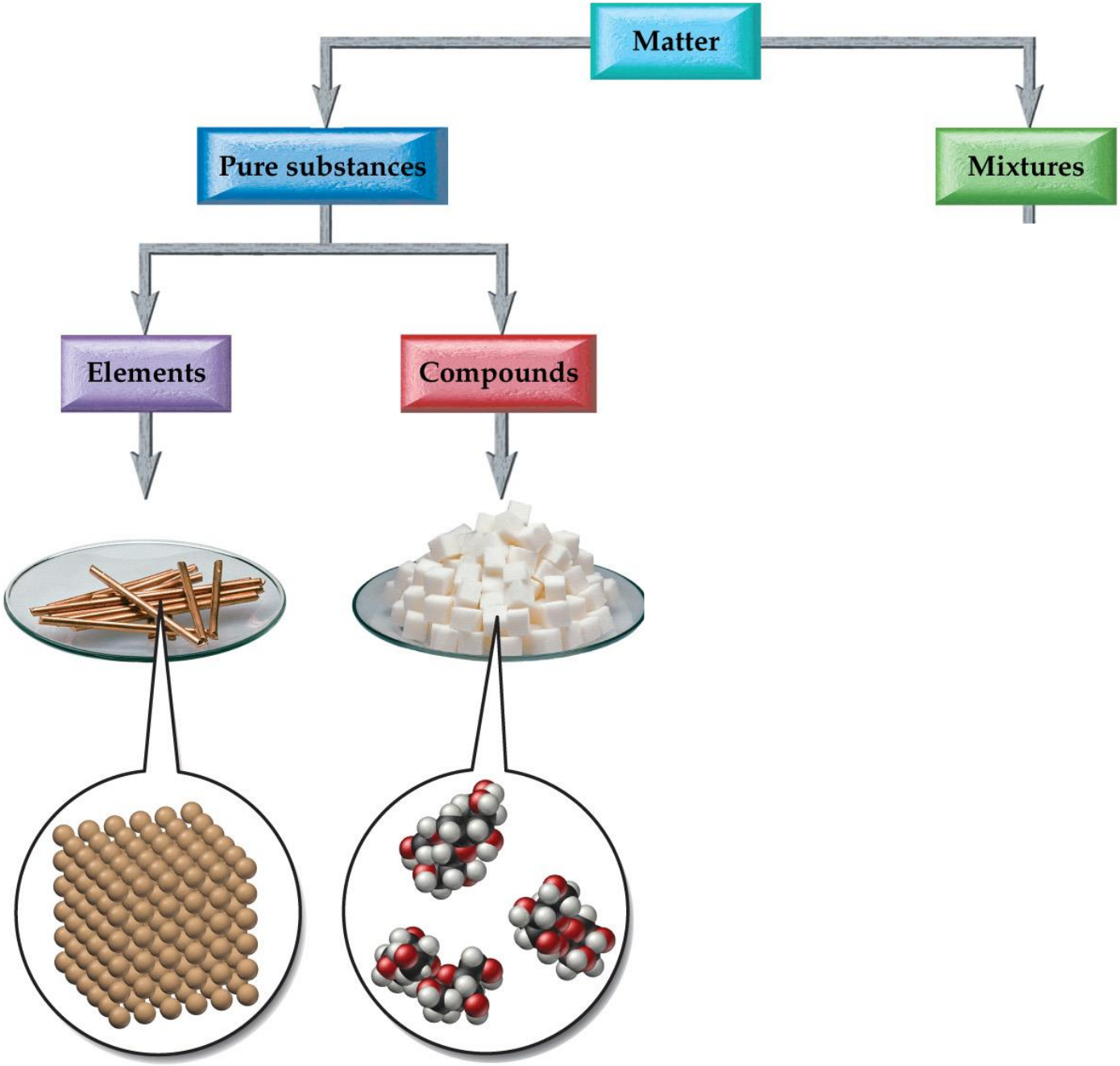
Module 2 Slides

Atoms and Elements

Part 1

- Atomic Theory
  - Sub-Atomic Particles
- Isotopes
  - Atomic mass
- Periodic Table
- Ions



Dalton's Atomic Theory

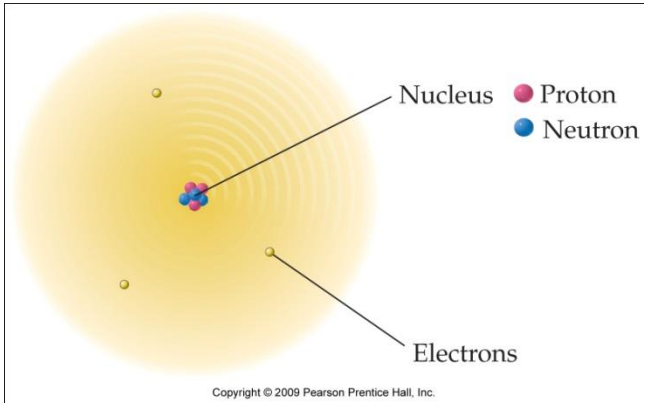
1. Each element is composed of tiny indestructible particles called atoms.
2. All atoms of a given element have unique properties which distinguish them from all other elements.
3. Atoms combine in simple, whole-number ratios to form compounds.

What is an atom?

- Please read 4.2 and 4.3. It is a history lesson which carries you from the ancient Greeks to about 70 years ago.
- We will cut to the chase.
  - What do we know about atoms?

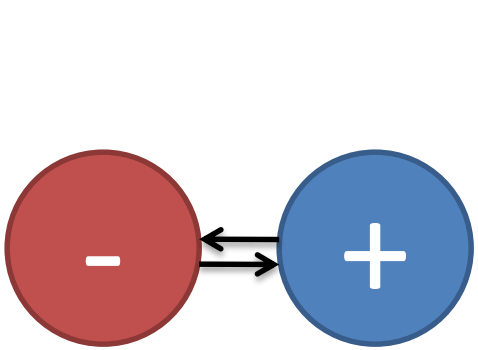
The Modern Atom

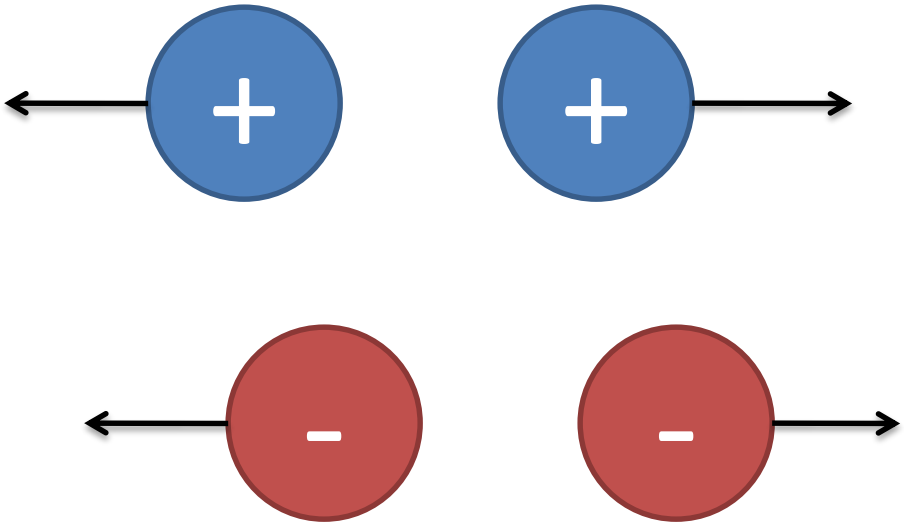
- We know atoms are composed of three main pieces—protons, neutrons, and electrons.
- The nucleus contains protons and neutrons.
- The nucleus is very small compared to the diameter of the atom.
- The electrons move outside the nucleus.
  - Therefore, the radius of the atom is about 100000 times larger than the radius of the nucleus.



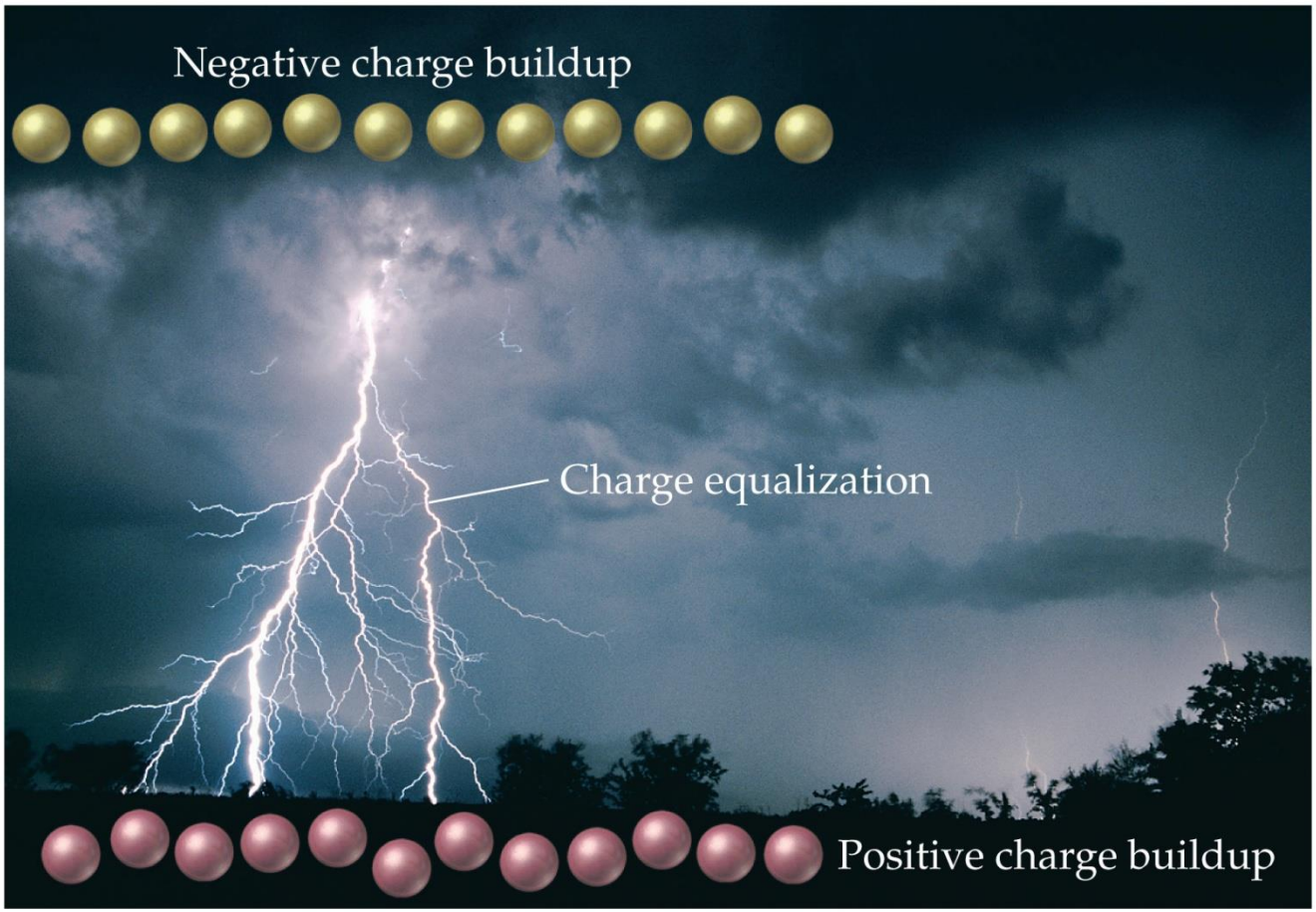
Charged Particles

- Protons and electrons are charged particles.
- Positively and negatively charged objects attract each other. (We say they have "opposite charges".)
- Like charged objects repel each other.





What is electrical charge?



Subatomic Particles

	Mass (amu)	Charge
Proton	1	+1
Neutron	1	0
Electron	0.00055	-1

Charges are Additive

- The more protons you have in an atom, the larger the positive charge.
- The more electrons you have the larger the negative charge.
- The charge of a proton and the charge of an electron cancel each other out.

  1 proton and 1 electron

  Charge = +1+ (-1) =0

Examples

Practice—An Atom Has 20 Protons. Determine if Each of the Following Statements Is True or False?

- If it is a neutral atom, it will have 20 electrons.
- If it also has 20 neutrons, its mass will be approximately 40 amu.
- If it has 18 electrons, it will have a net -2 charge.

Dalton's Atomic Theory

1. Each element is composed of tiny indestructible particles called atoms.
2. All atoms of a given element have unique properties which distinguish them from all other elements.
3. Atoms combine in simple, whole-number ratios to form compounds.

Atomic Number

- The number of protons in an atom

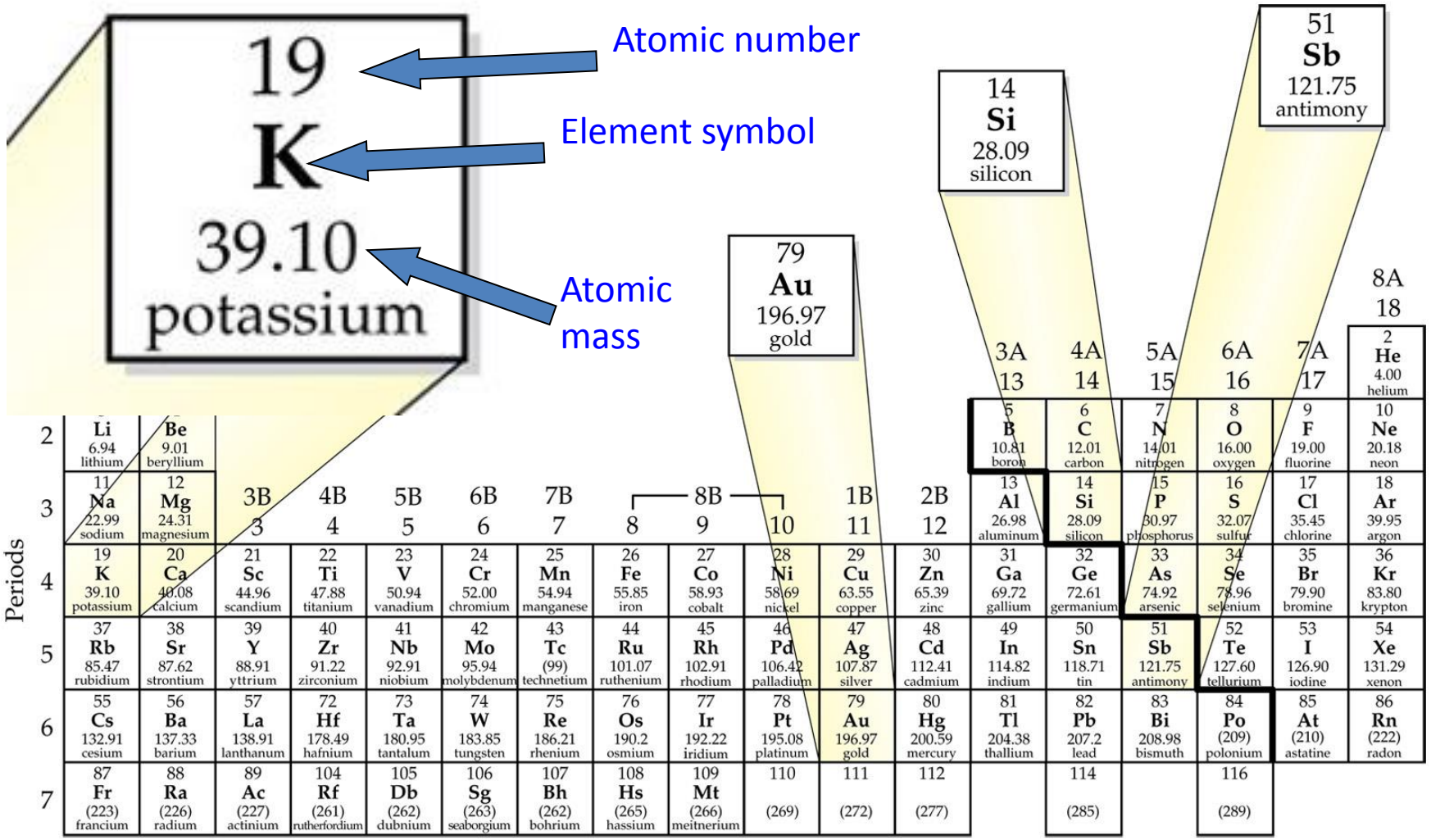
Element Symbols

- One or two letters.
- First letter is the ONLY one capitalized.
- Example:
  - Si-silicon
  - SI- sulfur and iodine
- Most are the first letter or two in the element name
- A few are really strange…
- You don’t need to memorize the names and symbols.

Mass Number

- The number of protons + the number of neutrons in an atom

The Periodic Table of Elements



Isotopes

- When atoms have the same number of protons (Z) but different numbers of neutrons (so, different A).
- Neutrons don’t do much, so the chemistry is the same.
- Some elements have many isotopes, others have only one.

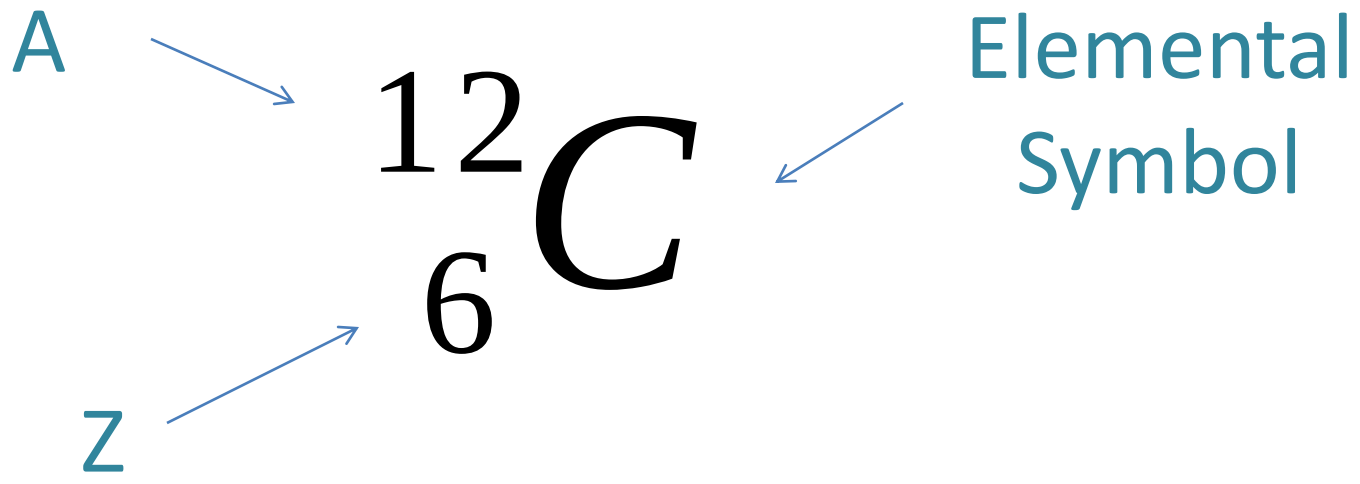
Percent Natural Abundance

- Out of a natural sample of this atom, the percent natural abundance tells us the amount of each isotope we should find.
- Answers the question: Out of 100 atoms of this element, how many are this particular isotope?

Example: Chlorine, Cl	
A=	Percent Abundance
35 amu	75%
37 amu	25%

Writing Isotope Symbols

- The Isotopes of an element can be written symbolically:



Writing Isotope Symbols

- The Isotopes of an element can be written symbolically:

Example: Isotopes of Neon

Symbol	Number of protons	Number of neutrons	A, mass number	Percent natural abundance
	10	10	20	90.48%
	10	11	21	0.27%
	10	12	22	9.25%

Calculating Atomic Mass

- The average mass of each element.
- Located on the periodic table under the symbol.
- You can calculate this number for a given element using the actual masses of each of the isotopes with their corresponding percent abundance.
- It is the same type calculation as calculating a final grade for one of your classes.

Percent

- “Per cent” means “per 100”
- We don’t want that…

Calculating a Grade…

Percent of Final Grade	Sally's grades in each of these areas
Exams: 30%	89
Quizzes: 15%	98
Lab: 10%	70
Final Exam: 20%	86
Project: 25%	90

- Calculate Sally's final grade in the class.

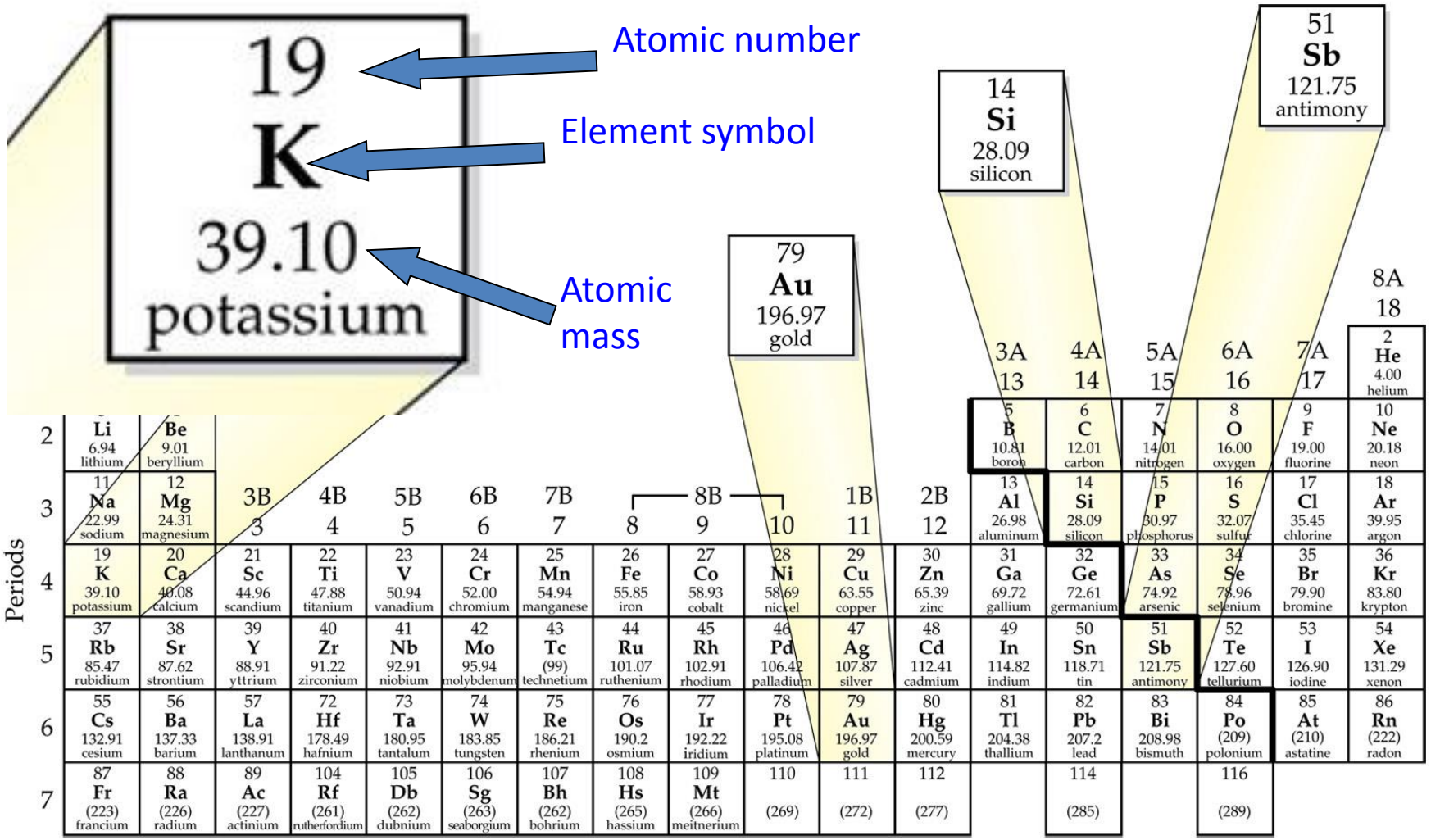
Calculate the Atomic Mass of Cl

Example: Chlorine, Cl	
Mass of the Isotope	Percent Abundance
34.97 amu	75.77%
36.97 amu	24.23%

Example: Isotopes of Neon

Symbol	Number of protons	Number of neutrons	A, mass number	Percent natural abundance
Ne-20 or $^{20}_{10}\mathrm{Ne}$	10	10	20	90.48%
Ne-21 or $^{21}_{10}\mathrm{Ne}$	10	11	21	0.27%
Ne-22 or $^{22}_{10}\mathrm{Ne}$	10	12	22	9.25%

The Periodic Table of Elements



Review

- What is the atomic number of boron, B?
- What is the atomic mass of silicon, Si?
- How many protons does a chlorine atom have?
- How many electrons does a neutral neon atom have?
- Will an atom with 6 protons, 6 neutrons, and 6 electrons be electrically neutral?
- Will an atom with 27 protons, 32 neutrons, and 27 electrons be electrically neutral?
- Will an Na atom with 10 electrons be electrically neutral?

Review

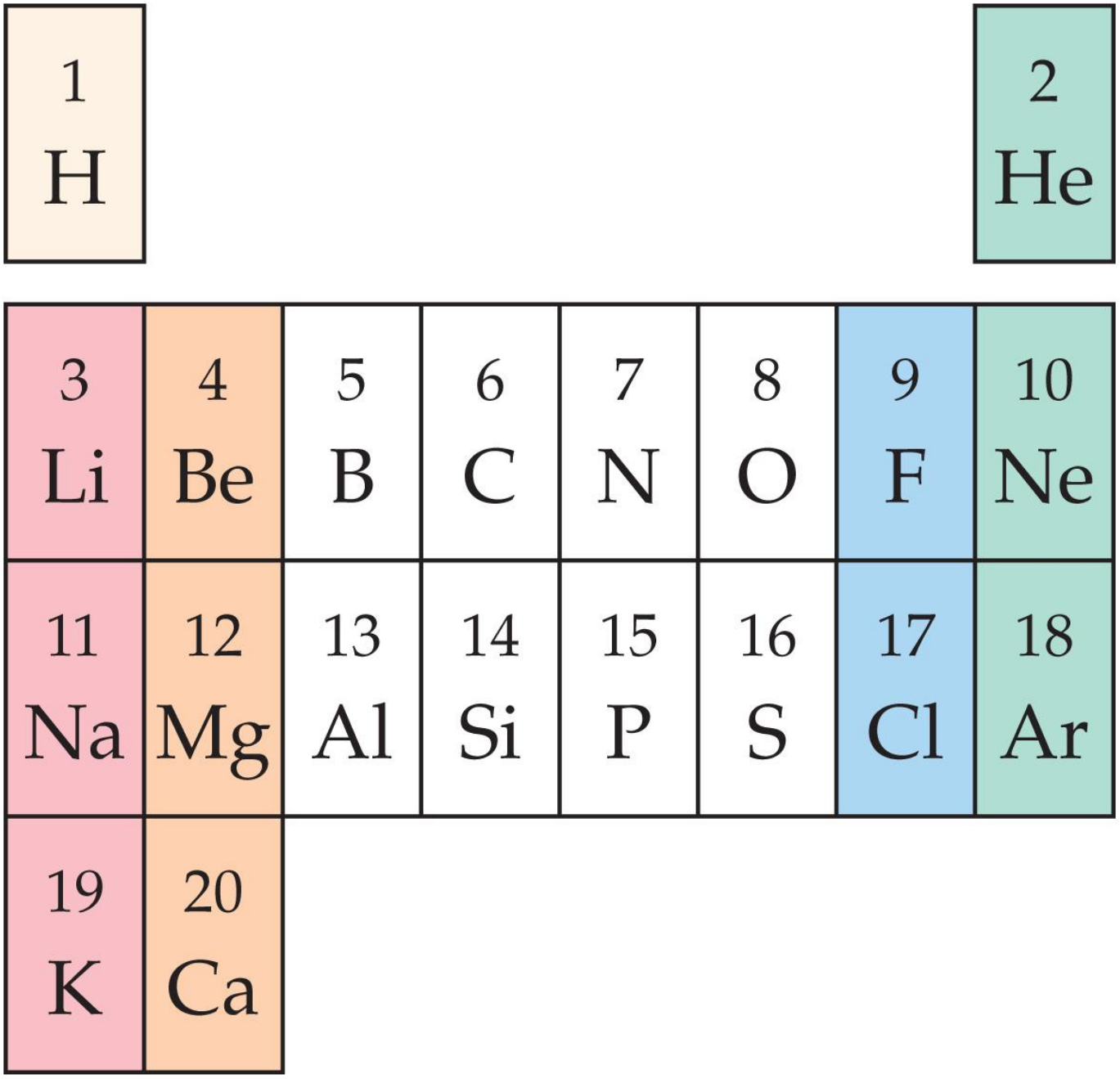
- What is the atomic number of boron, B? 5
- What is the atomic mass of silicon, Si? 28.09 amu
- How many protons does a chlorine atom have? 17
- How many electrons does a neutral neon atom have? 10
- Will an atom with 6 protons, 6 neutrons and 6 electrons be electrically neutral? Yes
- Will an atom with 27 protons, 32 neutrons, and 27 electrons be electrically neutral? Yes
- Will an Na atom with 10 electrons be electrically neutral? No

Mendeleev

- Ordered elements by atomic mass.
- Saw a repeating pattern of properties.
- **Periodic law—**When the elements are arranged in order of increasing relative mass, certain sets of properties recur periodically.
- Used pattern to predict properties of undiscovered elements.
- Where atomic mass order did not fit other properties, he reordered by other properties.
  - Te & I

Patterns

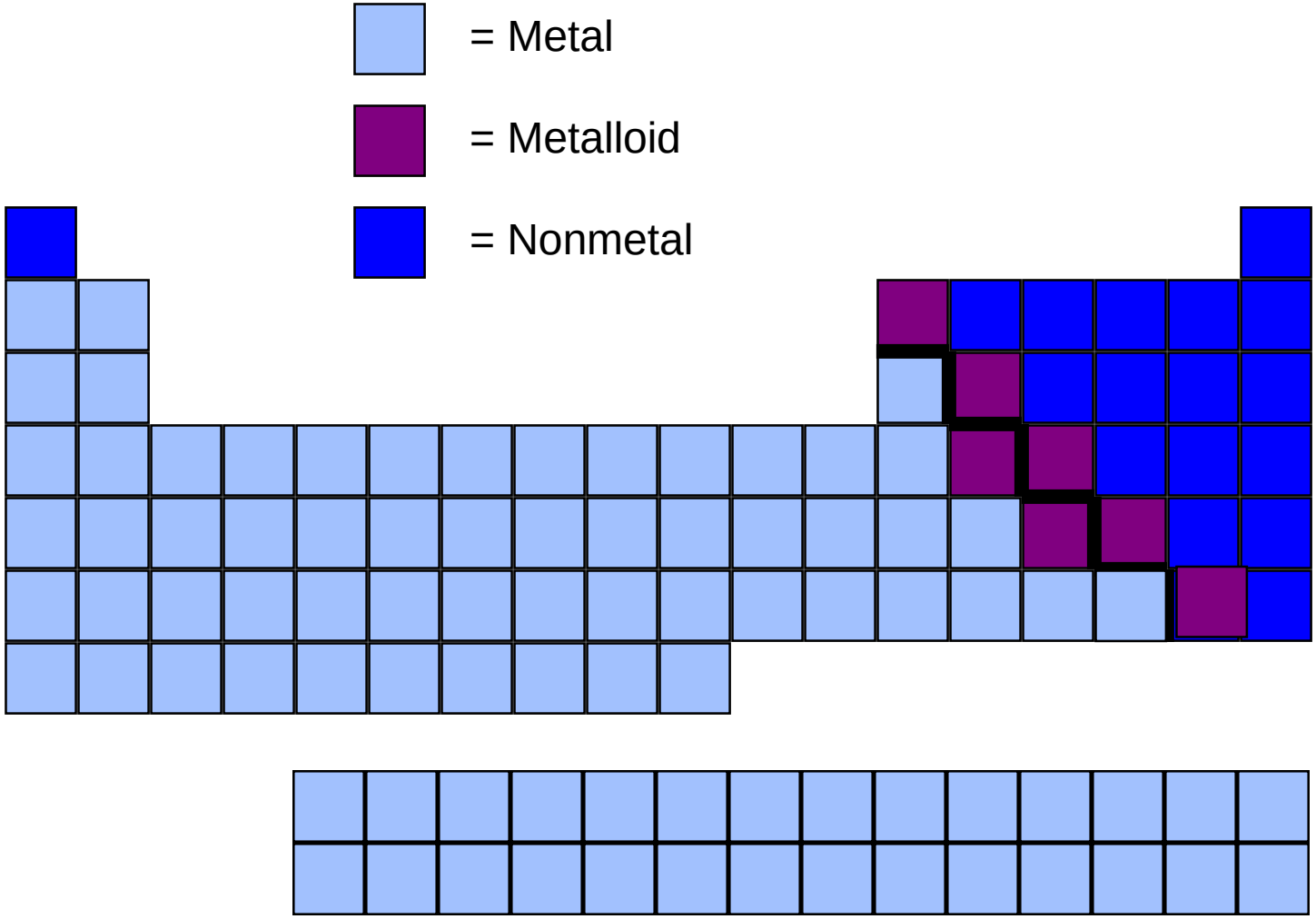
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca



Mendeleev's Predictions for Ekasilicon (Germanium)

Property	***Silicon's props***	***Tin's props***	***Predicted value***	***Measured value***
Atomic mass	28	118	72	72.6
Color	Gray	White metal	Gray	Gray-white
Density	2.32	7.28	5.5	5.4
Reaction with acid and base	Resists acid, reacts base	Reacts acid, resists base	Resists both	Resists both
Oxide	SiO_2	SnO_2	Eks_1O_2	GeO_2

Periodicity

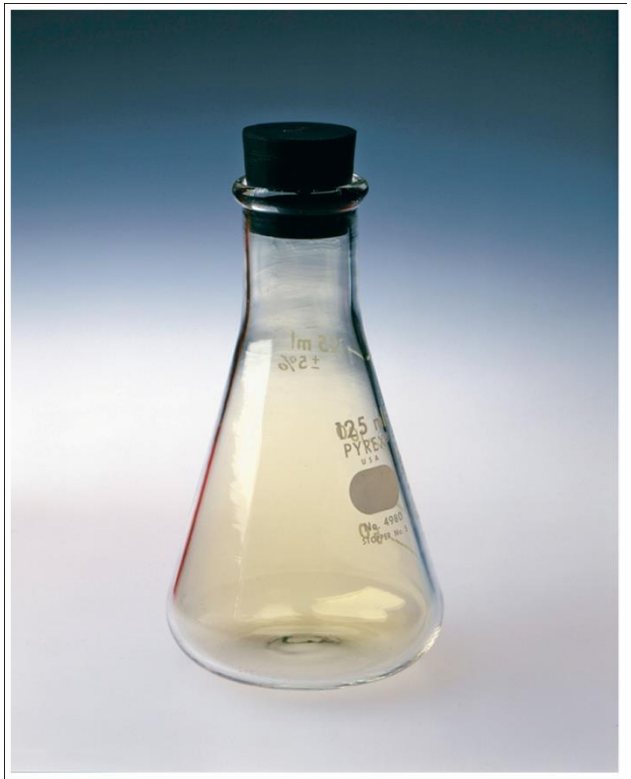


Metals

- Solids at room temperature, except Hg.
- Reflective surface.
  - Shiny
- Conduct heat.
- Conduct electricity.
- Malleable.
  - Can be shaped.
- Ductile.
  - Drawn or pulled into wires.
- Lose electrons and form positive ions in reactions.
- About 75% of the elements are metals.
- Lower left on the table.

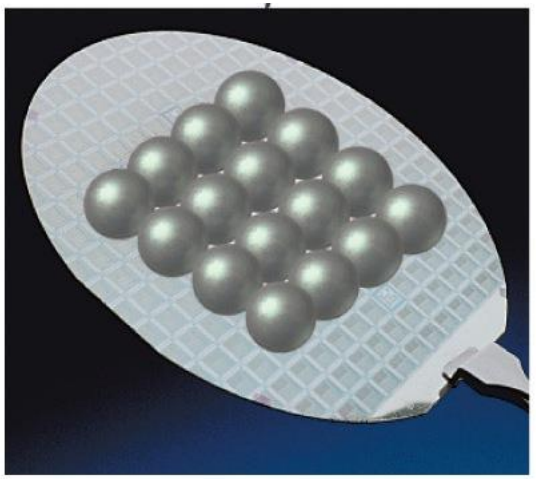
Nonmetals

- Found in all 3 states.
- Poor conductors of heat.
- Poor conductors of electricity.
- Solids are brittle.
- Gain electrons in reactions to become negative ions.
- Upper right on the table.
  - Except H.



Metalloids

- Show some properties of metals and some of nonmetals.
- Also known as semiconductors.



Properties of Silicon:

✓Shiny

✓Conducts electricity

✓Does not conduct heat well

✓Brittle

Practice—Classify Each Element as Metal, Nonmetal, or Metalloid.

- Xenon, Xe
- Tungsten, W
- Bromine, Br
- Arsenic, As
- Cerium, Ce

Practice—Classify Each Element as Metal, Nonmetal, or Metalloid.

- Xenon, Xe — Nonmetal
- Tungsten, W — Metal
- Bromine, Br — Nonmetal
- Arsenic, As — Metalloid
- Cerium, Ce — Metal

The Modern Periodic Table

- Elements with similar chemical and physical properties are in the same column.
- Columns are called **Groups** or **Families**.
  - Designated by a number and letter at top.
- Rows are called **Periods**.
- Each period shows the pattern of properties repeated in the next period.

The Modern Periodic Table, Continued

- Main group = predictable elements = “A” groups.
- Transition elements = “B” groups.
  - All metals.
- Bottom rows = inner transition elements = rare earth elements.
  - Metals
  - Really belong in periods 6 and 7.

= Alkali metals

= Alkali earth metals

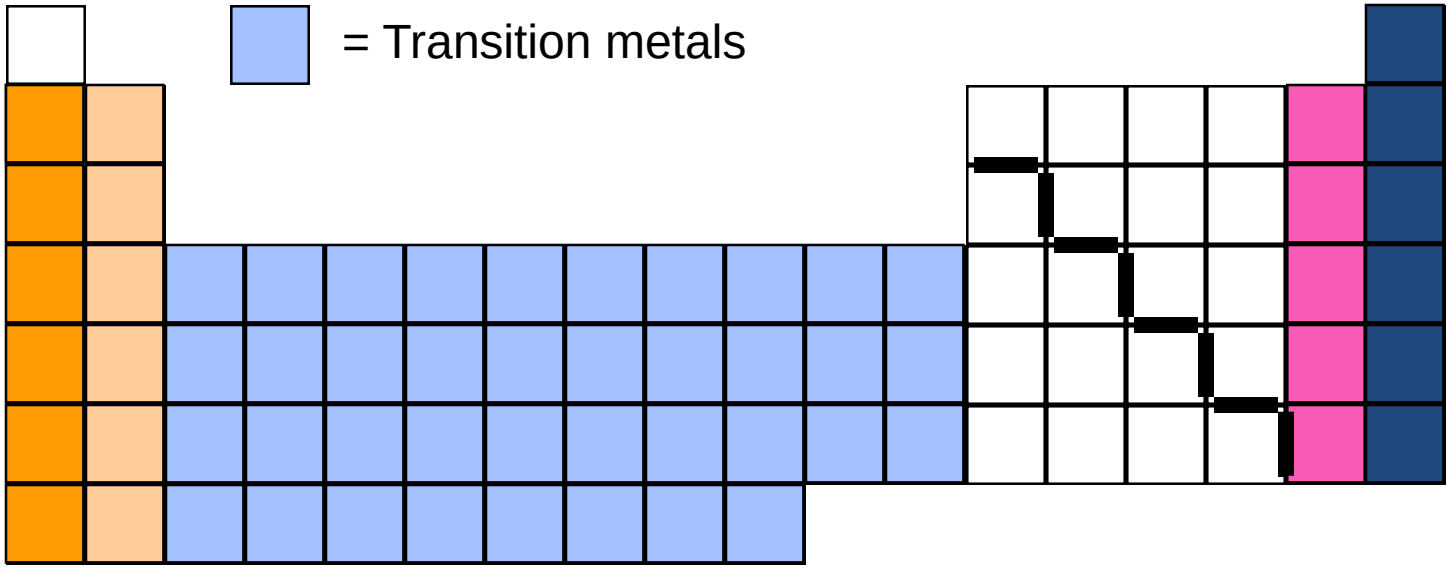
= Noble gases

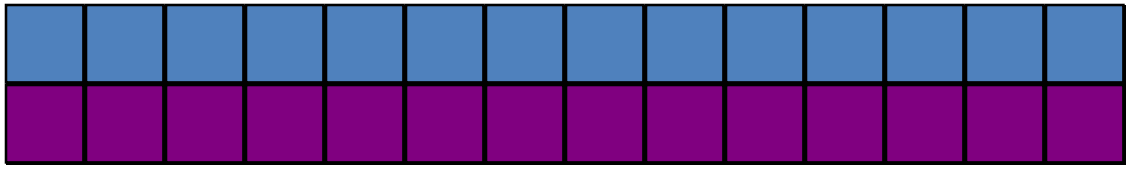
= Halogens

= Lanthanides

= Actinides

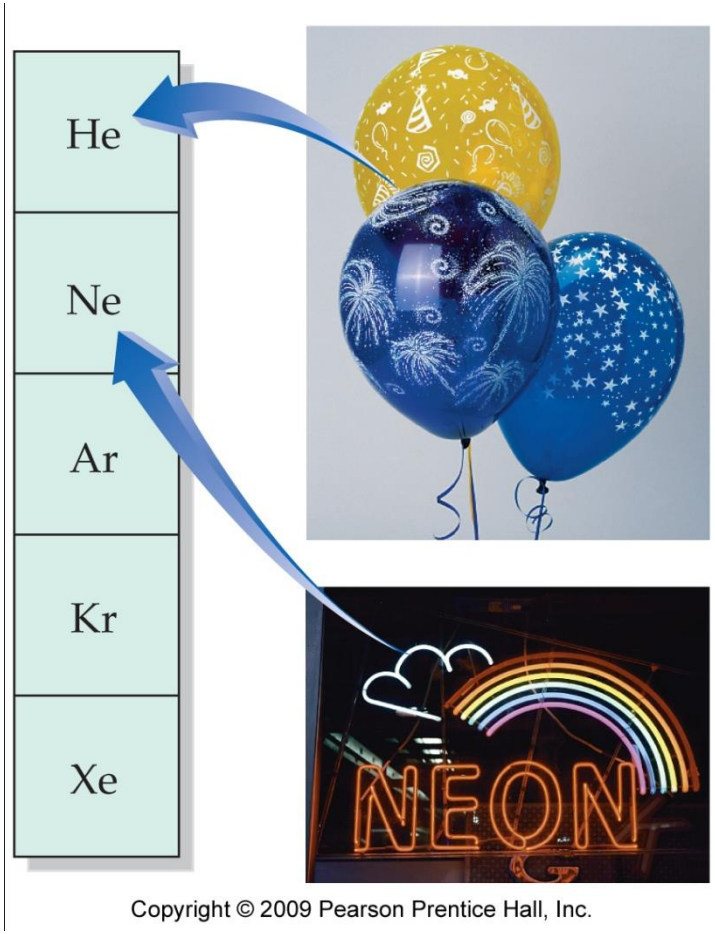
= Transition metals





Important Groups—Noble Gases

- Group VIIIA = Noble gases.
- All gases at room temperature.
  - Very low melting and boiling points.
- Very unreactive, practically inert.
- Very hard to remove electron from or give an electron to.

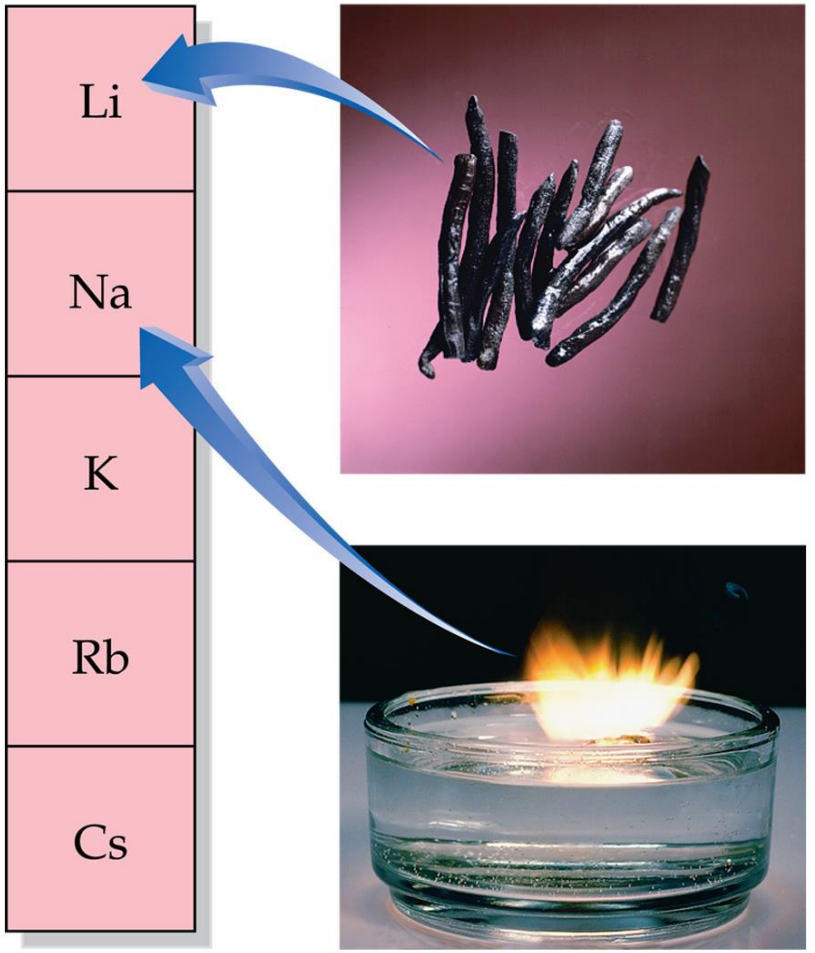


Important Groups— Alkali Metals

- Group IA = Alkali metals.
- Hydrogen is usually placed here, though it doesn't belong.
- Soft, low melting points, low density.
- Flame tests: Li = red, Na = yellow, and K = violet.
- Very reactive, never found uncombined in nature.
- Tend to form water soluble compounds that are crystallized from seawater
    - Colorless solutions.
- React with water to form basic (alkaline) solutions and H_2:

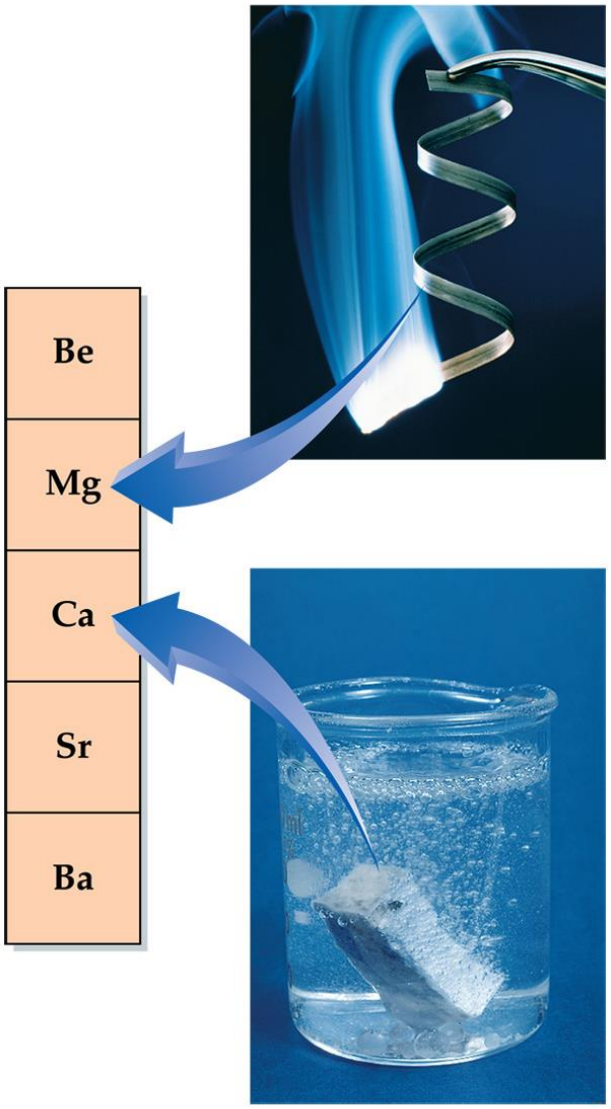
    $2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2$

    - Releases a lot of heat.



Important Groups—Alkaline Earth Metals

- Group IIA = Alkali earth metals.
- Harder, higher melting, and denser than alkali metals.
  - Mg alloys used as structural materials.
- Flame tests: Ca = red, Sr = red, and Ba = yellow-green.
- Reactive, but less than corresponding alkali metal.
- Form stable, insoluble oxides from which they are normally extracted.
- Oxides are basic = alkaline earth.
- Reactivity with water to form H_2: Not nearly as violent as the alkali metals

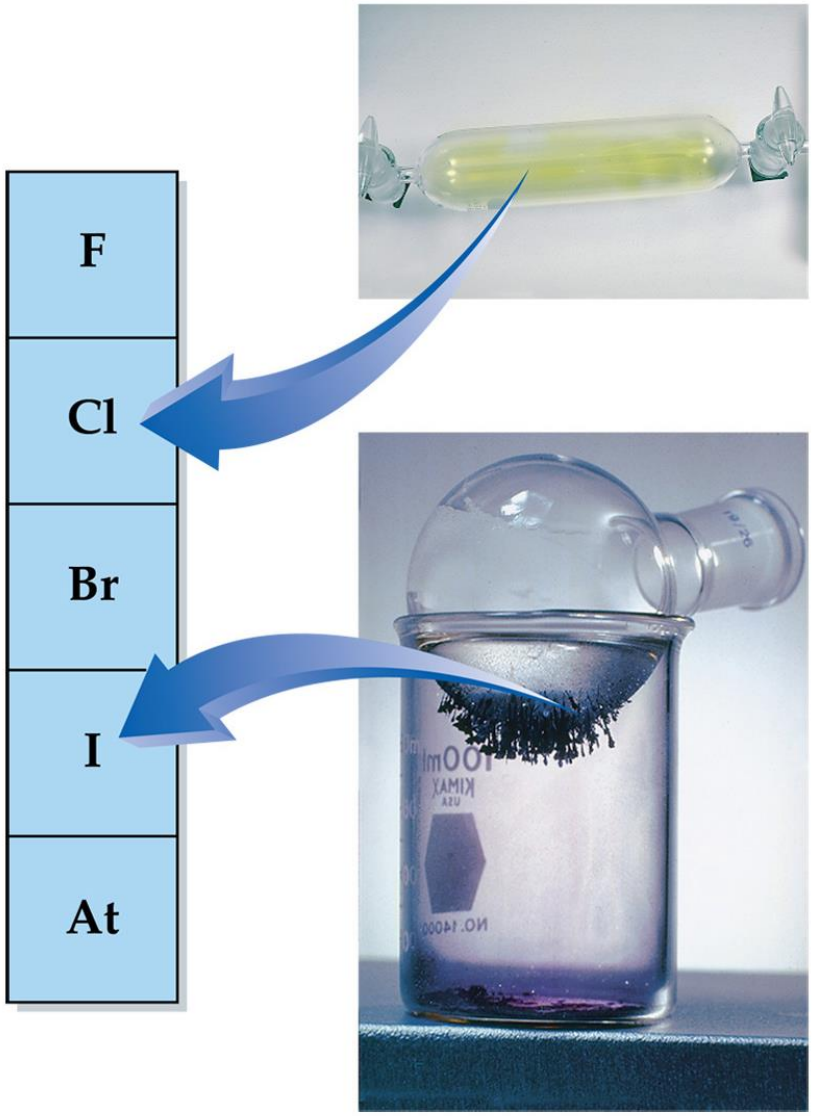


Important Groups—Halogens

- Group VIIA = Halogens.
- Nonmetals.
- F_2 and Cl_2 gases, Br_2 liquid, and I_2 solid.
- All diatomic.
- Very reactive.
- Cl_2, and Br_2 react slowly with water:

$$Br_2 + H_2O \rightarrow HBr + HOBr$$

- React with metals to form ionic compounds.
- hydrogen halides all acids:
  - HF weak < HCl < HBr < HI.



Ions

- In chemical reactions, atoms often gain or lose electrons to form ions.

- Cation-positively charged ions
- Anion –negatively charged ions

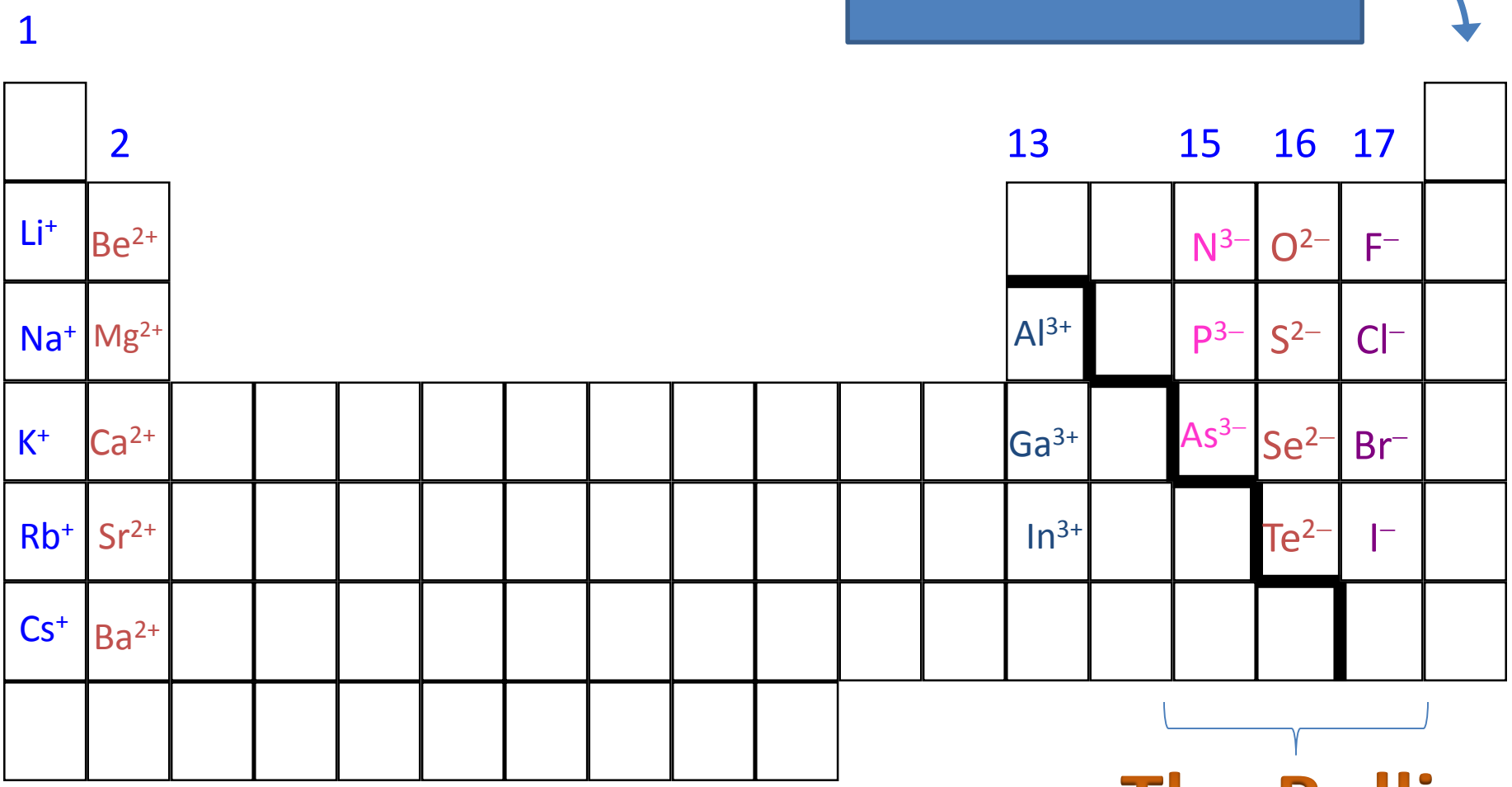
Practice—Fill in the Table.

Ion	p^+	e^-
Cl^{1-}		
K^{1+}		
S^{2-}		
Sr^{2+}		

Practice—Fill in the Table, Continued.

Ion	p^+	e^-
Cl^{1-}	17	18
K^{1+}	19	18
S^{2-}	16	18
Sr^{2+}	38	36

Group 18 elements rarely form ions.



The Bullies

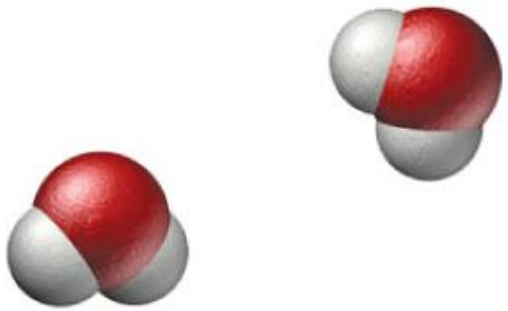
Dalton's Atomic Theory

1. Each element is composed of tiny indestructible particles called atoms.
2. All atoms of a given element have unique properties which distinguish them from all other elements.
3. Atoms combine in simple, whole-number ratios to form compounds.

The Law of Constant Composition

- All samples of a given compound have the same proportions of their constituent elements.

Example: Water



- A water molecule is made of 2 Hydrogen atoms, and 1 oxygen atom, or 2:1.
- What is the ratio of the mass of oxygen to the mass of hydrogen in one molecule?
- In 2 molecules of water?
- What about in 100 molecules?

Example: Water

- If a sample contains 116 g of oxygen and 14.5g of hydrogen, can you prove that this sample has a mass ratio consistent with that of water?

The Law of Multiple Proportions

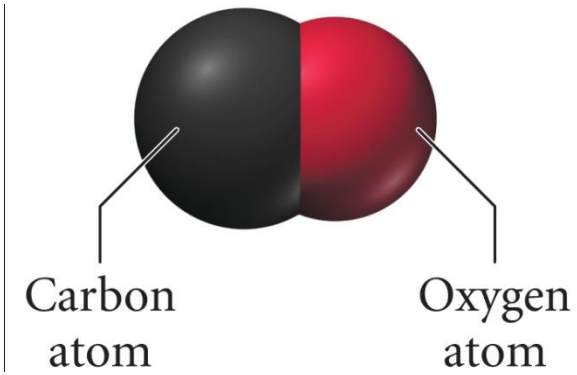
- Substances that are made with the same elements, but have different mass ratios, will be different substances with different properties.

Structure Determines Properties

- The properties of matter are determined by the atoms and molecules that compose it.

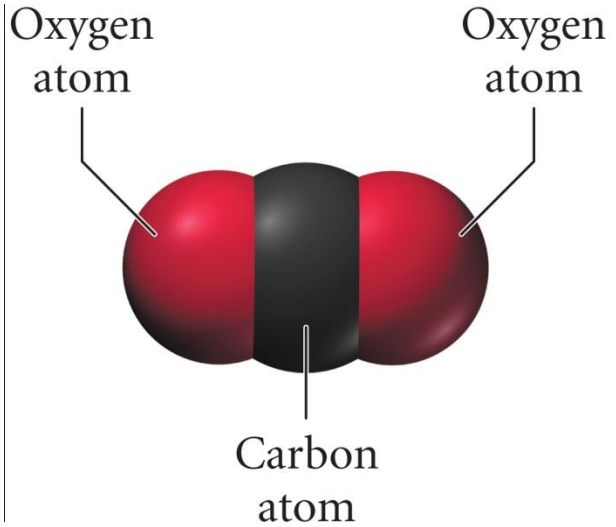
Carbon Monoxide

1. Composed of one carbon atom and one oxygen atom.
2. Colorless, odorless gas.
3. Burns with a blue flame.
4. Binds to hemoglobin.



Carbon Dioxide

1. Composed of one carbon atom and two oxygen atoms.
2. Colorless, odorless gas.
3. Incombustible.
4. Does not bind to hemoglobin.



Example:

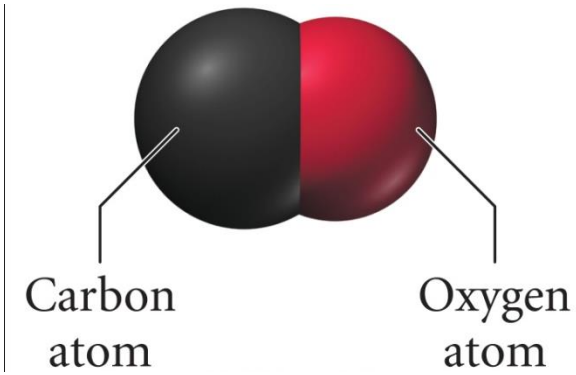
- Two samples of carbon monoxide, obtained from different sources, were decomposed into carbon and oxygen. One sample produced 4.3g O and 3.2g C, and the other sample produced 7.5g O and 5.6 g carbon. Are these results consistent with the law of constant composition?

Chemical Formulas

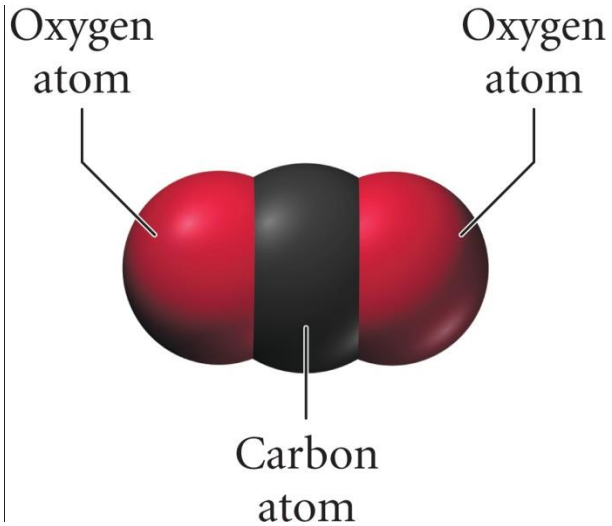
- A chemical formula indicates the types of elements present in the substance.
- The number of atoms of each element in that compound is indicated by a subscript
  - By convention, the subscript 1 is omitted.

Example:

- Carbon Monoxide:



- Carbon Dioxide



Writing a Chemical Formula

- Order to list elements:
  - Most metallic first!
  - If, two non-metals, use this list:
  - Elements on the left are written before elements on the right

C	P	N	H	S	I	Br	Cl	O	F

Example:

- Write the chemical formula for the following:
  a) The compound containing two aluminum (Al) atoms and three oxygen (O) atoms.
  b) The compound containing three oxygen atoms to every sulfur atom.
  c) The compound containing four chlorine atoms (Cl) to every carbon atom.

Example:

a) 2 silver (Ag) atoms, and one sulfur (S) atom

b) 2 nitrogen (N) atoms and one oxygen (O) atom

c) 2 oxygen atoms and one titanium (Ti) atom

Polyatomic Ions

- Groups of atoms that act as a unit when they form compounds with other elements.
- Carry a charge, and are listed first or last based on that charge.
  - Metals are usually cations (positive)
  - Nonmetals are usually anion (negative)
  - Polyatomic ions are listed first if a cation, last if an anion.

Example

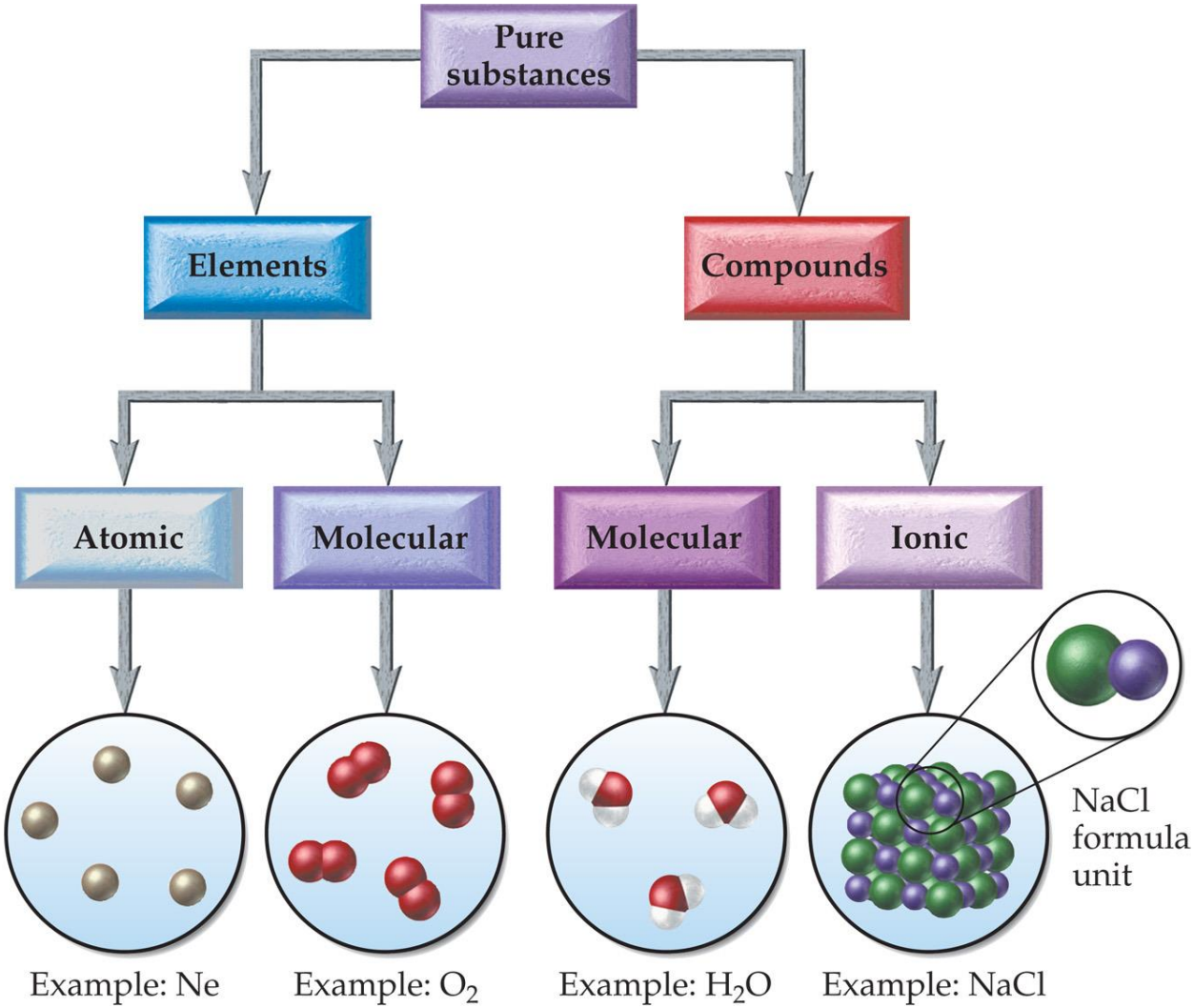
- Write the formula for a compound containing:

a) Three calcium atoms (Ca) and two phosphate ions (PO_4^{3-})

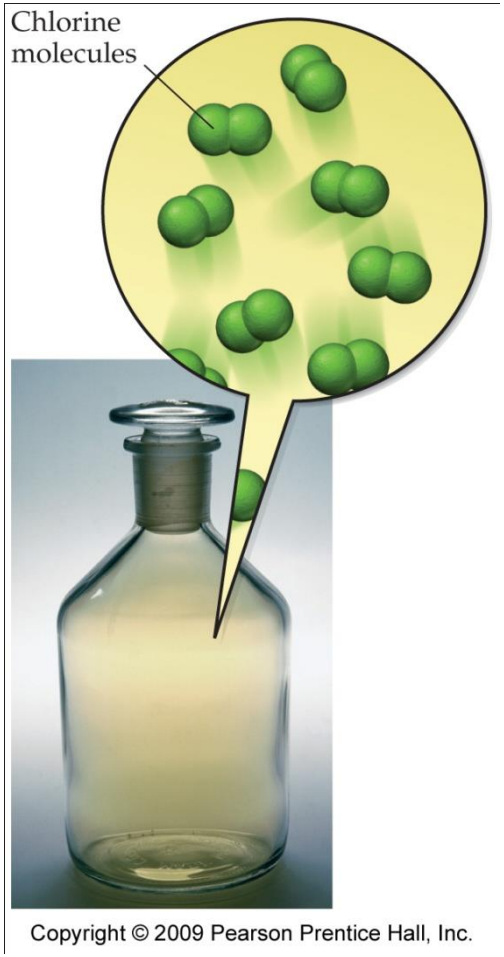
b) One chlorine atom and one ammonium ion (NH_4^+)

c) Three lithium (Li) atoms and one phosphate ion (PO_4^{3-})

Elements and Compounds



Atomic and Molecular Elements

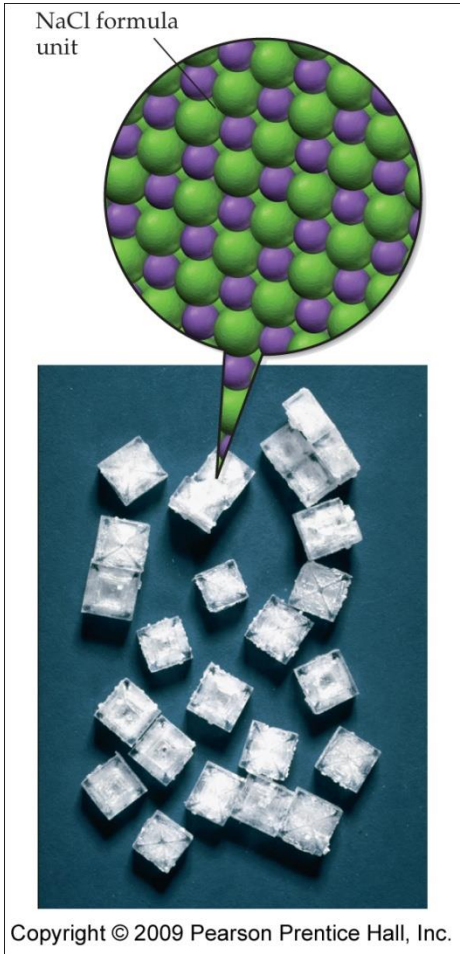


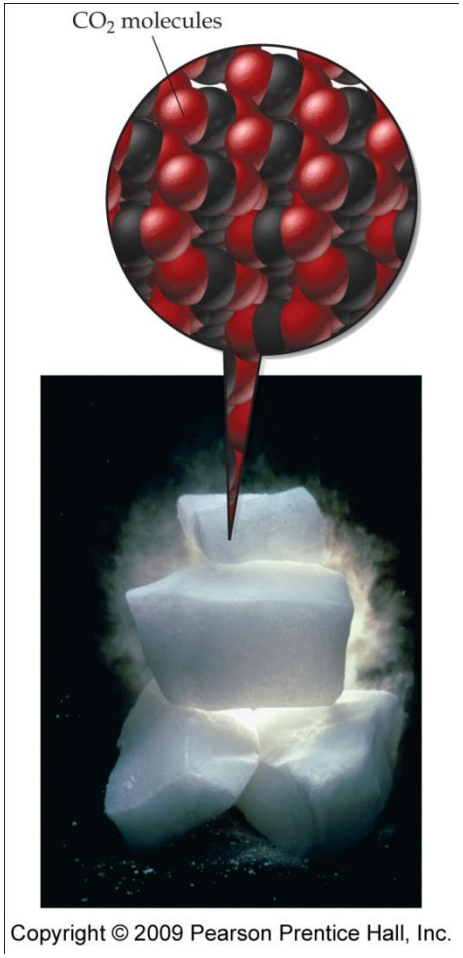
Compounds

- Molecular Compounds
  - Formed from 2 or more Non-metals
  - Covalent Bond (share electrons)

- Ionic Compounds
  - Formed from a metal and a nonmetal. (Polyatomic Ions count here, too)
  - Formed when a cation and an anion “stick together” because or their charges.

Ionic and Molecular Compounds





Example

- Classify each as an atomic element, molecular element, molecular compound, or ionic compound

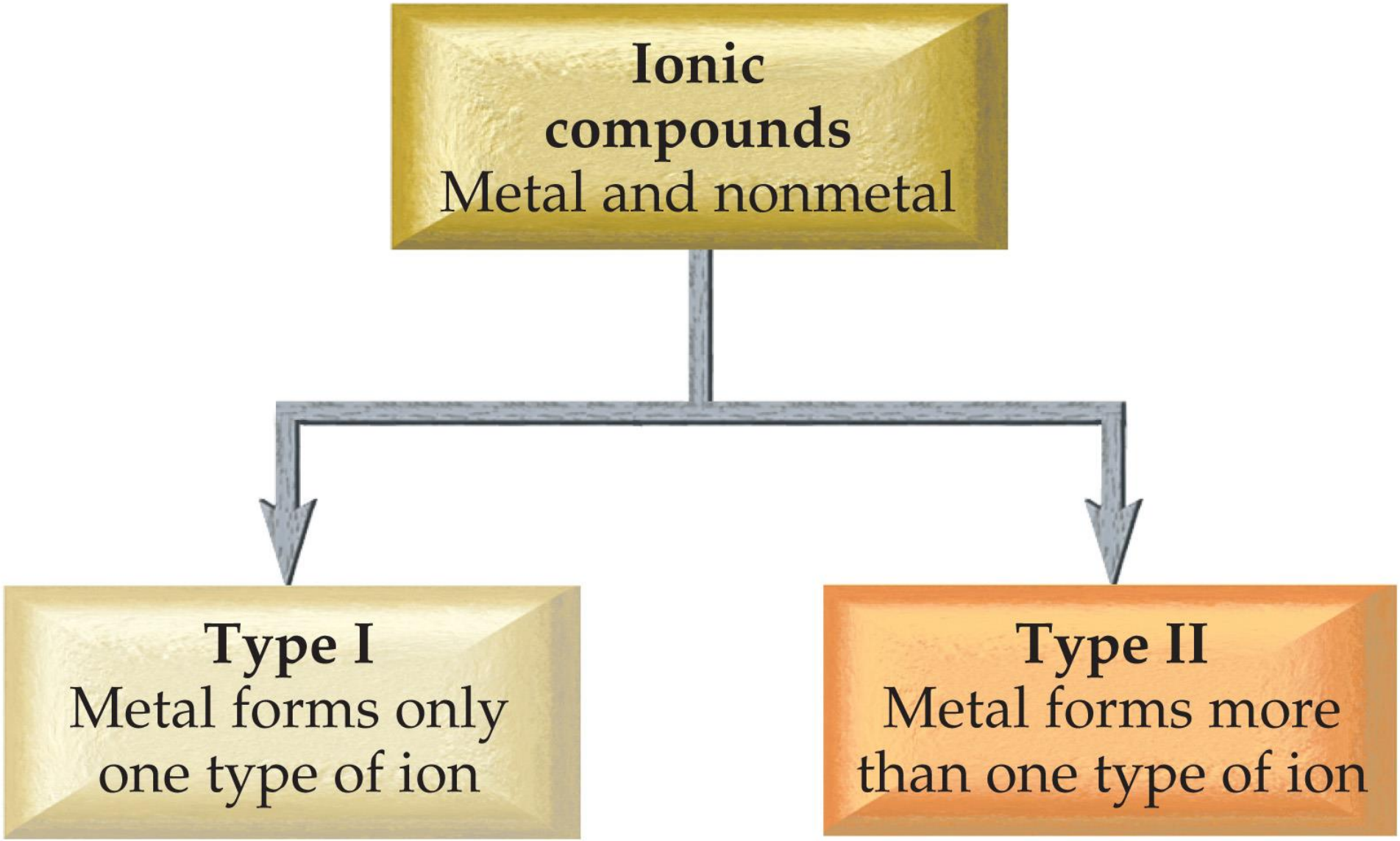
a) Helium

b) $CoCl_2$

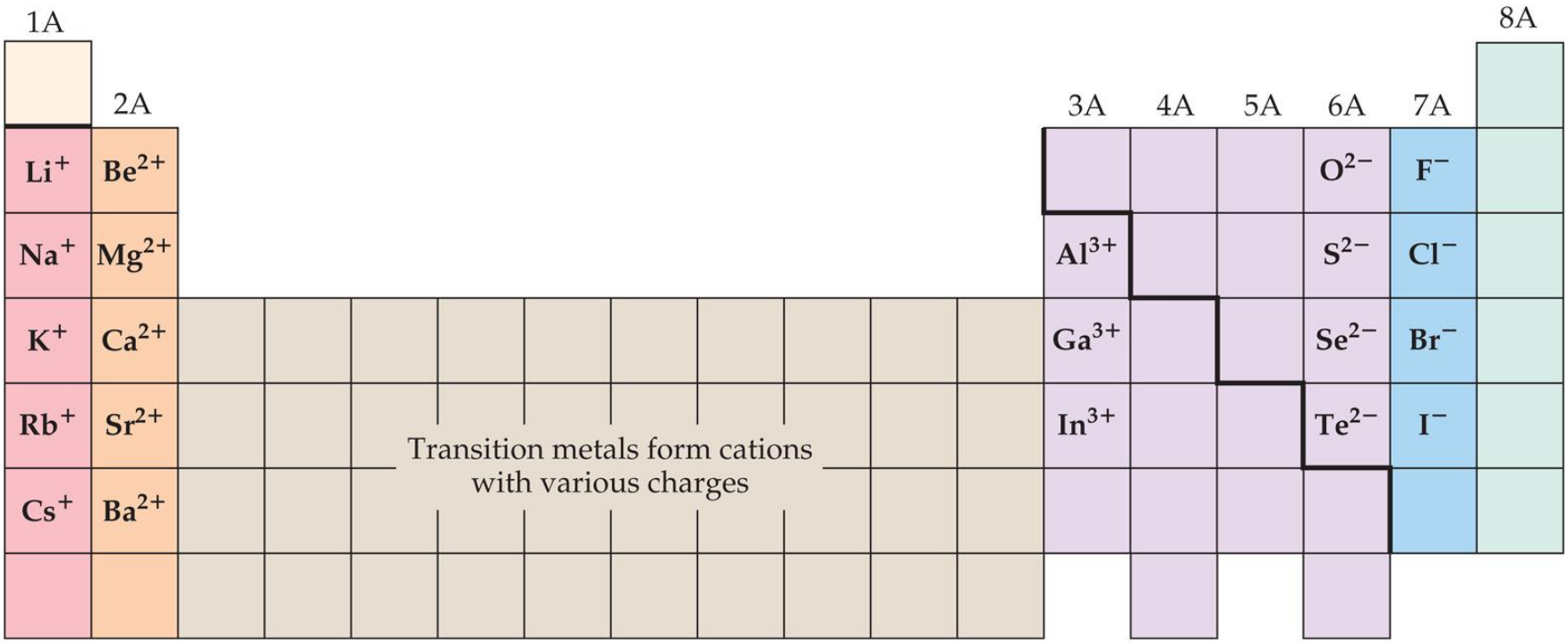
c) Nitrogen

d) SO_2

e) KNO_3



Ions with a Definite Charge



Polyatomic Ions fall in this category, too.

Writing Formulas for Ionic Compounds

1. Write the symbol for the cation (metal) and its charge, followed by the anion (nonmetal) and its charge.
2. Make the charge (number only, no sign) of each element become the subscript for the other element.
3. Reduce the subscripts to give the lowest whole number values. (If you can.)
4. Check that the sum of the charges in the compound is zero.

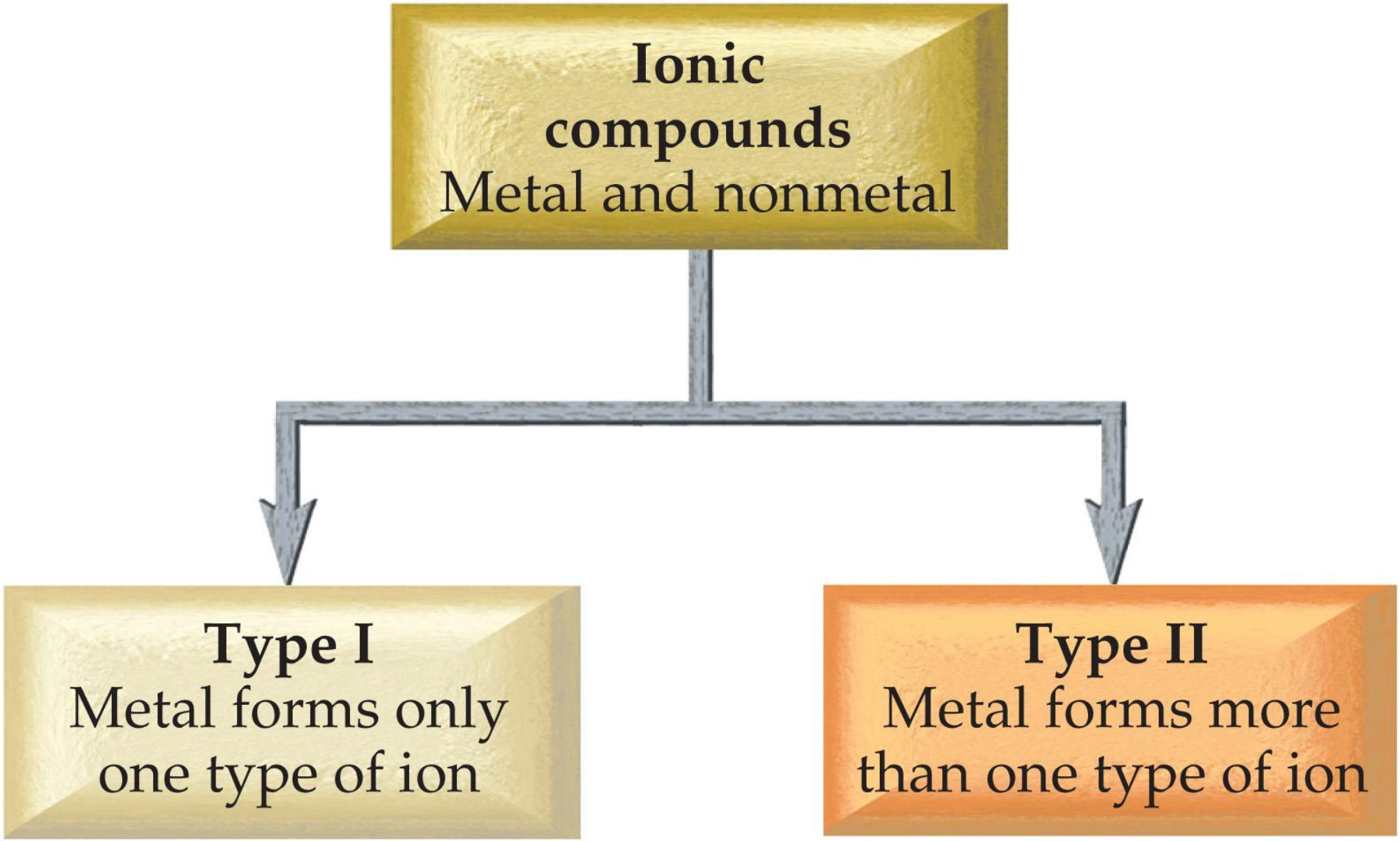
Naming Type I Binary Ionic Compounds

name of cation (metal)

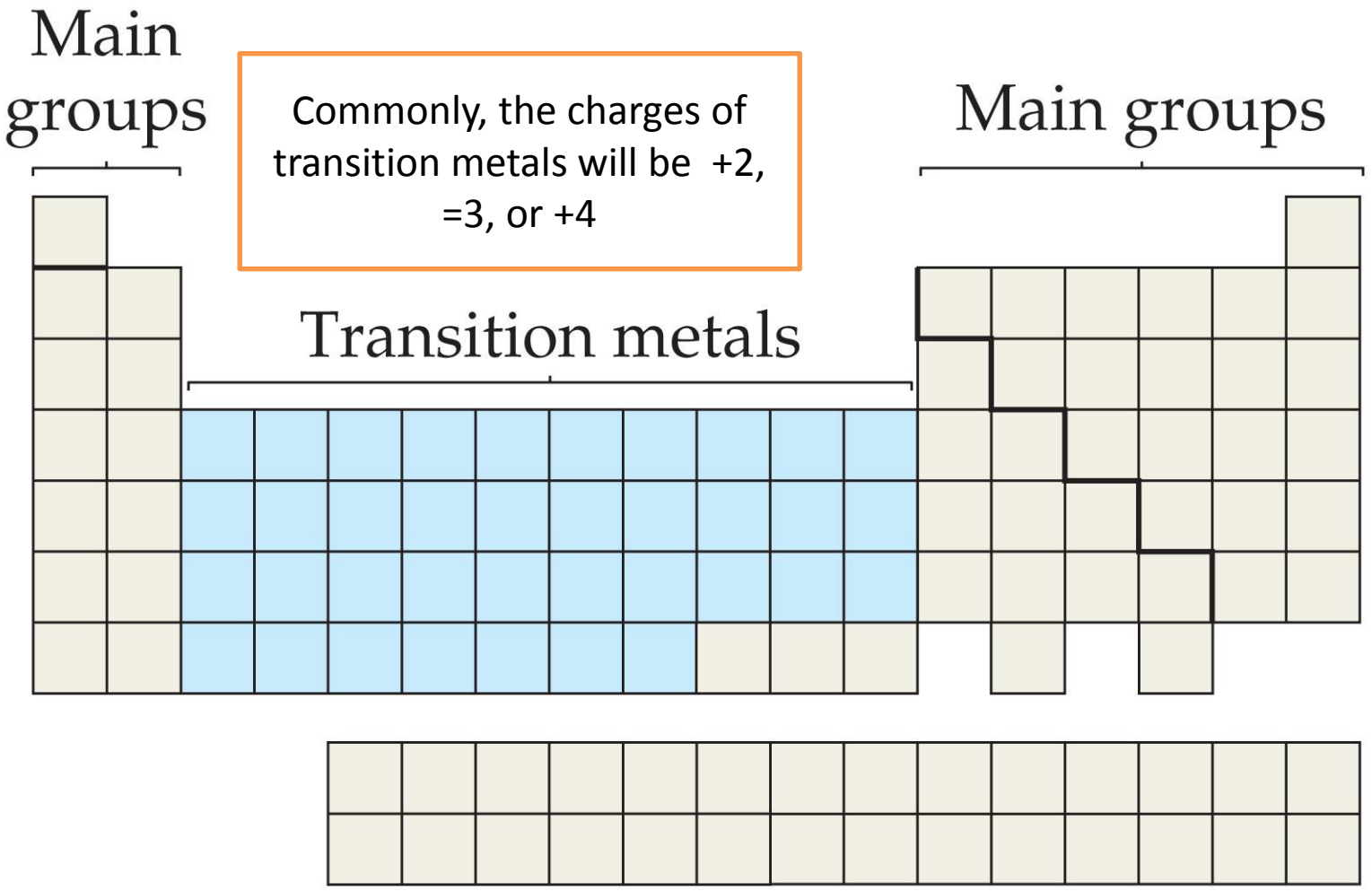
base name of anion (nonmetal) + *-ide*

Name the Following:

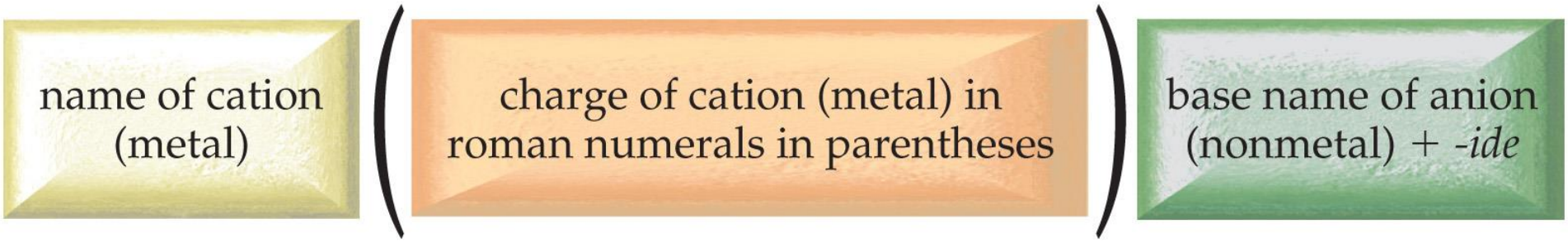
- $CsBr_2$
- Al_2O_3
- KBr
- CaS



Type II: Metal could form more than one cation



Naming a Type II Binary Ionic Compound



***Determine the charge of the metal first, then name as usual.**

Practice–Name the Following Compounds.

- $TiCl_4$
- $PbBr_2$
- Fe_2S_3

Practice–Name the Following Compounds, Continued.

- $TiCl_4$ **Titanium(IV) chloride**.
- $PbBr_2$ **Lead(II) bromide**.
- Fe_2S_3 **Iron(III) sulfide**.

Practice–Name the Following

1. NH_4Cl

2. $CaCl_2$

3. CuI_2

Practice–Name the Following, Continued

1. NH_4Cl Ammonium chloride.

2. $CaCl_2$ Calcium chloride.

3. $Cu(NO_3)_2$ Copper(II) nitrate.

$NO_3 = 2(-1) = -2$

$Cu = +2 = 1(2+)$

Molecular Compounds

- Atoms are connected by covalent bonds.
- **Made of two nonmetals!**

Naming Molecular (Covalent) Compounds

Prefix List:

1- mono	5- penta
2- di	6- hexa
3- tri	7- hepta
4- tetra	8- octa

Practice – Naming Covalent Compounds

- CO
- CO_2
- N_2O_4