

(*No carbon atom actually has a mass of 12.01 amu– it's an average mass.)

Ex probs

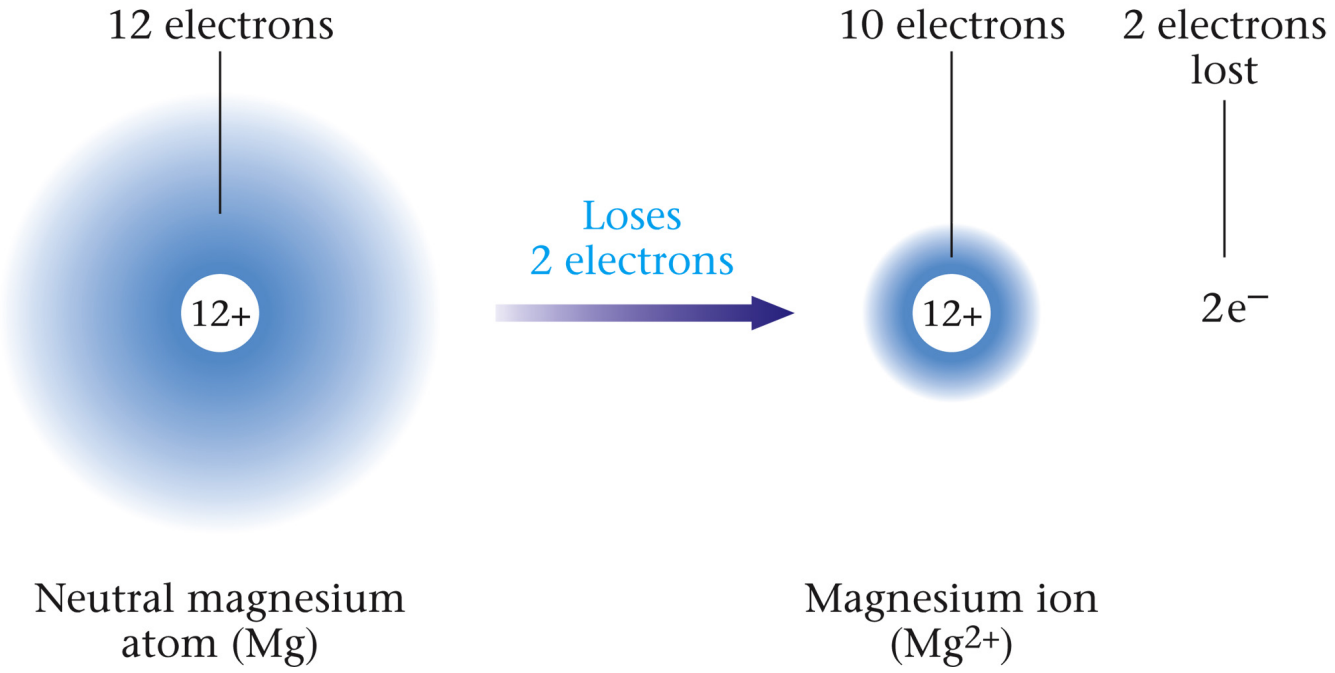
Ions

Ions

- Atoms are neutral, having a net charge of zero.
- When electrons are removed from or added to a neutral atom, a charged particle called ion is formed.

Cations

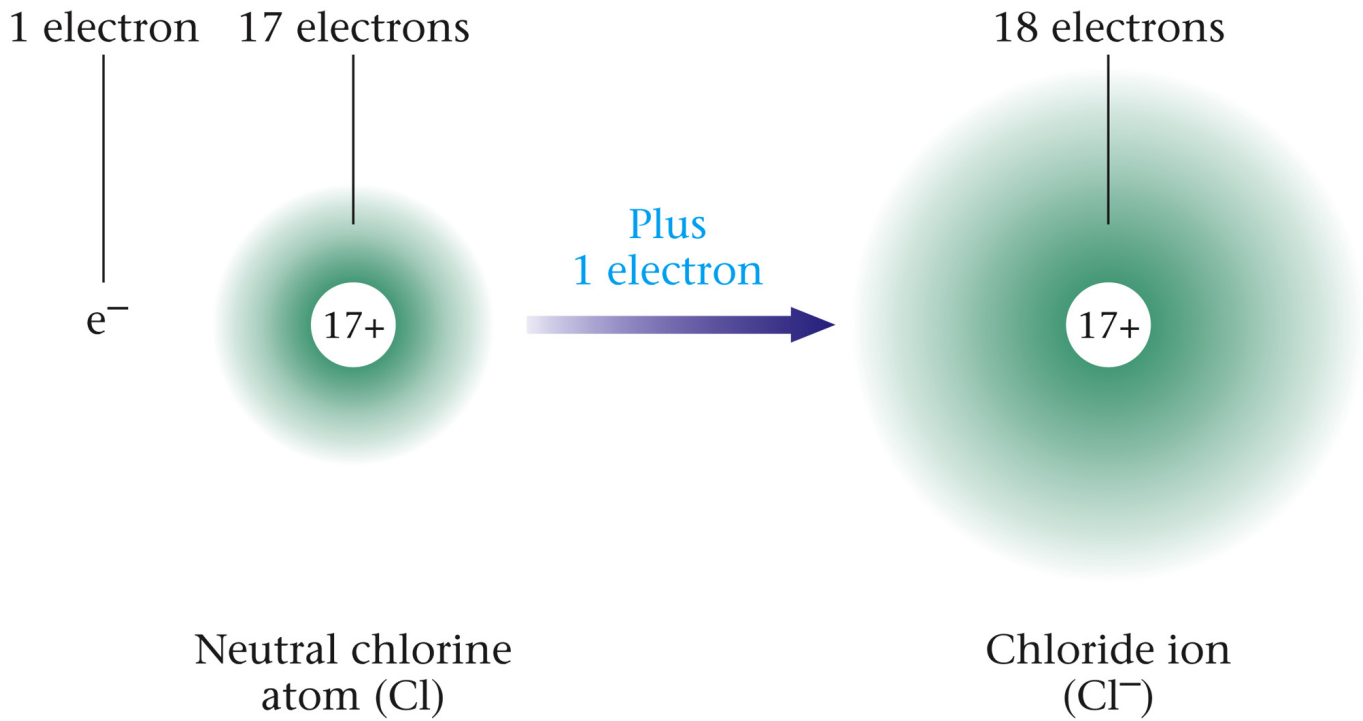
- Atoms lose one or more electrons to form positive ions called cations.



$Mg \rightarrow Mg^{2+} + 2e^-$

Anions

- Atoms gain one or more electrons to form negative ions called anions.



$Cl + e^- \rightarrow Cl^-$

Isotope Symbols for Ions

- Ions can also be represented by isotope symbols.

$$^{23}_{11}Na^{+}$$

Ex Probs

Elements and the Periodic Table

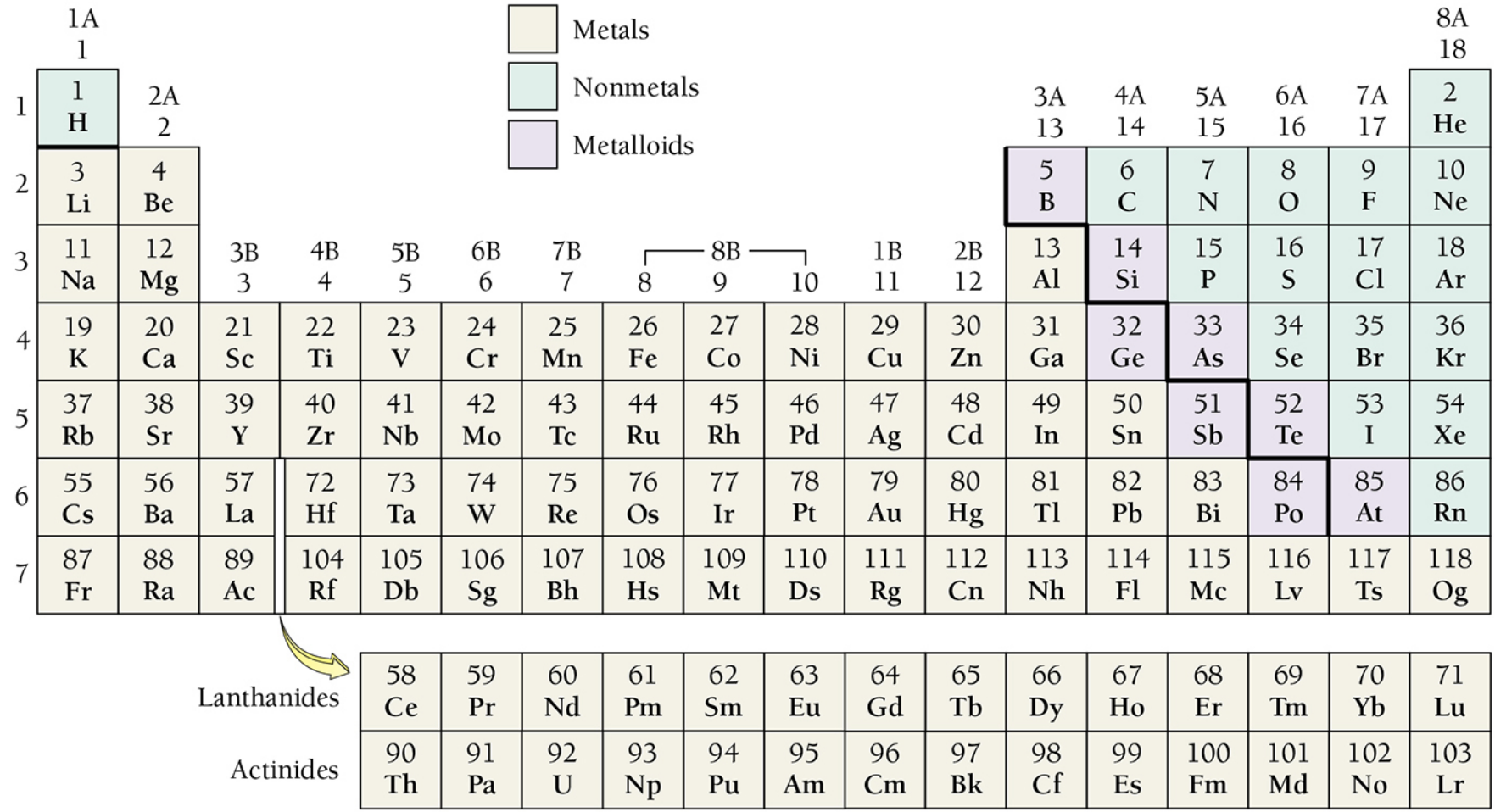
Periodic Table

- A way of organizing elements
- First arranged by Dmitri Mendeleev in 1869
- Modern periodic table is arranged by atomic number.
- Shows recurring properties, so helps predict properties of elements

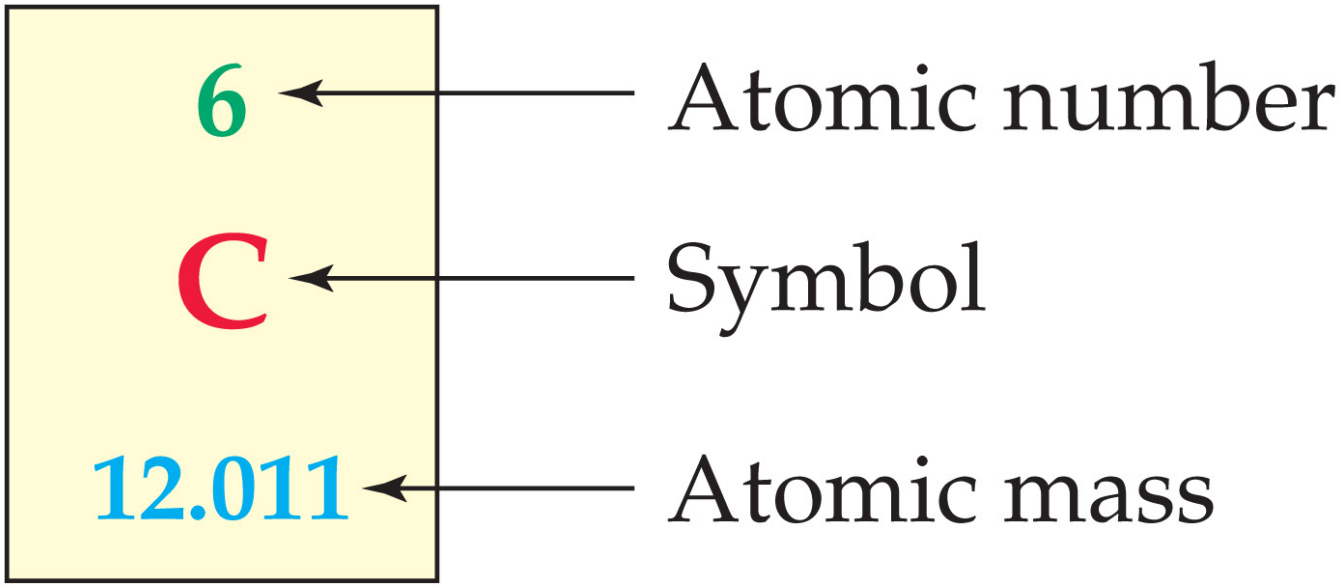
The properties (colors) of these elements form a repeating pattern.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca

The Periodic Table of the Elements



Periodic Table Entries



Element Symbols

- Each element has a unique one- or two-letter symbol.
- First letter is always capitalized and the second is not.
- The symbol usually consists of the first one or two letters of the element's name.

  Oxygen O

  Krypton Kr

- Sometimes the symbol is taken from the elements original Latin or Greek name.

  Gold Au (aurum)
  Lead Pb (plumbum)

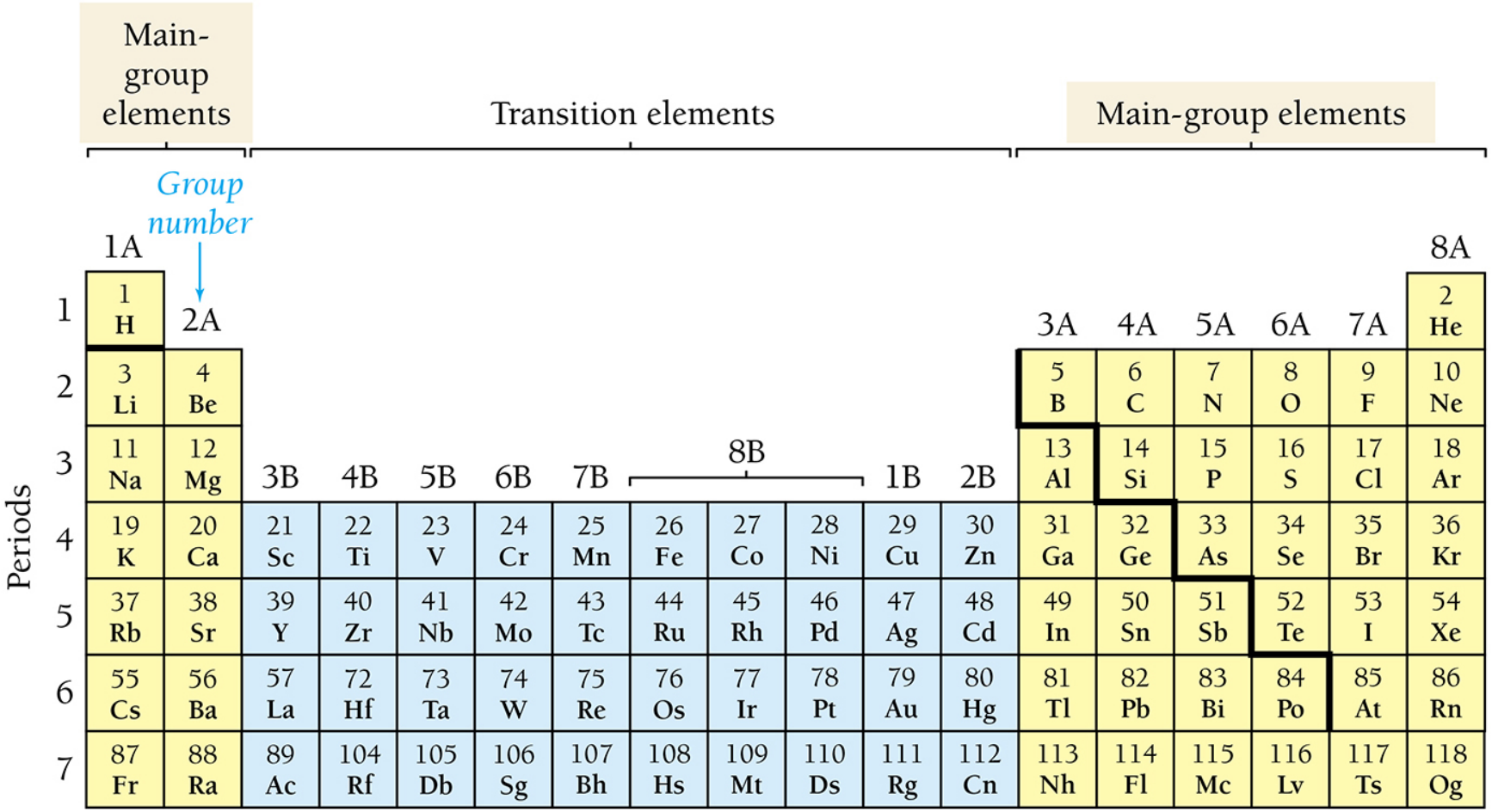
Names and Symbols of Common Elements

Table 4.3 The Names and Symbols of the Most Common Elements

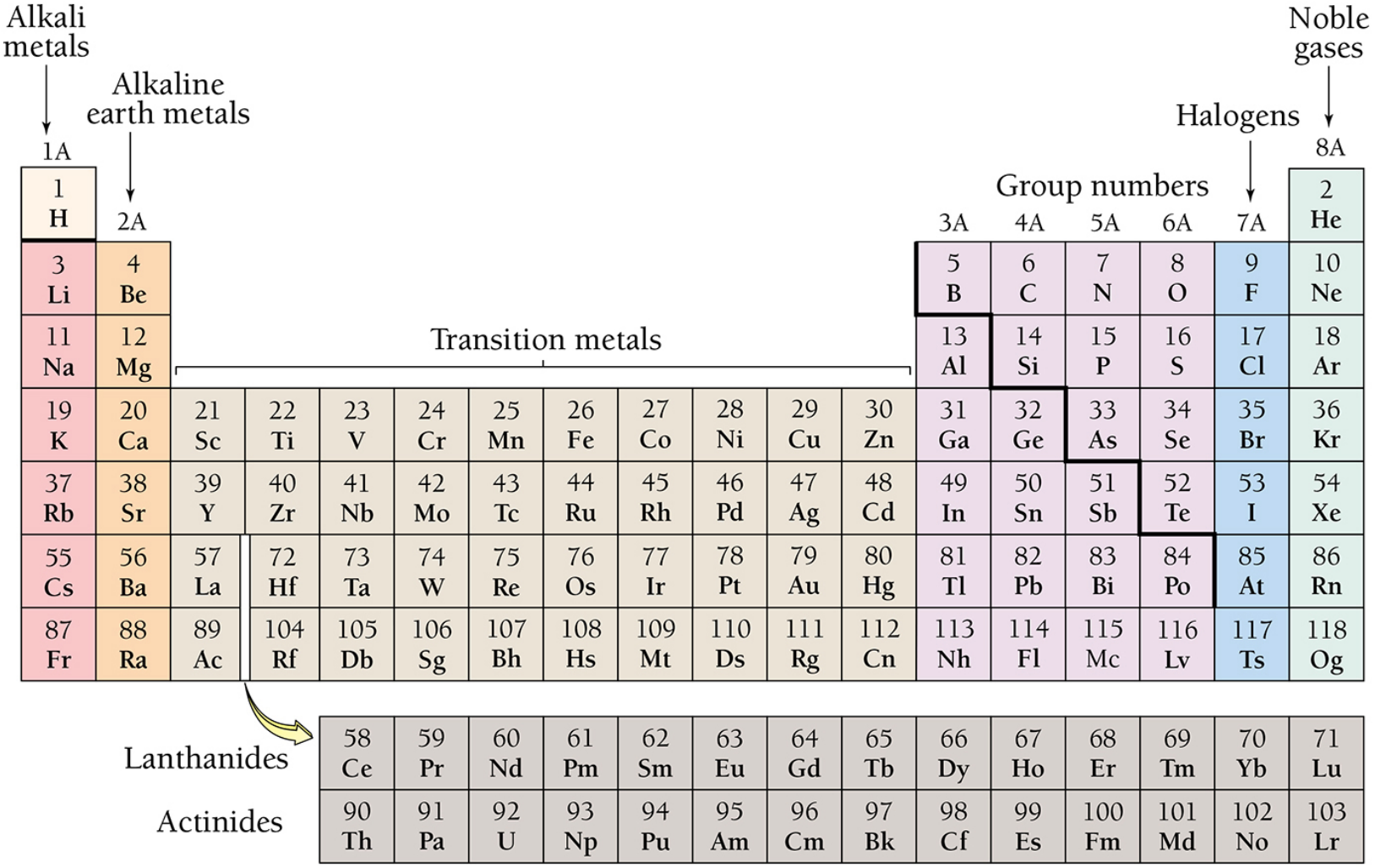
Element	Symbol	Element	Symbol
aluminum	Al	lithium	Li
antimony (stibium)*	Sb	magnesium	Mg
argon	Ar	manganese	Mn
arsenic	As	mercury (hydrargyrum)	Hg
barium	Ba	neon	Ne
bismuth	Bi	nickel	Ni
boron	B	nitrogen	N
bromine	Br	oxygen	O
cadmium	Cd	phosphorus	P
calcium	Ca	platinum	Pt
carbon	C	potassium (kalium)	K
chlorine	Cl	radium	Ra
chromium	Cr	silicon	Si
cobalt	Co	silver (argentium)	Ag
copper (cuprum)	Cu	sodium (natrium)	Na
fluorine	F	strontium	Sr
gold (aurum)	Au	sulfur	S
helium	He	tin (stannum)	Sn
hydrogen	H	titanium	Ti
iodine	I	tungsten (wolfram)	W
iron (ferrum)	Fe	uranium	U
lead (plumbum)	Pb	zinc	Zn

*Where appropriate, the original name is shown in parentheses so that you can see where some of the symbols came from.

Periodic Table



Periodic Table



Features of the Periodic Table

- Row = Period
  - Numbering of periods (7 periods)
  - Some periods are named: Lanthanides, Actinides

Features of the Periodic Table, cont'd

- Column = Group = Family
  - Numbering of groups (18 groups, A and B groups)
  - Names of groups:
    - A groups = Main Group elements
    - B groups = Transition Metal elements
    - 1A = alkali metals
    - 2A = alkaline earth metals
    - 7A = halogens
    - 8A = noble gases

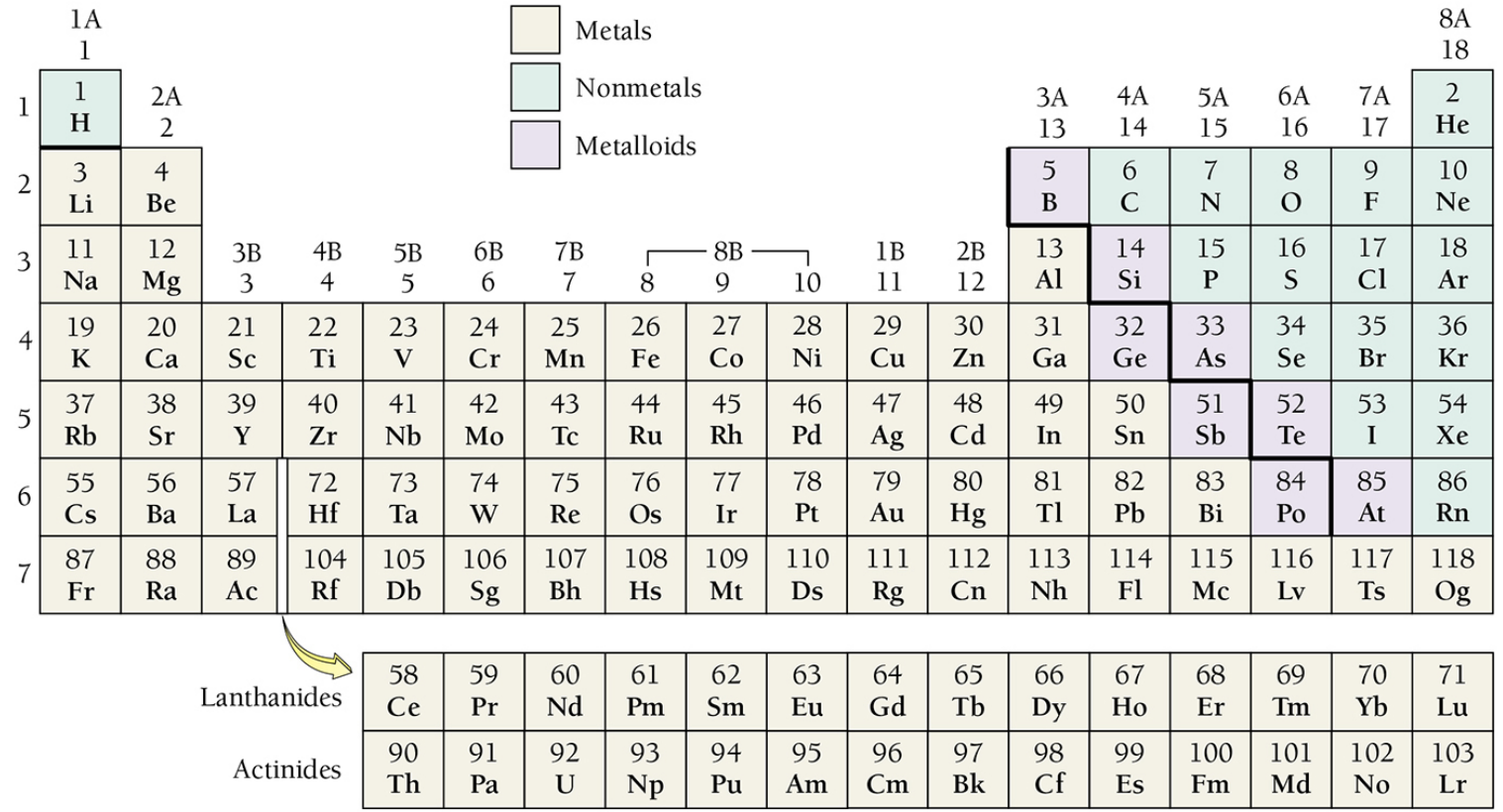
Periodic Table Shows Periodic Patterns

Members of same groups have similar chemical and physical properties.

- Group 1A (alkali metals): Shiny soft metals, low melt pts, react rapidly with water to form alkaline (basic) products.
- Group 2A (alkaline earth metals): Shiny metals, less reactive than 1A metals.
- Group 7A (halogens): Colorful, corrosive nonmetals.
- Group 8A (noble gases): Colorless gases, distinct lack of chemical reactivity.

Metals, Nonmetals, and Metalloids

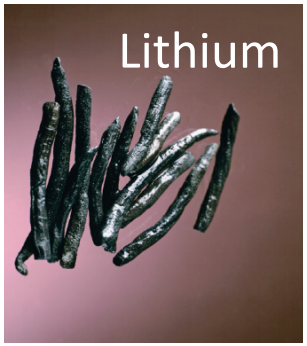
- Metals: Left of stair-step line
- Nonmetals: Right of stair-step line
- Metalloids/ semimetals: Along stair-step line

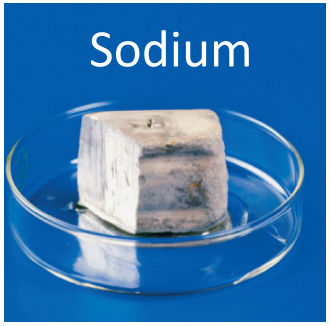


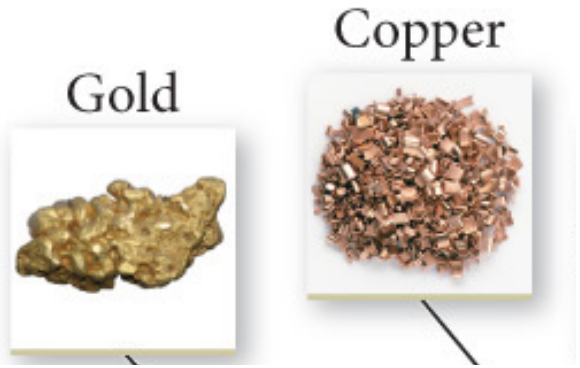
Metal Elements

Physical Properties of Metals

- Efficiently conducts heat and electricity
- Malleable (can be hammered into thin sheets)
- Ductile (can be pulled into wires)
- Lustrous (shiny)
- Almost all metals are solids at normal temperatures (Exception: Mercury is liquid.)







Nonmetal Elements

Physical Properties of Nonmetals

- Do not conduct electricity.
- More variable than metals.
- Solid nonmetals are usually hard, brittle.
- Most nonmetals are gases or solids [Exception: Bromine is liquid.]

Carbon

Sulfur

Iodine

Bromine

Metalloid or Semimetal Elements

Physical Properties of Metalloids

- Have both metallic and nonmetallic properties.
- Good semiconductors: Poor conductors of electricity at room temperature, but become moderately good conductors at higher temperature or with addition of impurities

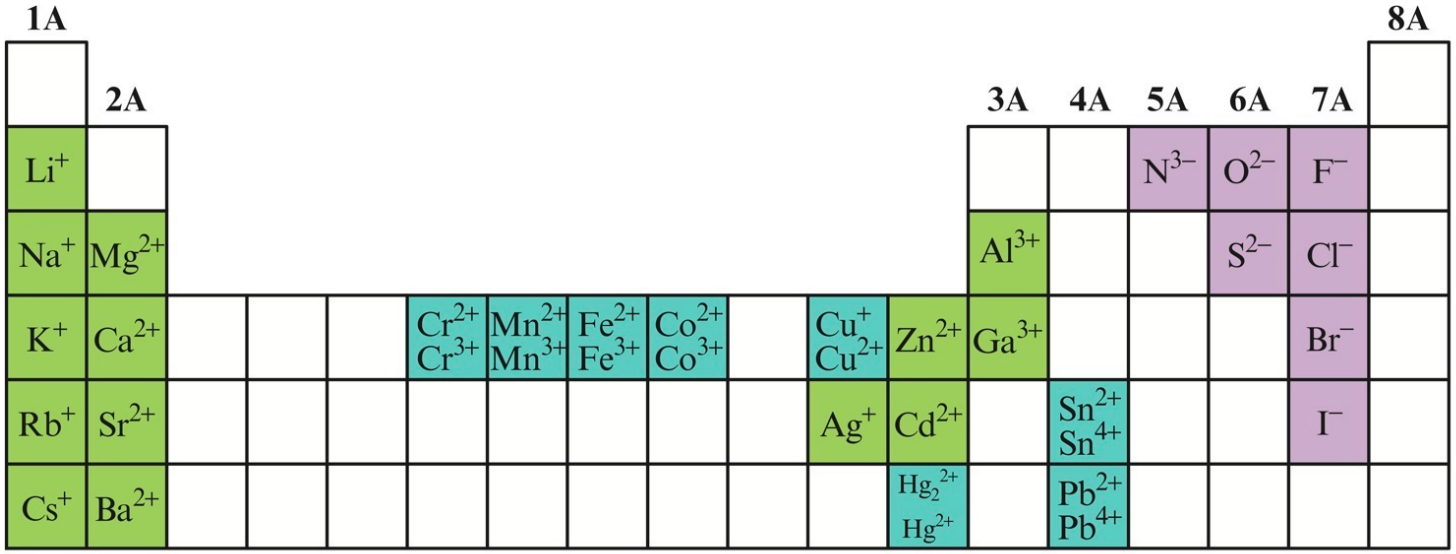
Ex Probs

Periodic Table Shows Ion Formation Trend

In a chemical reaction:

- Metal elements tend to lose electrons and form cations (positive ions).
- Nonmetal elements tend to gain electrons and form anions (negative ions).

Common Ion Charges (Know!)



Metals form cations.

- Groups 1A,2A,3A:

  charge = group #

- Transitions metals: Many have variable charges.

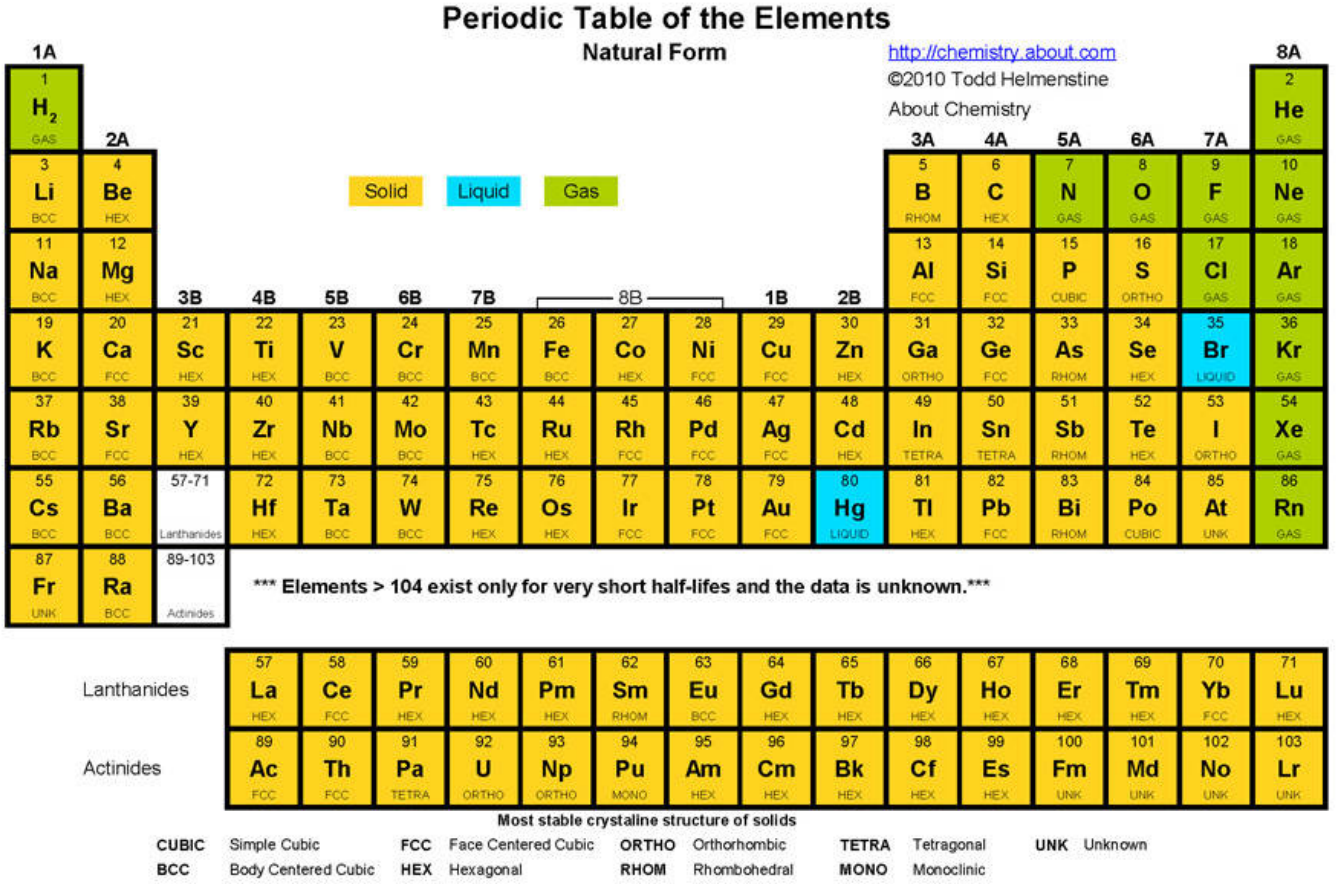
Nonmetals form anions.

- Group 5A: charge = -3
- Group 6A: charge = -2
- Group 7A (halogens): charge = -1
- Group 8A (noble gases): charge =0

Ex Probs

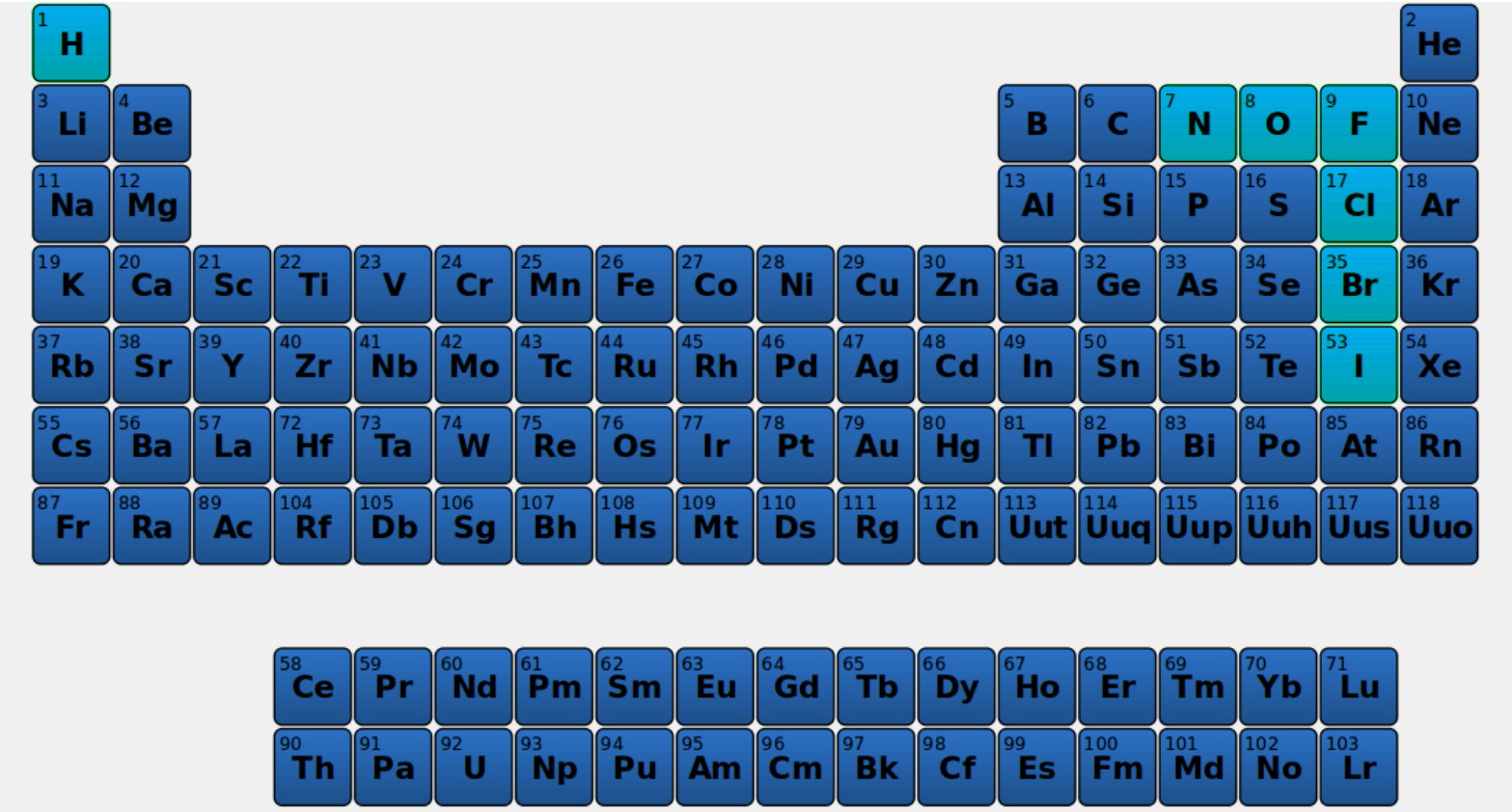
Periodic Table: Natural States of Elements

Most elements are solids at room temperature.



Periodic Table: Natural States of Elements

Some elements exist as diatomic molecules (molecules of two atoms): H_2, N_2, O_2, all group 7A elements



Hydrogen

- In natural state, hydrogen is a nonmetal (It is NOT an alkali metal).
- In natural state, hydrogen is a diatomic element.
- Hydrogen can form cation (H^+ = proton) or anion (H^- = hydride).
- A hydrogen atom does not have a neutron!

Expanded Periodic Table of the Elements