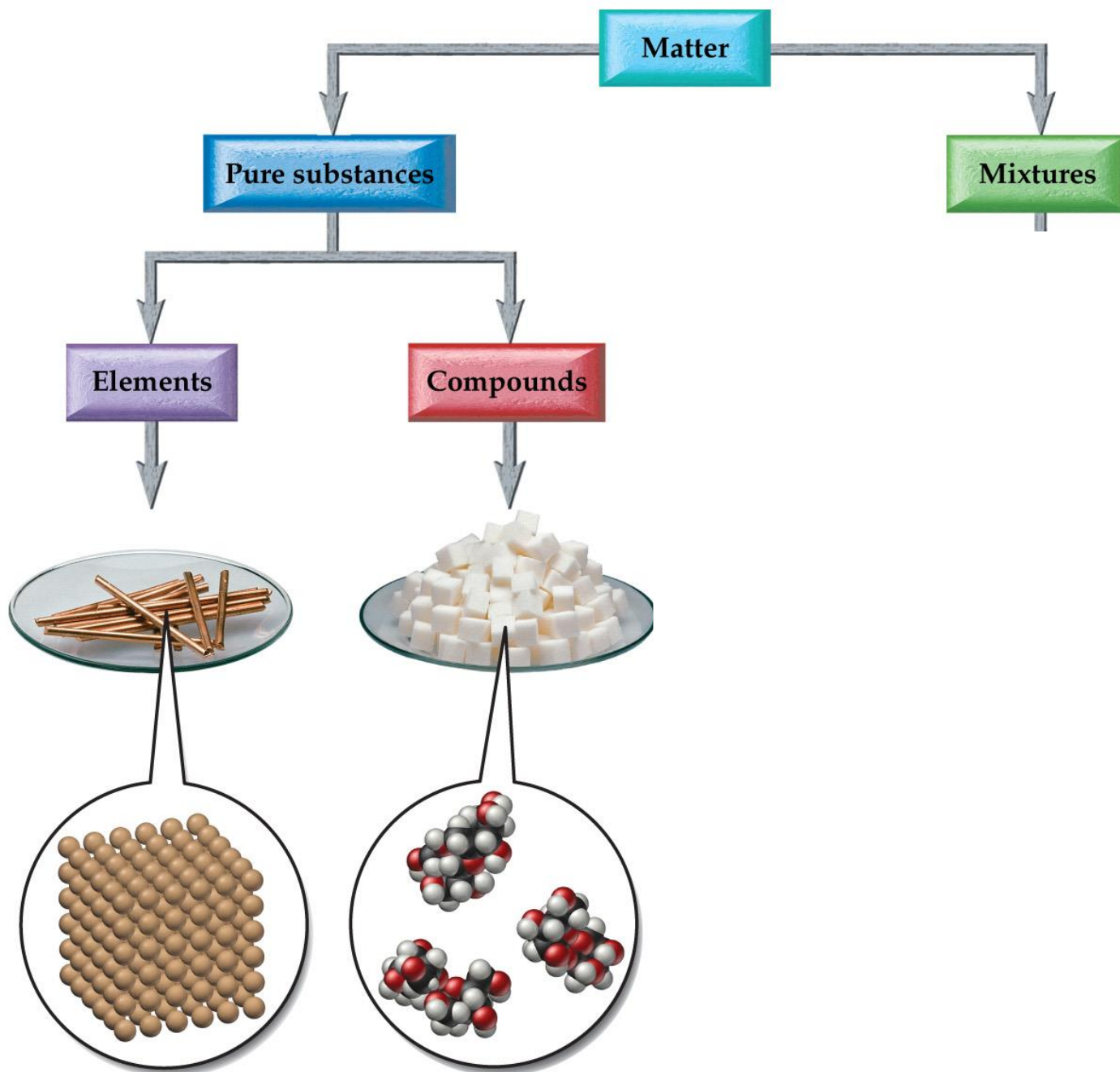


Module 2 Slides

Atoms and Elements

Part 1

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



Dalton's Atomic Theory

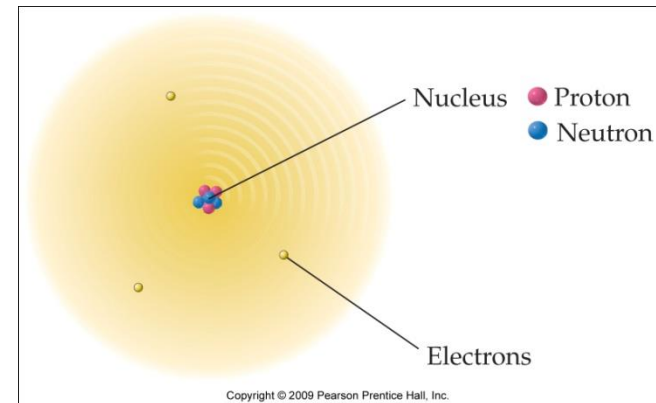
1. Each element is composed of tiny indestructible particles called atoms.
2. All atoms of a given element have unique properties which distinguish them from all other elements.
3. Atoms combine in simple, whole-number ratios to form compounds.

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?

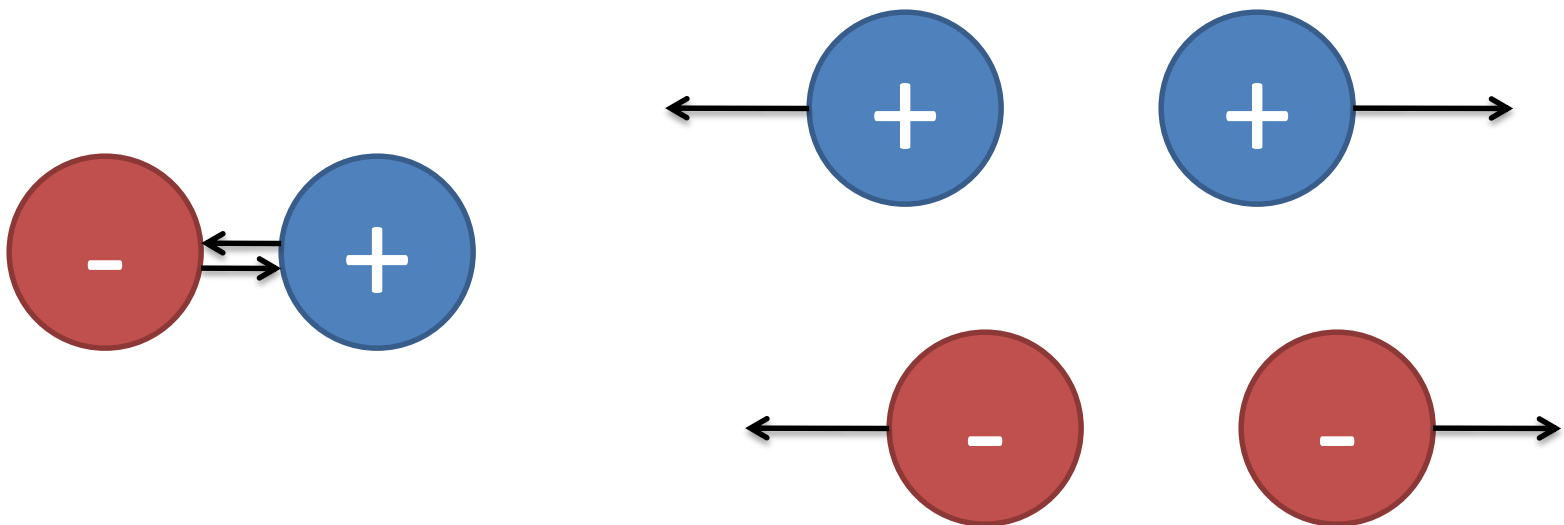
The Modern Atom

- 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.

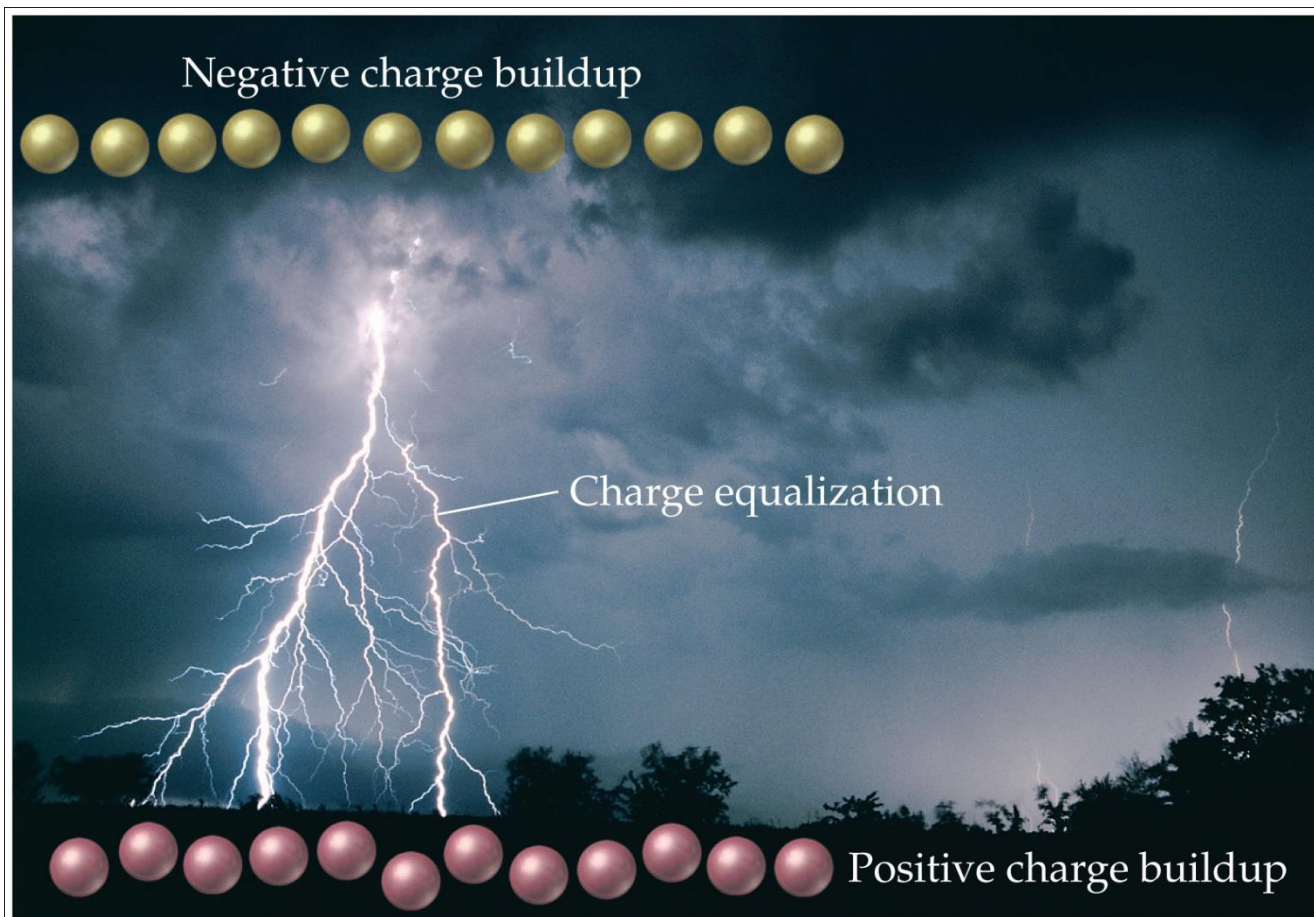


Charged Particles

- 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?



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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

$$\text{Charge} = +1 + (-1) = 0$$

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
 - I- 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

Atomic number

Element symbol

Atomic mass

Periods	1A	2A	3A	4A	5A	6A	7A	8A										
2	3 Li 6.94 lithium	4 Be 9.01 beryllium						2 He 4.00 helium										
3	11 Na 22.99 sodium	12 Mg 24.31 magnesium	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10	1B 11	2B 12	13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.07 sulfur	17 Cl 35.45 chlorine	18 Ar 39.95 argon		
4	19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.88 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.69 nickel	29 Cu 63.55 copper	30 Zn 65.39 zinc	31 Ga 69.72 gallium	32 Ge 72.61 germanium	33 As 74.92 arsenic	34 Se 78.96 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
5	37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.94 molybdenum	43 Tc (99) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.42 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.71 tin	51 Sb 121.75 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.29 xenon
6	55 Cs 132.91 cesium	56 Ba 137.33 barium	57 La 138.91 lanthanum	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.2 osmium	77 Ir 192.22 iridium	78 Pt 195.08 platinum	79 Au 196.97 gold	80 Hg 200.59 mercury	81 Tl 204.38 thallium	82 Pb 207.2 lead	83 Bi 208.98 bismuth	84 Po (209) polonium	85 At (210) astatine	86 Rn (222) radon
7	87 Fr (223) francium	88 Ra (226) radium	89 Ac (227) actinium	104 Rf (261) rutherfordium	105 Db (262) dubnium	106 Sg (263) seaborgium	107 Bh (262) bohrium	108 Hs (265) hassium	109 Mt (266) meitnerium	110 (269)	111 (272)	112 (277)		114 (285)	116 (289)			

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.

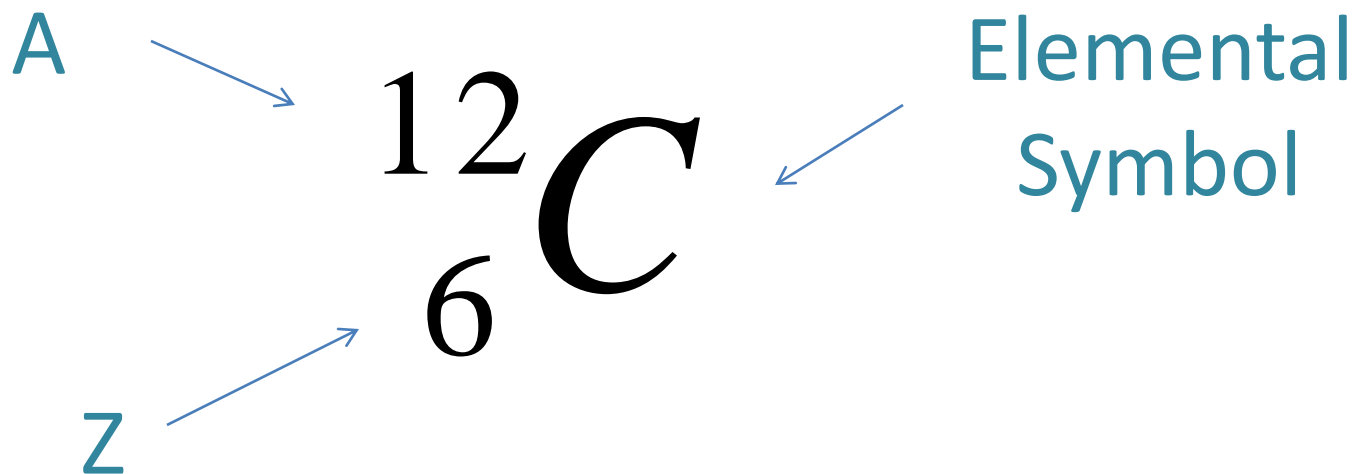
Percent Natural Abundance

- 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

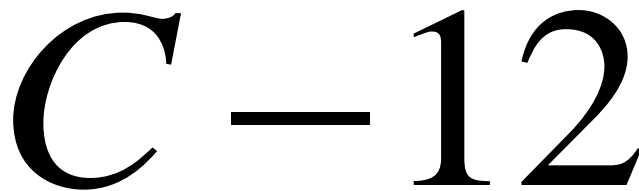
- The Isotopes of an element can be written symbolically:



Writing Isotope Symbols

- The Isotopes of an element can be written symbolically:

Elemental
Symbol



A

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 ${}_{10}^{20}\text{Ne}$	10	10	20	90.48%
Ne-21 or ${}_{10}^{21}\text{Ne}$	10	11	21	0.27%
Ne-22 or ${}_{10}^{22}\text{Ne}$	10	12	22	9.25%

The Periodic Table of Elements

Atomic number

Element symbol

Atomic mass

	3A																4A		5A		6A		7A		8A	
	13																14		15		16		17		18	
2	Li 6.94 lithium	Be 9.01 beryllium											B 10.81 boron	C 12.01 carbon	N 14.01 nitrogen	O 16.00 oxygen	F 19.00 fluorine	Ne 20.18 neon								
3	Na 22.99 sodium	Mg 24.31 magnesium	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10		1B 11	2B 12	Al 26.98 aluminum	Si 28.09 silicon	P 30.97 phosphorus	S 32.07 sulfur	Cl 35.45 chlorine	Ar 39.95 argon									
4	K 39.10 potassium	Ca 40.08 calcium	Sc 44.96 scandium	Ti 47.88 titanium	V 50.94 vanadium	Cr 52.00 chromium	Mn 54.94 manganese	Fe 55.85 iron	Co 58.93 cobalt	Ni 58.69 nickel	Cu 63.55 copper	Zn 65.39 zinc	Ga 69.72 gallium	Ge 72.61 germanium	As 74.92 arsenic	Se 78.96 selenium	Br 79.90 bromine	Kr 83.80 krypton								
5	Rb 85.47 rubidium	Sr 87.62 strontium	Y 88.91 yttrium	Zr 91.22 zirconium	Nb 92.91 niobium	Mo 95.94 molybdenum	Tc (99) technetium	Ru 101.07 ruthenium	Rh 102.91 rhodium	Pd 106.42 palladium	Ag 107.87 silver	Cd 112.41 cadmium	In 114.82 indium	Sn 118.71 tin	Sb 121.75 antimony	Te 127.60 tellurium	I 126.90 iodine	Xe 131.29 xenon								
6	Cs 132.91 cesium	Ba 137.33 barium	La 138.91 lanthanum	Hf 178.49 hafnium	Ta 180.95 tantalum	W 183.85 tungsten	Re 186.21 rhenium	Os 190.2 osmium	Ir 192.22 iridium	Pt 195.08 platinum	Au 196.97 gold	Hg 200.59 mercury	Tl 204.38 thallium	Pb 207.2 lead	Bi 208.98 bismuth	Po (209) polonium	At (210) astatine	Rn (222) radon								
7	Fr (223) francium	Ra (226) radium	Ac (227) actinium	Rf (261) rutherfordium	Db (262) dubnium	Sg (263) seaborgium	Bh (262) bohrium	Hs (265) hassium	Mt (266) meitnerium	(269)	(272)	(277)	(285)	(289)												

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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



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- 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

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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
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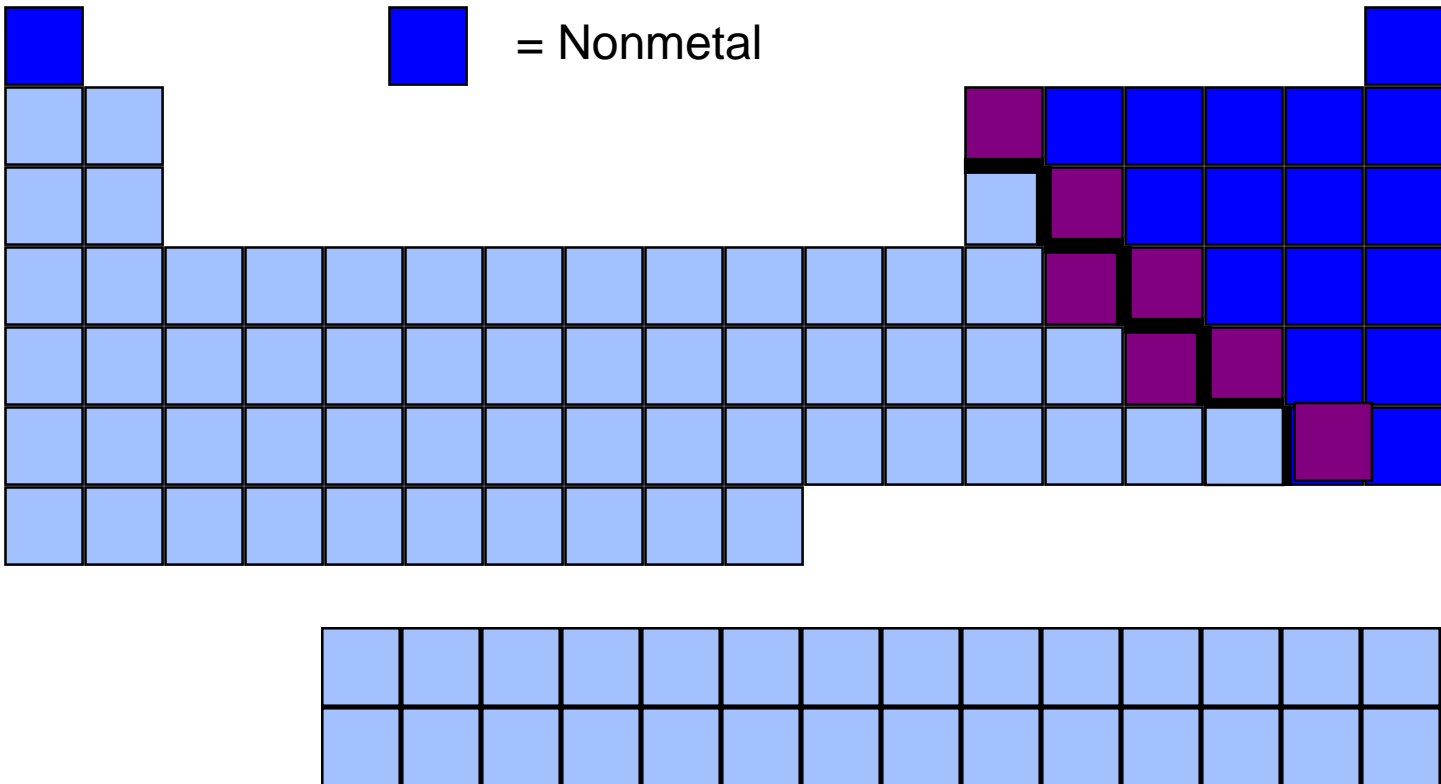
19 K	20 Ca
---------	----------

Mendeleev's Predictions for Ekasilicon (Germanium)

<i>Property</i>	<i>Silicon's props</i>	<i>Tin's props</i>	<i>Predicted value</i>	<i>Measured value</i>
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 ₁ O ₂	GeO ₂

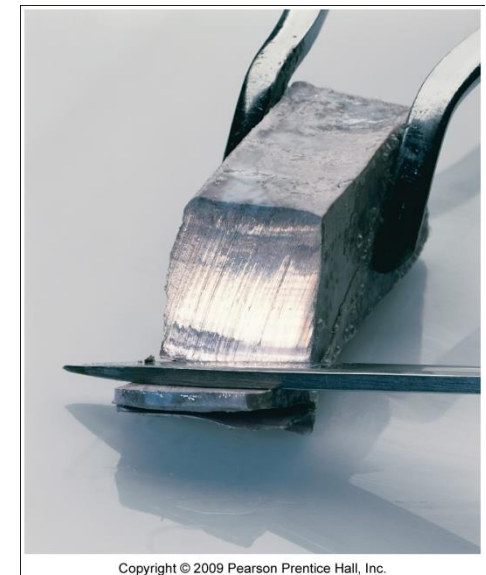
Periodicity

-  = Metal
-  = Metalloid
-  = Nonmetal



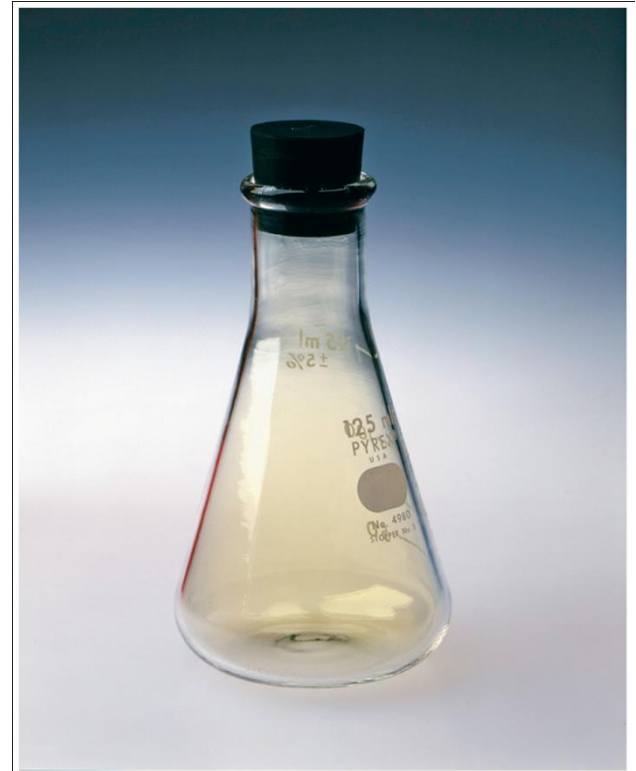
Metals

- 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

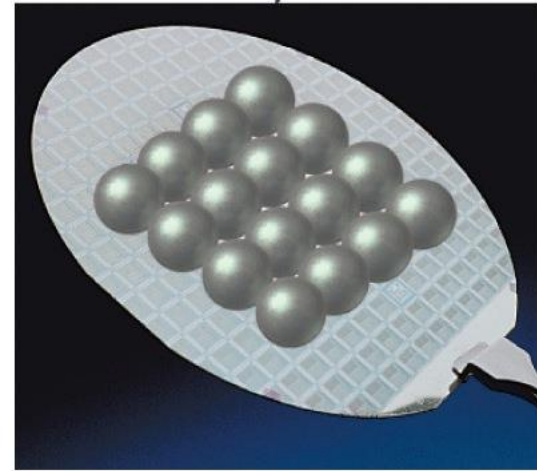
- Found in all 3 states.
- Poor conductors of heat.
- Poor conductors of electricity.
- Solids are brittle.
- Gain electrons in reactions to become negative ions.
- Upper right on the table.
 - Except H.



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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

 = Halogens

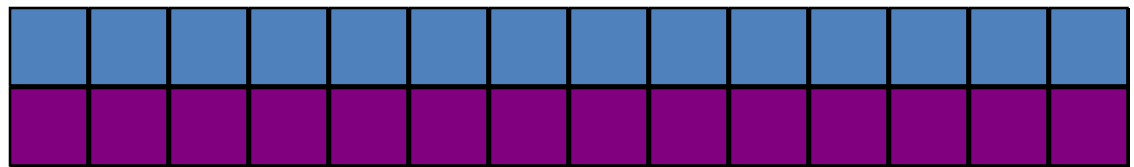
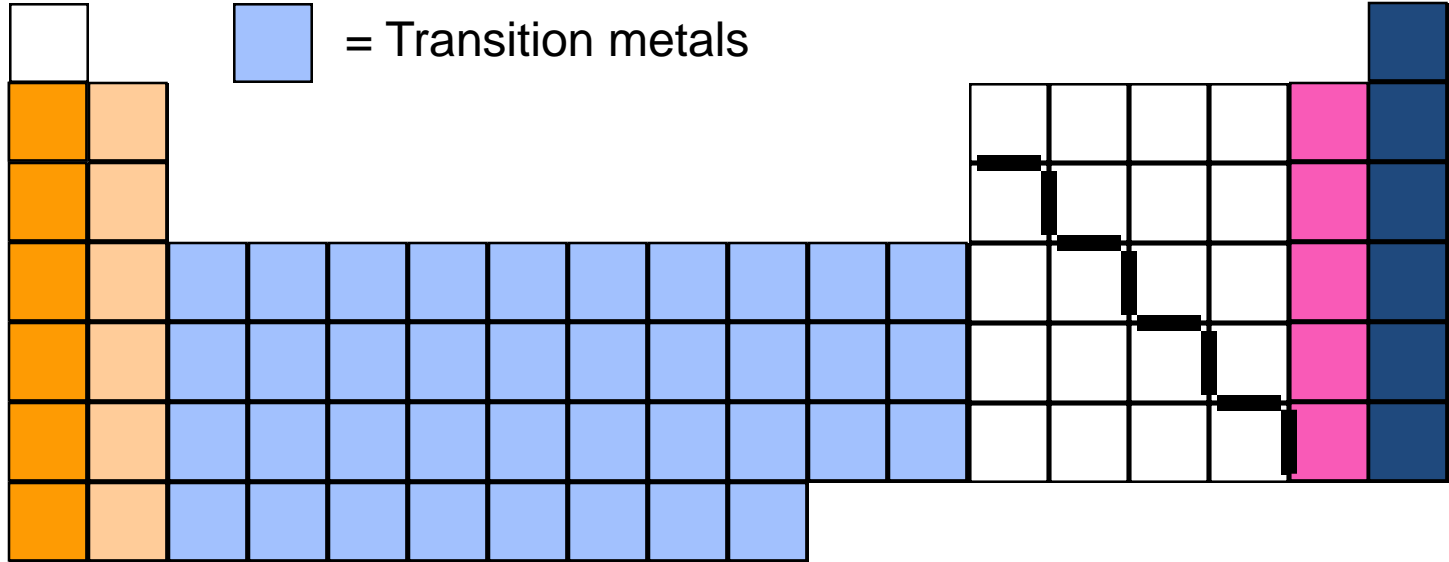
 = Alkali earth metals

 = Lanthanides

 = Noble gases

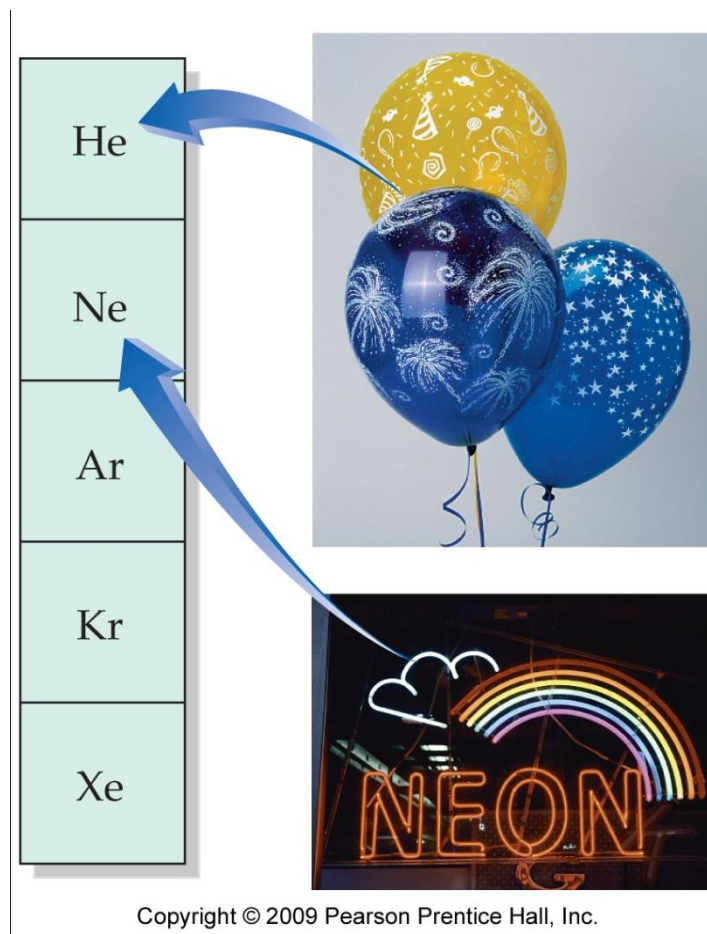
 = Actinides

 = Transition metals



Important Groups—Noble Gases

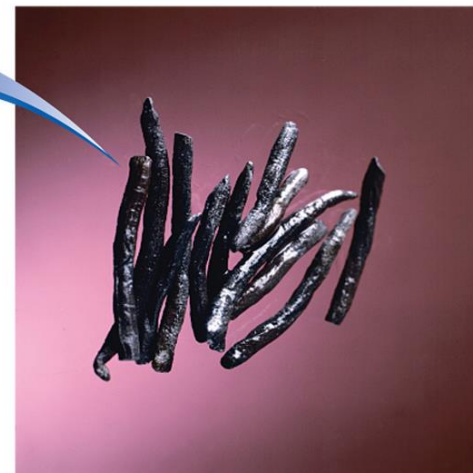
- Group VIIIA = Noble gases.
- All gases at room temperature.
 - Very low melting and boiling points.
- Very unreactive, practically inert.
- Very hard to remove electron from or give an electron to.



Important Groups— Alkali Metals

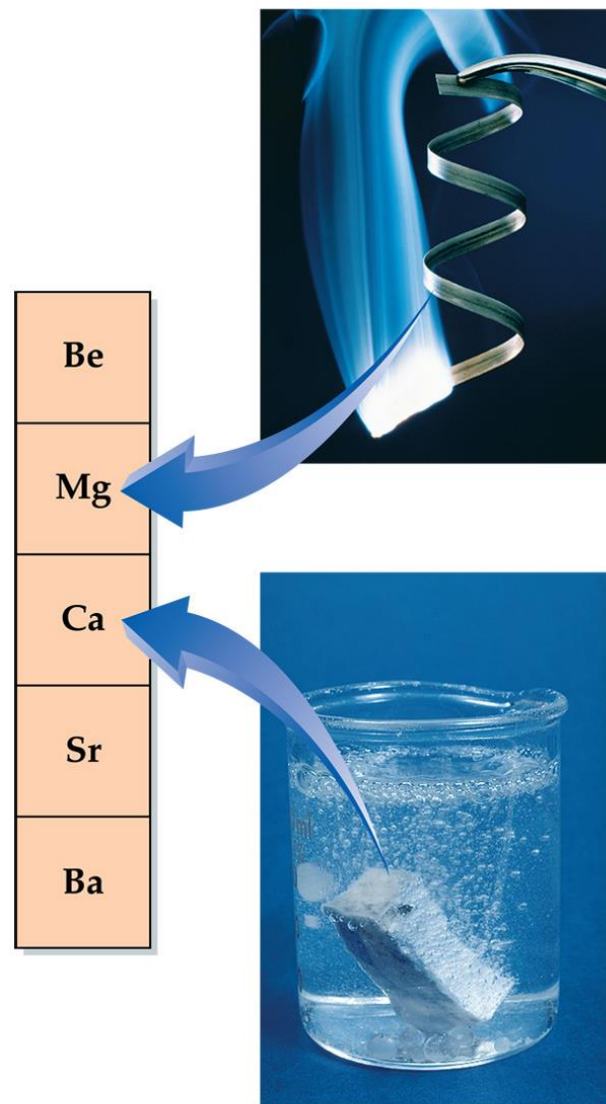
- Group IA = Alkali metals.
- Hydrogen is usually placed here, though it doesn't belong.
- Soft, low melting points, low density.
- Flame tests: Li = red, Na = yellow, and K = violet.
- Very reactive, never found uncombined in nature.
- Tend to form water soluble compounds that are crystallized from seawater
 - Colorless solutions.
- React with water to form basic (alkaline) solutions and H₂:
 - $$2 \text{Na} + 2 \text{H}_2\text{O} \rightarrow 2 \text{NaOH} + \text{H}_2$$
 - Releases a lot of heat.

Li
Na
K
Rb
Cs



Important Groups—Alkaline Earth Metals

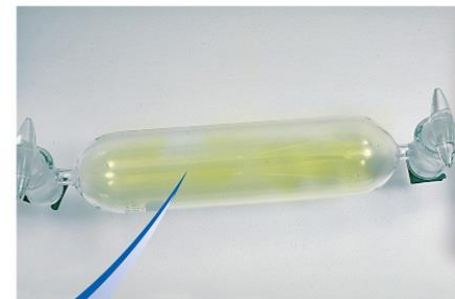
- Group IIA = Alkali earth metals.
- Harder, higher melting, and denser than alkali metals.
 - Mg alloys used as structural materials.
- Flame tests: Ca = red, Sr = red, and Ba = yellow-green.
- Reactive, but less than corresponding alkali metal.
- Form stable, insoluble oxides from which they are normally 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.
- F₂ and Cl₂ gases, Br₂ liquid, and I₂ solid.
- All diatomic.
- Very reactive.
- Cl₂ and Br₂ react slowly with water:
$$\text{Br}_2 + \text{H}_2\text{O} \rightarrow \text{HBr} + \text{HOBr}$$
- React with metals to form ionic compounds.
- hydrogen halides all acids:
 - HF weak < HCl < HBr < HI.

F
Cl
Br
I
At



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⁻
Cl¹⁻		
K¹⁺		
S²⁻		
Sr²⁺		

Practice—Fill in the Table, Continued.

Ion	p⁺	e⁻
Cl¹⁻	17	18
K¹⁺	19	18
S²⁻	16	18
Sr²⁺	38	36

Group 18 elements rarely form ions.

1

	2											13	15	16	17	
Li ⁺	Be ²⁺											Al ³⁺	N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺											Ga ³⁺	P ³⁻	S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺											In ³⁺	As ³⁻	Se ²⁻	Br ⁻	
Rb ⁺	Sr ²⁺													Te ²⁻	I ⁻	
Cs ⁺	Ba ²⁺															

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

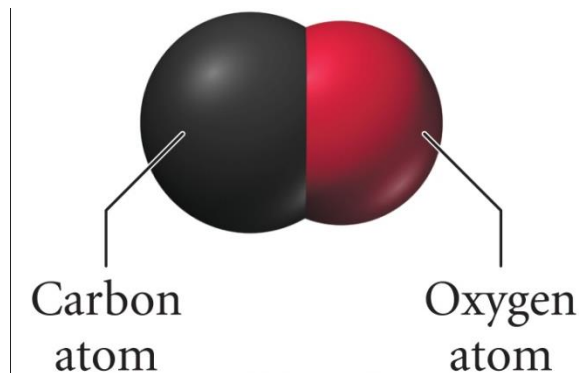
- Substances that are made with the same elements, but have different mass ratios, will be different substances with different properties.

Structure Determines Properties

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

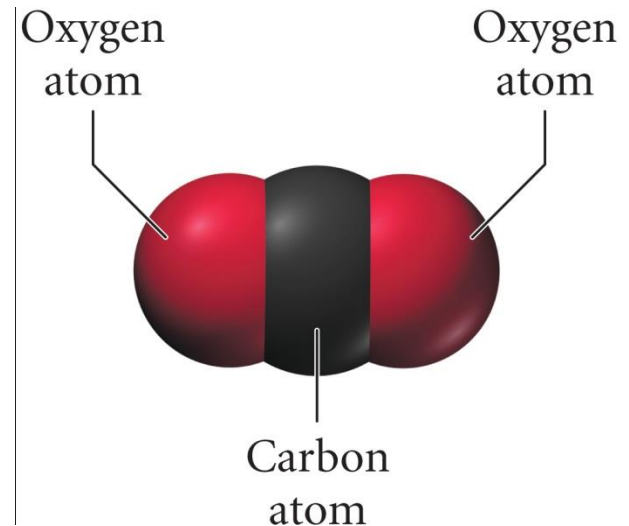
Carbon Monoxide

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:

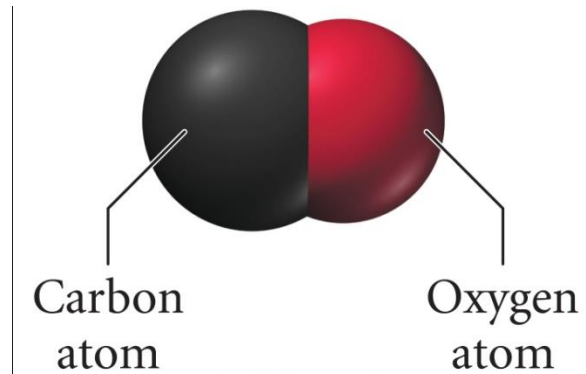
- Two samples of carbon monoxide, obtained from different sources, were decomposed into carbon and oxygen. One sample produced 4.3g O and 3.2g C, and the other sample produced 7.5g O and 5.6 g carbon. Are these results consistent with the law of constant composition?

Chemical Formulas

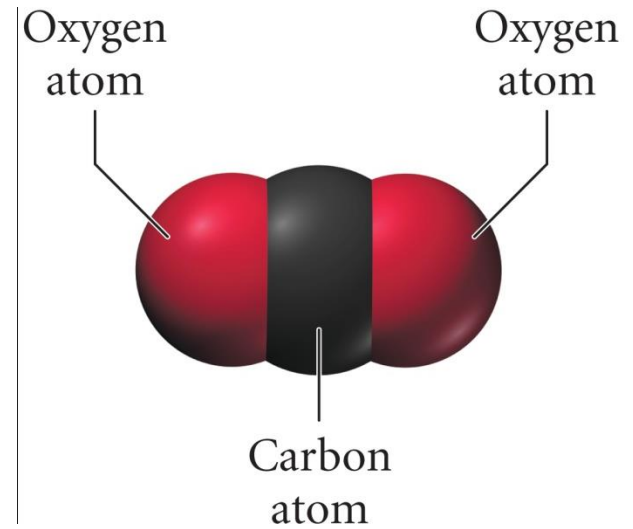
- A chemical formula indicates the types of elements present in the substance.
- The number of atoms of each element in that compound is indicated by a subscript
 - By convention, the subscript 1 is omitted.

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

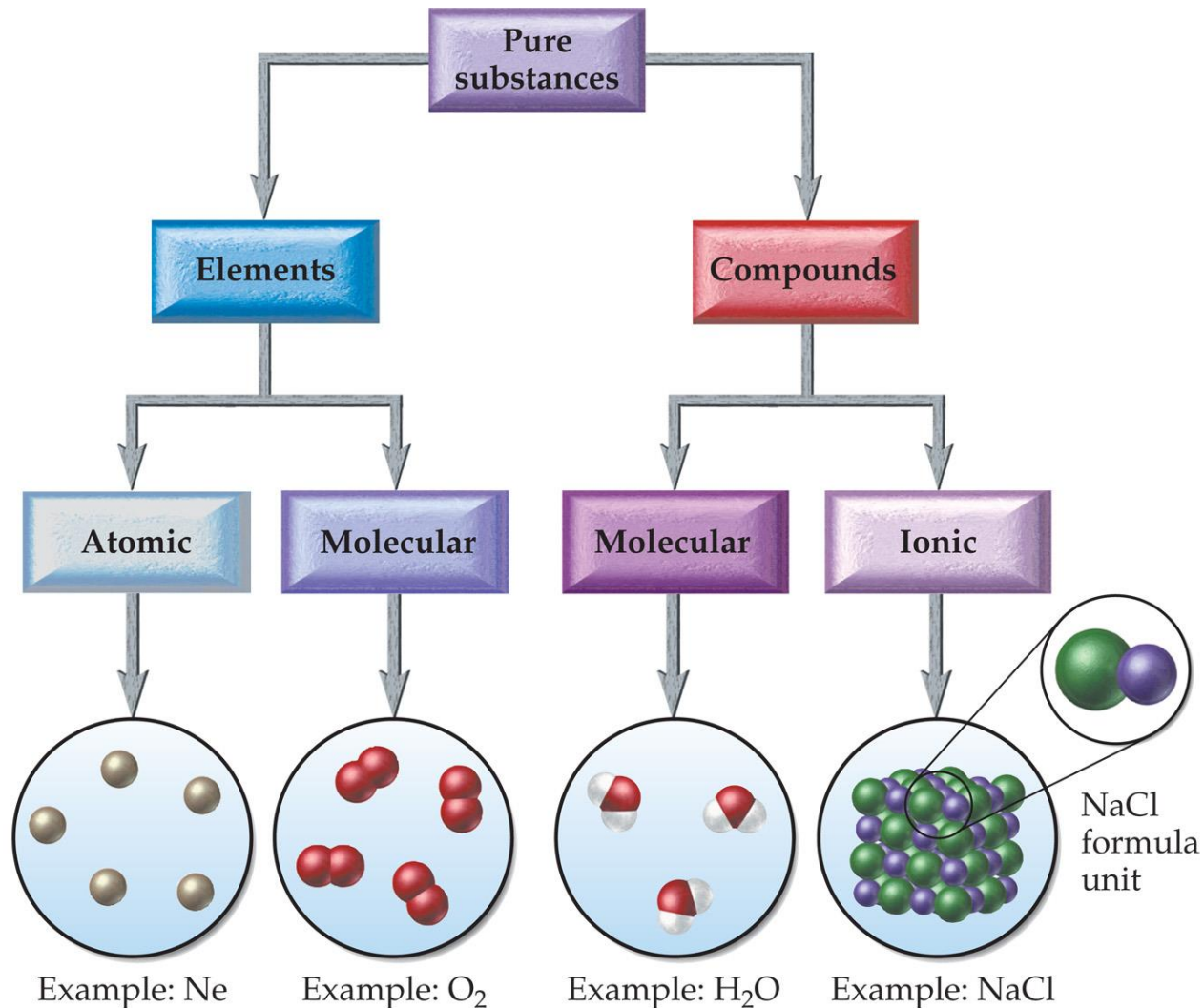
Polyatomic Ions

- 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



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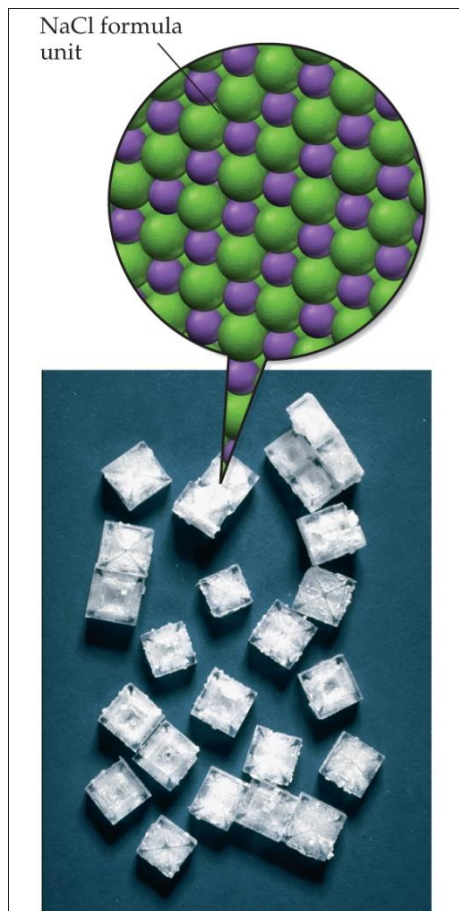


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Compounds

- 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 of their charges.

Ionic and Molecular Compounds



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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

**Ionic
compounds**
Metal and nonmetal

```
graph TD; A["Ionic compounds  
Metal and nonmetal"] --> B["Type I  
Metal forms only  
one type of ion"]; A --> C["Type II  
Metal forms more  
than one type of ion"];
```

Type I
Metal forms only
one type of ion

Type II
Metal forms more
than one type of ion

Ions with a Definite Charge

1A	2A											3A	4A	5A	6A	7A	8A
Li ⁺	Be ²⁺														O ²⁻	F ⁻	
Na ⁺	Mg ²⁺											Al ³⁺			S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺											Ga ³⁺			Se ²⁻	Br ⁻	
Rb ⁺	Sr ²⁺	Transition metals form cations with various charges										In ³⁺			Te ²⁻	I ⁻	
Cs ⁺	Ba ²⁺																

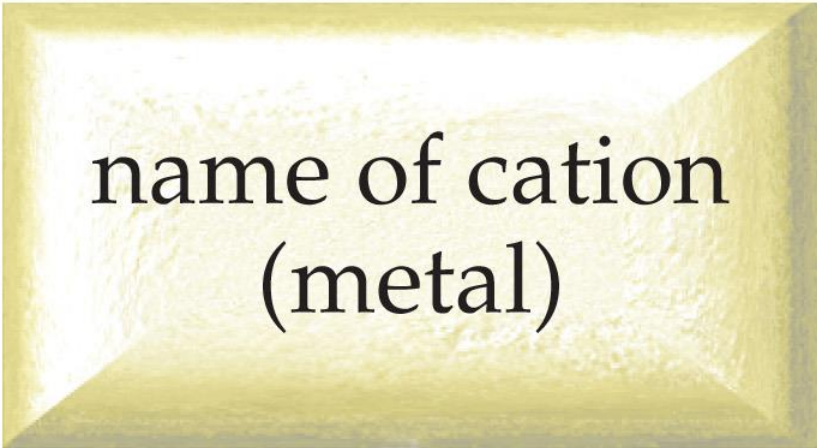
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Polyatomic ions fall in this category, too.

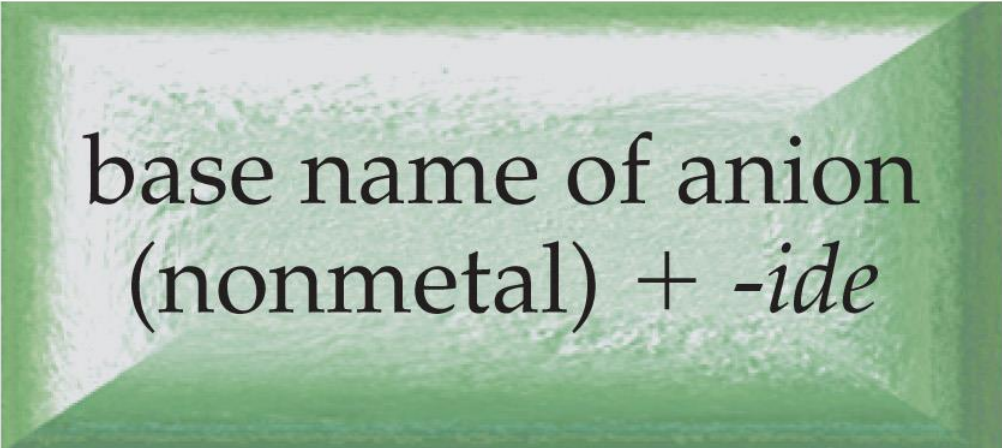
Writing Formulas for Ionic Compounds

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:



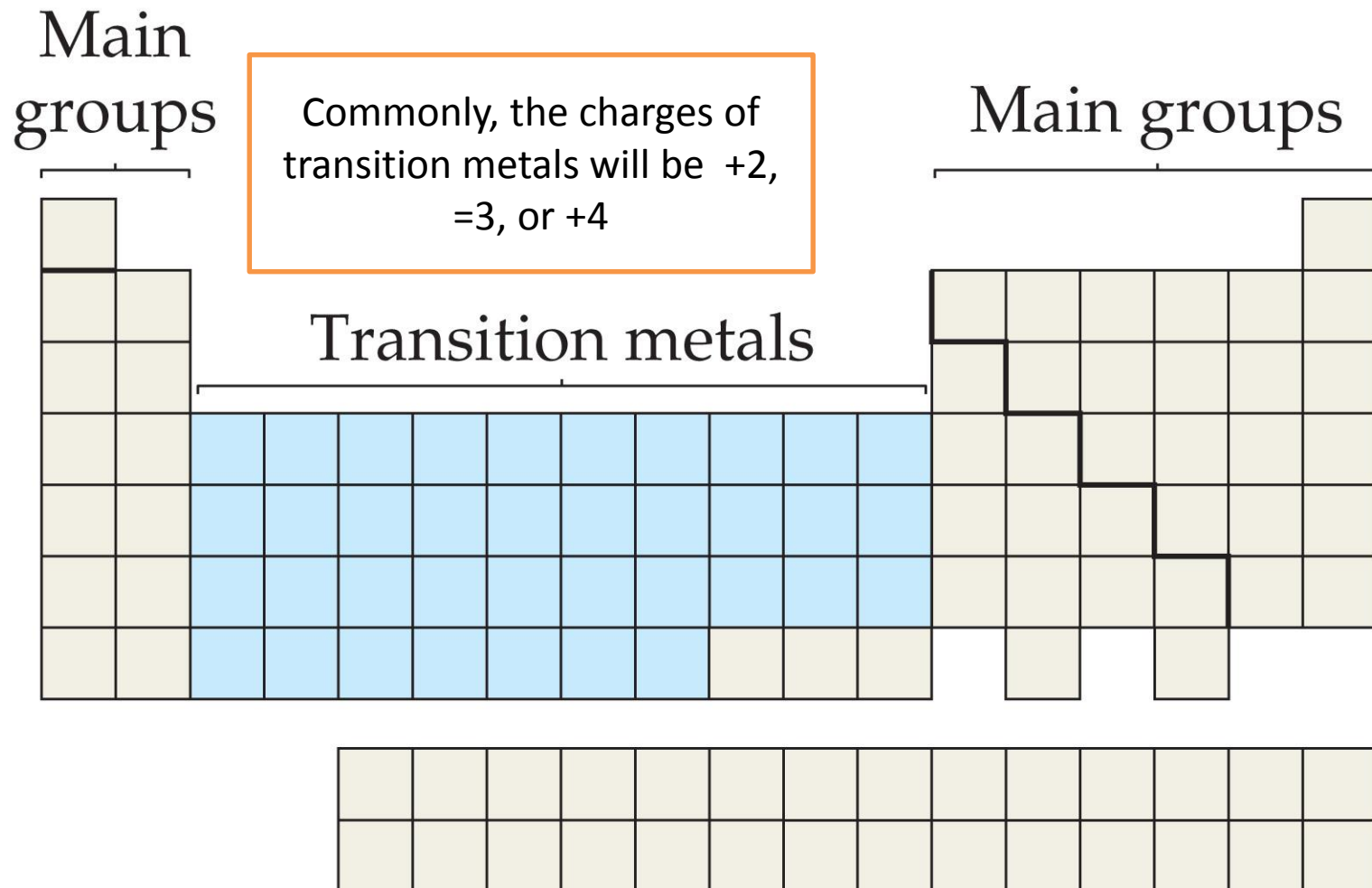
**Ionic
compounds**
Metal and nonmetal

```
graph TD; A["Ionic compounds  
Metal and nonmetal"] --> B["Type I  
Metal forms only  
one type of ion"]; A --> C["Type II  
Metal forms more  
than one type of ion"];
```

Type I
Metal forms only
one type of ion

Type II
Metal forms more
than one type of ion

Type II: Metal could form more than one cation



Naming a Type II Binary Ionic Compound

name of cation
(metal)

charge of cation (metal) in
roman numerals in parentheses

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

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***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



Practice—Name the Following, Continued

1. NH_4Cl Ammonium chloride.

2. CaCl_2 Calcium chloride.

3. $\text{Cu}(\text{NO}_3)_2$ Copper(II) nitrate.

$$\text{NO}_3 = 2(-1) = -2$$

$$\text{Cu} = +2 = 1(2+)$$

Molecular Compounds

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

Naming Molecular (Covalent) Compounds

prefix name of
1st element

prefix base name of
2nd element + *-ide*

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Prefix List:

1- mono

5- penta

2- di

6- hexa

3- tri

7- hepta

4- tetra

8- octa

Practice – Naming Covalent Compounds

- CO

- CO₂

- N₂O₄