Announcements for Wednesday, 02OCT2024

- My Office Hours are **cancelled** for tomorrow

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try This On Your Own

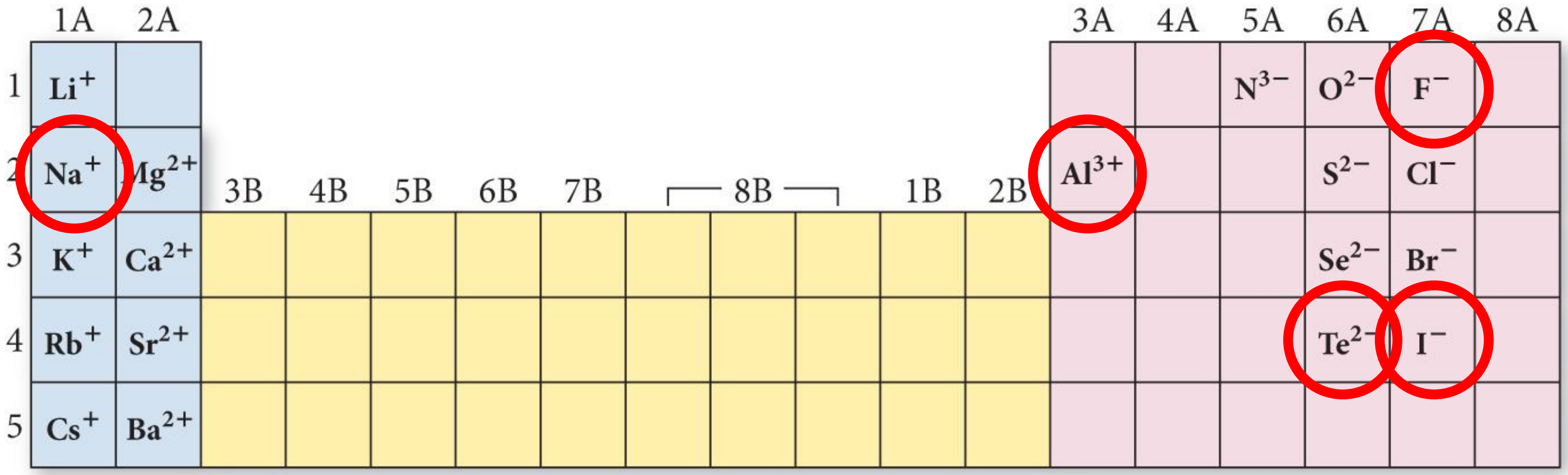
Rank the following ions in order of *decreasing* radius:

Al^{3+}, F^-, I^-, Na^+, Te^{2-}

Te^{2-}	>	I^-	>	F^-	>	Na^+	>	Al^{3+}
221 pm		216 pm		136 pm		95 pm		50 pm

isoelectronic

isoelectronic



Try This On Your Own

- Rank the following species in order of increasing ionization energy: Ba, Li, Be^+, Cs, Li^+

Cs < Ba < Li < Be^+ < Li^+ (Li^+ > Be^+; removal of core e^-)

Try This On Your Own

- Identify the element from **Period 2** has the following successive ionization energies: **carbon**

$\underbrace{\qquad\qquad}$ **Li, Be, B, C, N, O, F, Ne**

$IE_1 = 1{,}086$ kJ/mol

increase in ionization energy by a factor of $\frac{2353\text{ kJ}}{1086\text{ kJ}} = 2.16$

$IE_2 = 2{,}353$ kJ/mol

increase in ionization energy by a factor of $\frac{4621\text{ kJ}}{2353\text{ kJ}} = 1.96$

$IE_3 = 4{,}621$ kJ/mol

increase in ionization energy by a factor of $\frac{6223\text{ kJ}}{4621\text{ kJ}} = 1.35$

$IE_4 = 6{,}223$ kJ/mol

increase in ionization energy by a factor of $\frac{37831\text{ kJ}}{6223\text{ kJ}} = \mathbf{6.08!!}$

$IE_5 = 37{,}831$ kJ/mol

increase in ionization energy by a factor of $\frac{47277\text{ kJ}}{37831\text{ kJ}} = 1.25$

$IE_6 = 47{,}277$ kJ/mol

- The significant jump in energy between IE_4 and IE_5 indicates that the 5th electron is the first core electron being removed and that the first four electrons were valence electrons.
- Group 4 A elements have 4 valence electrons, so the Period 2 element is carbon

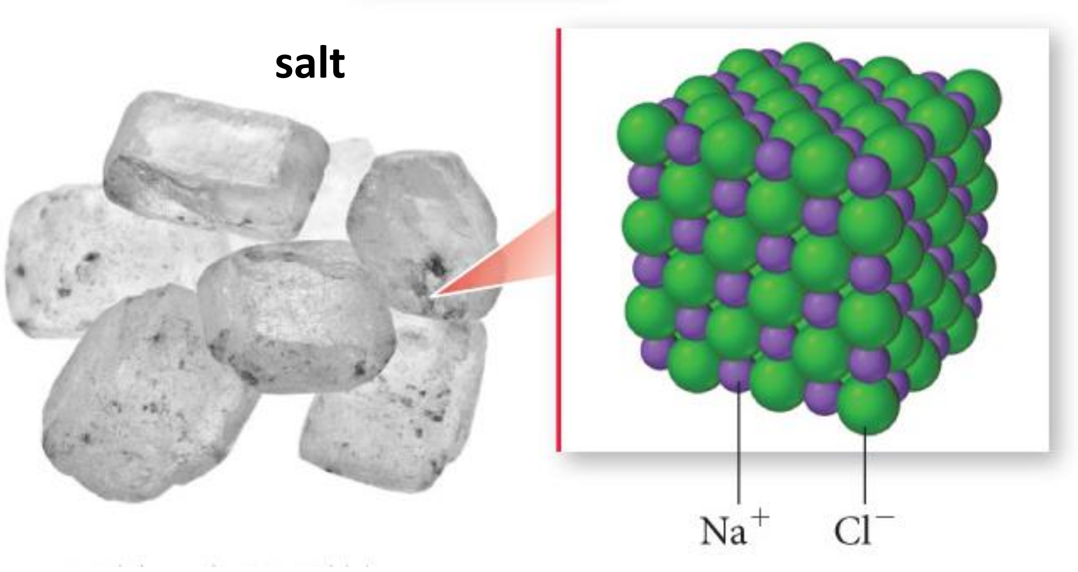
Chapter 4: Molecules and Compounds

Some questions we'll try to answer

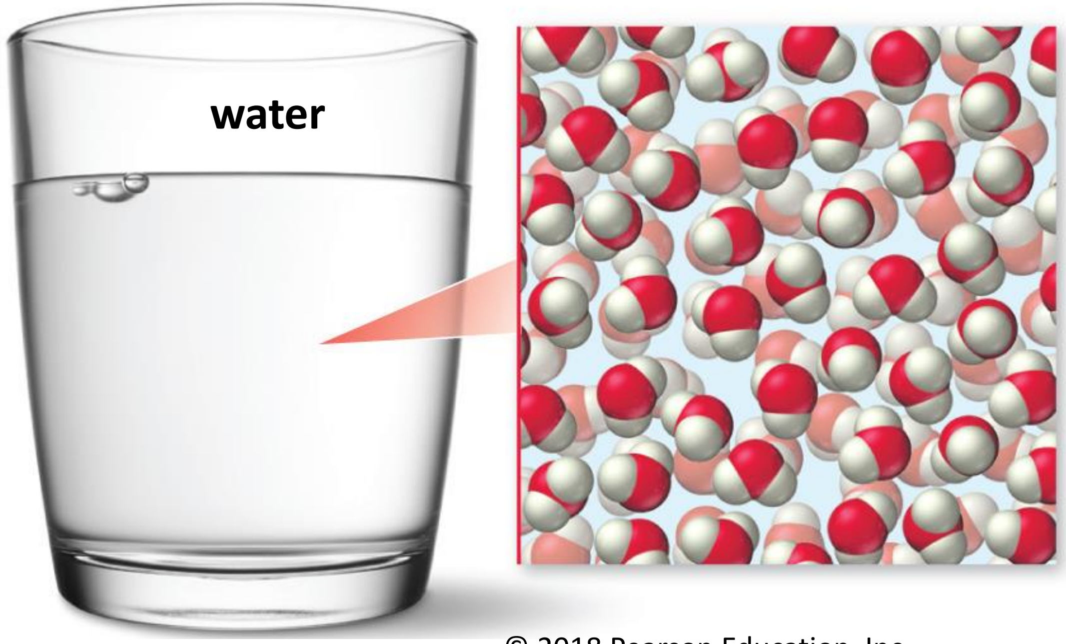
- How do ionic compounds differ from molecular compounds on both the atomic and macroscopic levels?
- What are the different ways that we can express the composition of a compound?
- How do we systematically name ionic and molecular compounds and how can we establish chemical formulas for these compounds from their names?
- How do monatomic ions differ from polyatomic ions?
- How can we use chemical formulas and mass percent compositions as conversion factors?
- How do we determine a compound's chemical formula from experimental data?

Types of Chemical Compounds: Ionic vs. Molecular

- Knowing the type of compound that you're dealing with IS HUGE!!
- dictates how you should picture it in your mind, how you represent the compound on paper, the type of properties you should expect from it, how you name it, how you represent its composition, etc.
- THE DIFFERENCES IN BEHAVIOR STEM FROM FUNDAMENTAL DIFFERENCES IN THE PARTICLES THAT COMPOSE THEM!



boiling point = 1413 °C
3-D lattice composed of cations and anions
no individual Na–Cl units
bonds based on electron transfer

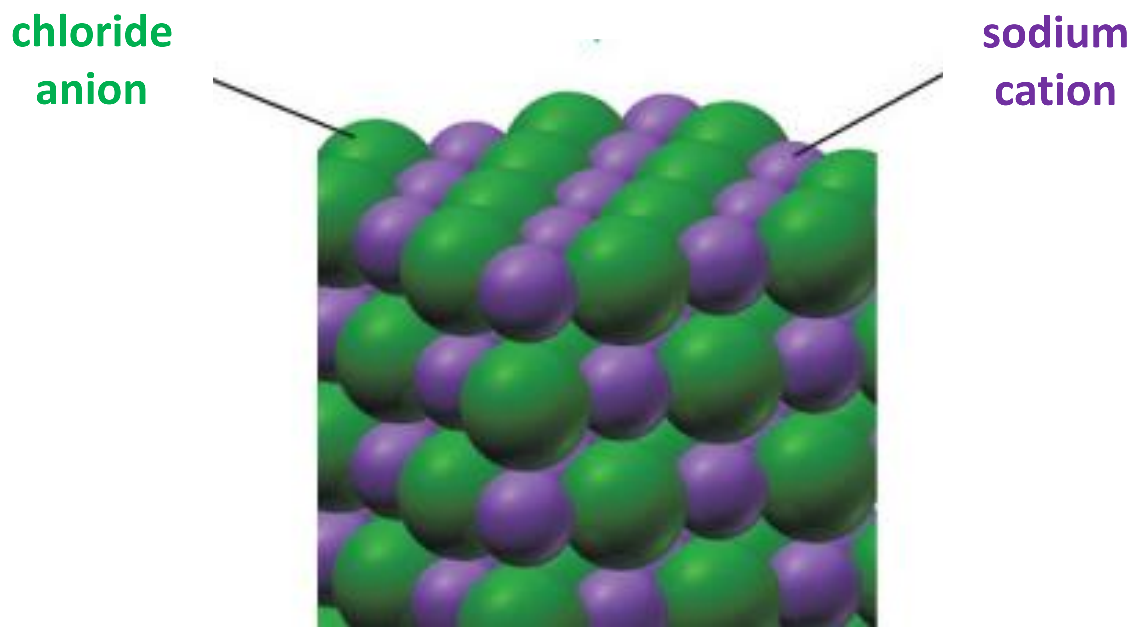


boiling point = 100 °C
molecules composed of neutral atoms
individual molecules w/specific shapes
bonds based on electron sharing

Types of Chemical Bonds: Ionic vs. Covalent

Why do bonds occur?

- forming bonds lowers the energy of the system
  - atoms /ions make bonds to achieve full outer shells
  - weak bonds are broken and replaced with stronger bonds



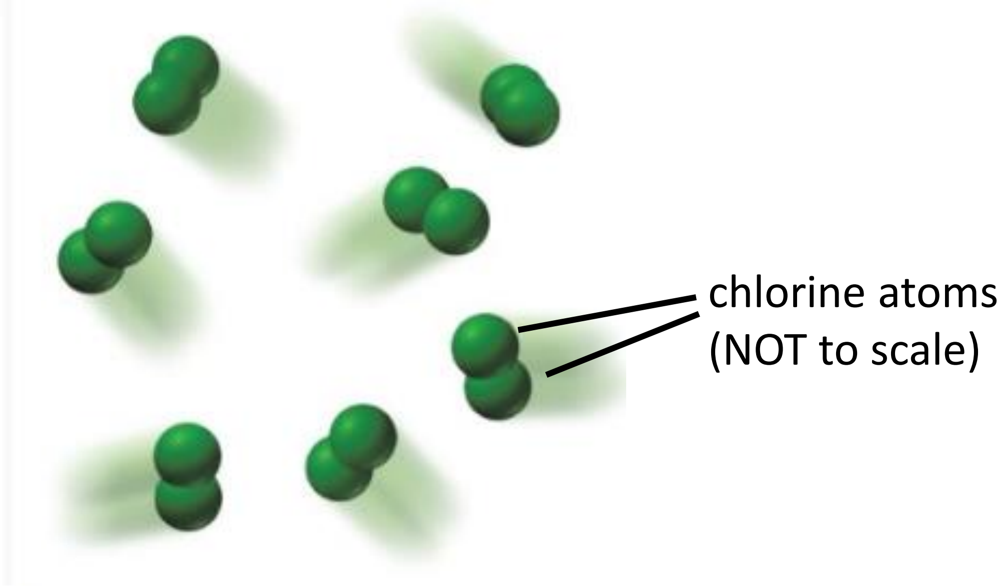
ionic bonds

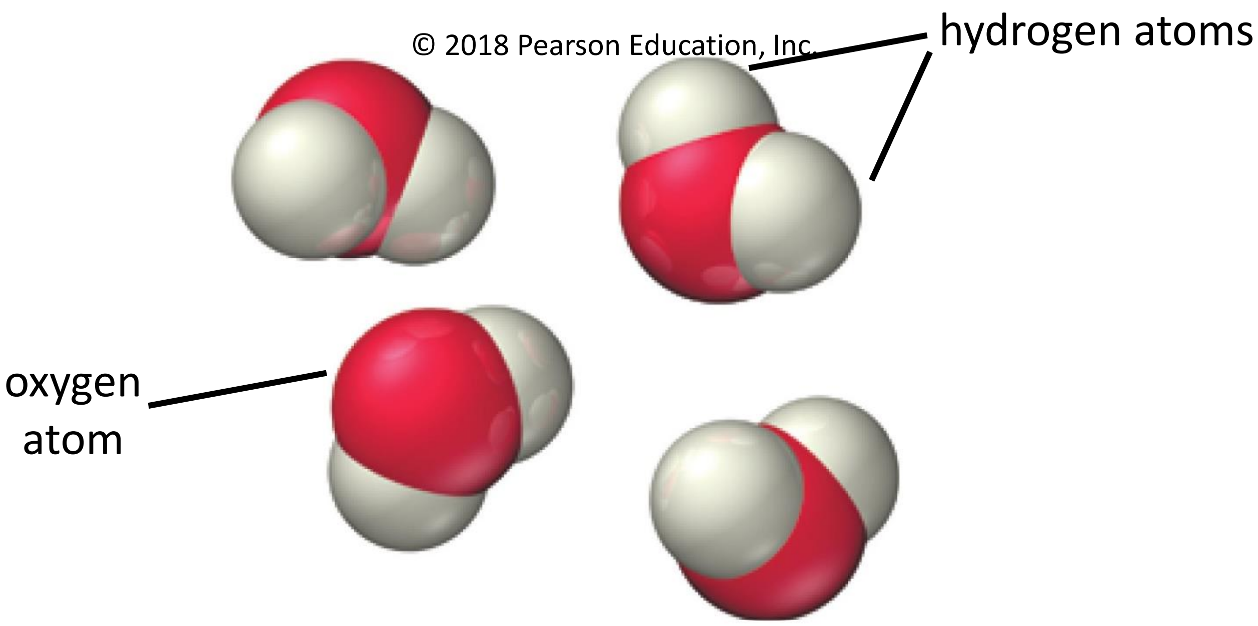
- ***usually*** occurs between metals and nonmetals (more to come…)
- more correctly, it's the bond between a cation and an anion
  - metals have low ionization energies, nonmetals have highly negative electron affinities
  - **electron(s) get transferred from metal to nonmetal so that both species achieve filled outer shells**

Types of Chemical Bonds: Ionic vs. **Covalent**

<u>covalent bonds</u>

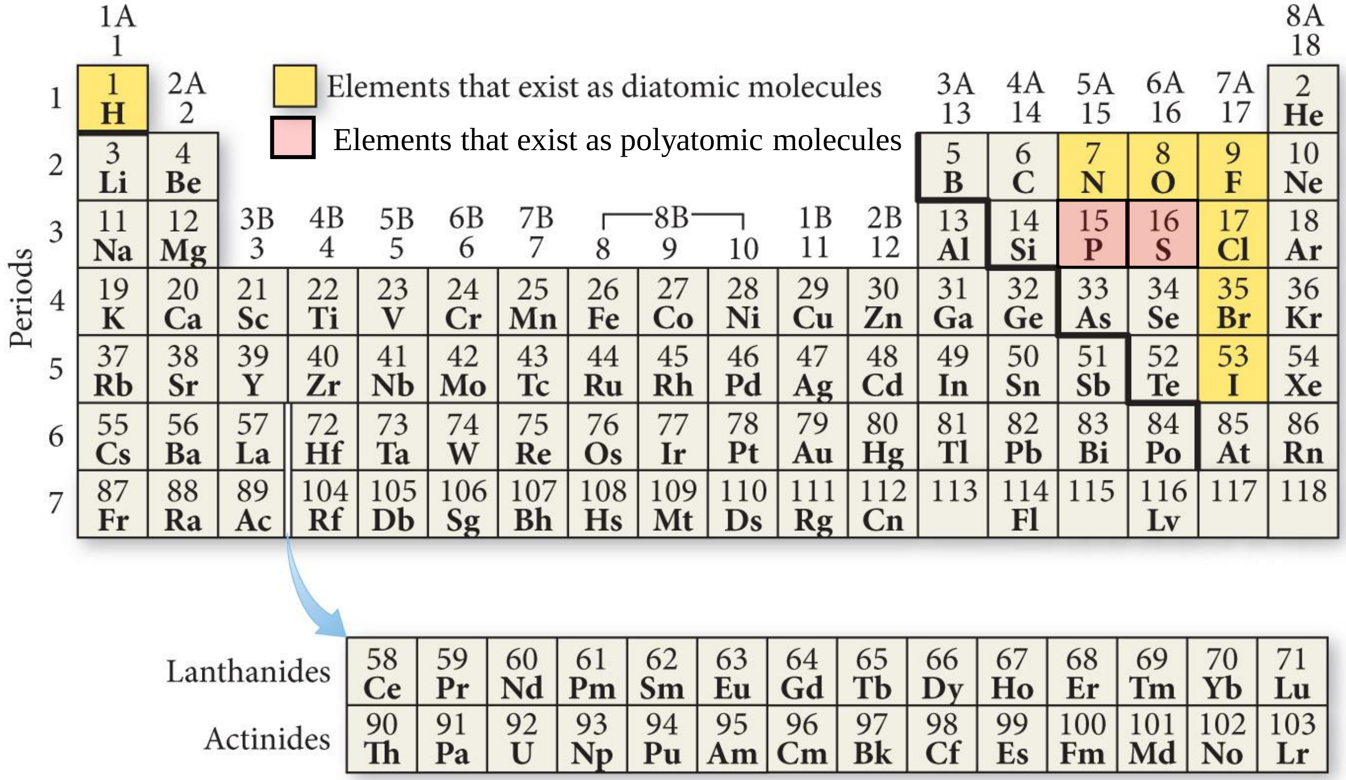
- ***usually*** occurs between nonmetals
  - can be the same (Cl_2, O_3, S_8 etc) or different (H_2O)
  - nonmetals have relatively high ionization energies and don't like to lose electrons
  - **they complete their outermost energy levels by sharing electrons between them**





An Aside: Diatomic and Polyatomic Elements

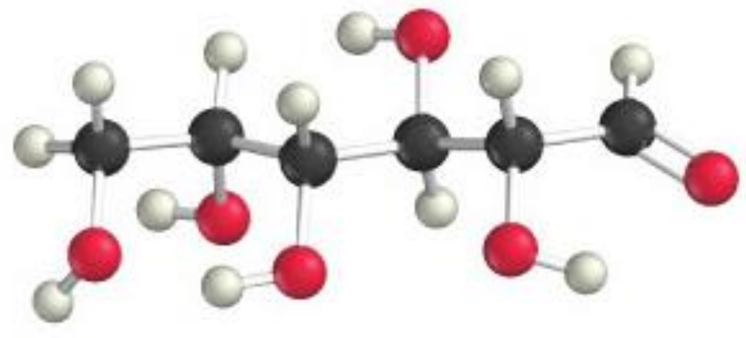
- elements that occur as molecules of two (or more) atoms covalently bonded together
- individual atoms of these elements are too reactive to exist on their own under normal conditions
  - Diatomic elements: H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2,
  - Polyatomic elements: P_4 and S_8
- Noble gases, metals and the rest of the elements can naturally occur as **monatomic(?!?)** species
- Beware of context when elemental names are being used
  - for example: “hydrogen reacts with oxygen to form water”
  - “hydrogen” = hydrogen GAS = hydrogen MOLECULES = $H_2(g)$ = molecular hydrogen
    - NOT individual hydrogen atoms
  - individual hydrogen atoms = “atomic hydrogen” and can be found plentifully in stars in the plasma state



Chemical Formulas: Empirical vs. Molecular

chemical formulas indicate the type and number of each element present in a compound

- **empirical formula**: gives *relative number of atoms* of each element expressed in *lowest whole number ratio*
- **molecular formula**: gives **actual number of atoms** of each element **in a molecule**
- chemical formulas of ionic compounds always given as empirical formulas



1 molecule of glucose

chemical formulas as source of conversion factors (IMPORTANT!)

Glucose: $C_6H_{12}O_6$

- 6 carbon *atoms* per 1 *molecule* of glucose **OR**
- 6 **moles of carbon** (atoms) per 1 **mole of glucose** (molecules)…etc.

empirical formula: CH_2O

$\downarrow \times 6$

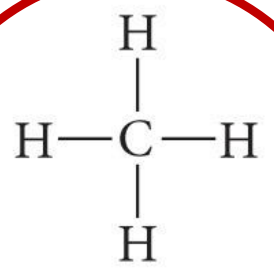
molecular formula: $C_6H_{12}O_6$

Ways to represent molecules

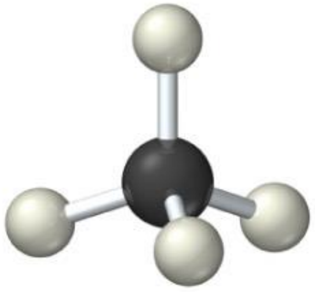
- elements that occur as molecules of two (or more) atoms covalently bonded together

CH_4

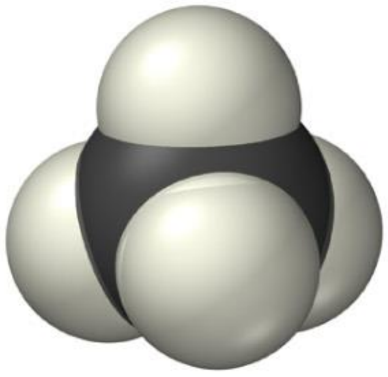
Molecular formula



Structural formula

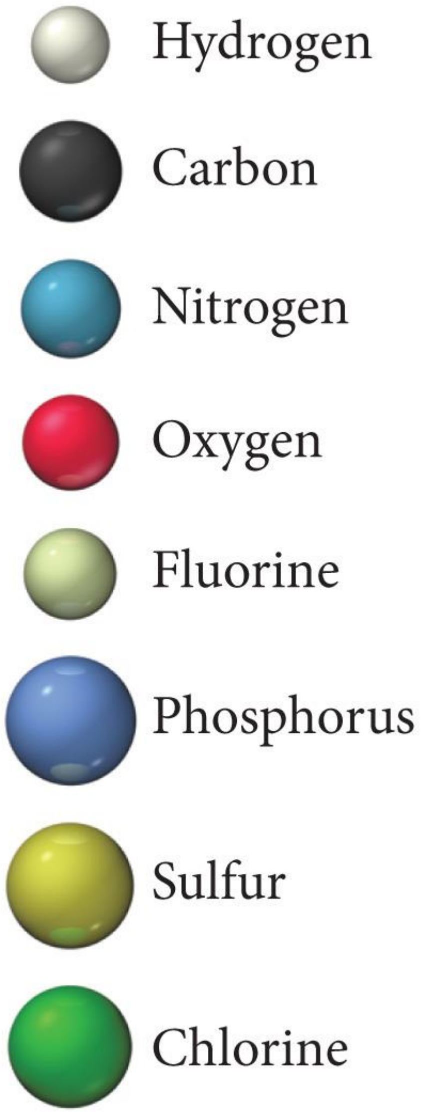


Ball-and-stick model



Space-filling model

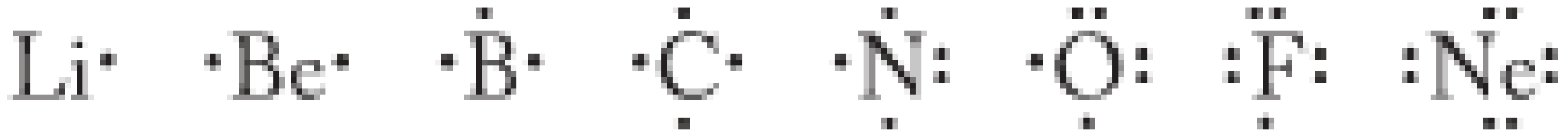
usual colors of atoms in model kits



STUDENT NOTE: Cover on your own

Lewis Electron-Dot Structures

- an atom’s valence electrons are represented as dots around the atom’s chemical symbol
- # dots = # valence electrons = Main Group #



- electron dot structures are an easy method to understand the bonding patterns of Main Group elements

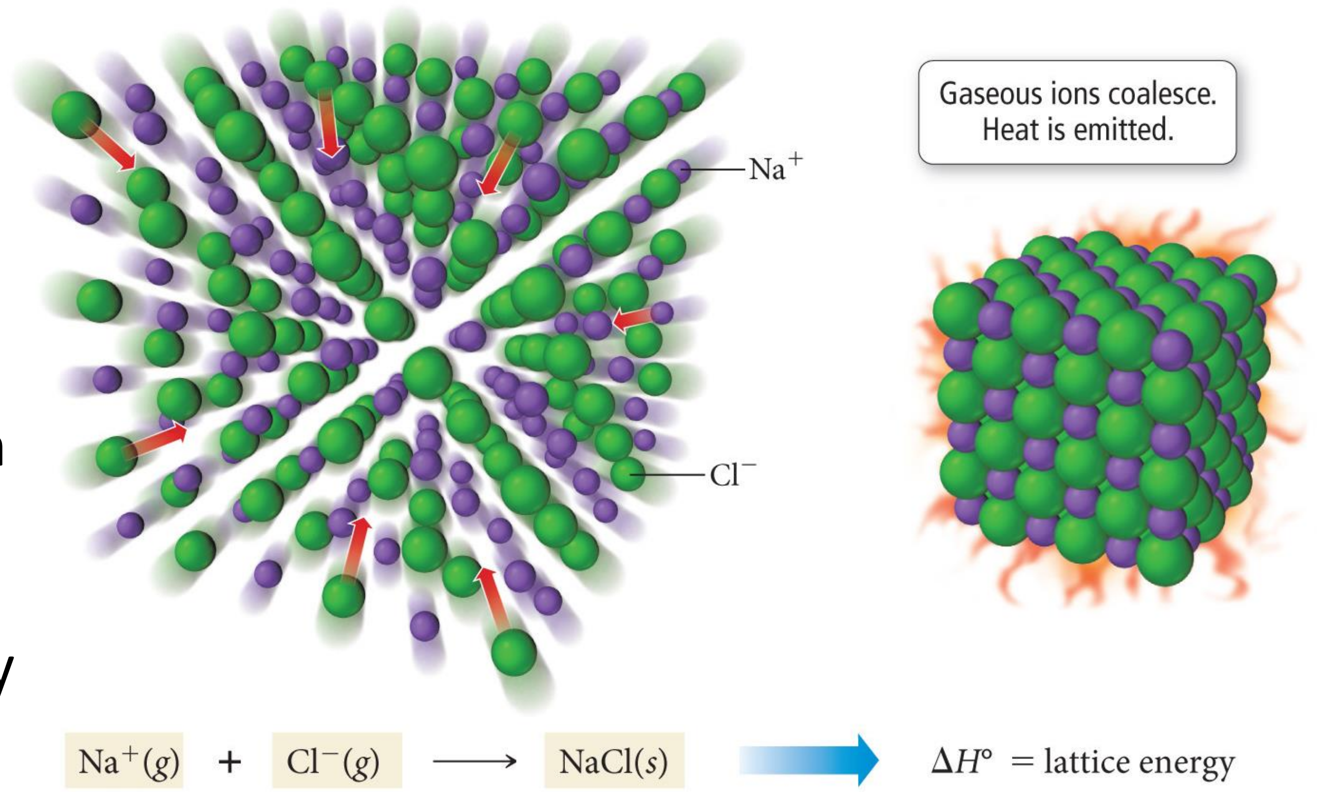
- Octet Rule: when atoms bond, they tend to gain, lose, or share electrons to result in a noble gas–like configuration.
  - $ns^2\ np^6$

STUDENT NOTE: Cover on your own

Energetics of Ionic Bonding

Why do ionic compounds form?

- **Lattice Energy =** the energy associated when ions in the gas phase combine to form an ionic solid
  - energy is always released (i.e., exothermic) due to the interaction of oppositely charged ions (remember Coulomb's law)
  - release of large amounts of energy causes the ionic solid to be relatively stable

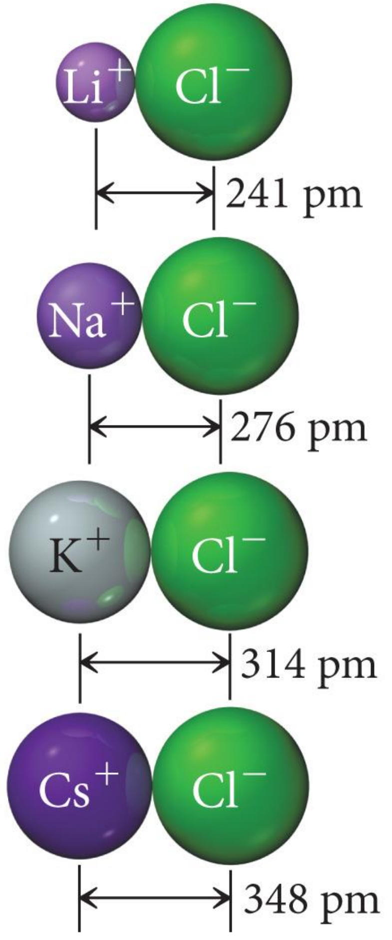


MEMORIZE: $X^{2+}(g) + 2\,Y^{-}(g) \rightarrow XY_2(s)$

Factors Impacting Lattice Energy

Lattice Energies of Some Compounds (kJ/mol)					
LiCl	–834				
NaCl	–788	MgO	–3795	ScN	–7547
KCl	–701	CaO	–3414		
CsCl	–657	SrO	–3217		

	$\lvert q_1 \times q_2 \rvert$
NaCl	1
MgO	4
ScN	9



- trends can be understood using ***Coulomb's law***
  - the potential energy between two charged particles

$$LE \propto \frac{q_1\, q_2}{r}$$

  - q_1 *and* q_2 = *charges of ions*, r = *distance between ions*
  - |LE| proportional to magnitude of charges
  - |LE| ***inversely*** proportional to distance (sum of ionic radii)
    - *usually* charge has more impact on lattice energy than distance

Try This

Rank the following ionic compounds in order of increasing ***magnitude*** of lattice energy:

$$|LE| \propto \frac{|q_1\, q_2|}{r}$$

$\lvert q_1 \times q_2 \rvert = 6$	$\lvert q_1 \times q_2 \rvert = 1$	$\lvert q_1 \times q_2 \rvert = 1$	$\lvert q_1 \times q_2 \rvert = 2$
3+ 2–	**1+ 1–**	**1+ 1–**	**1+ 2–**
Al_2O_3	NaI	NaF	Li_2O
	95 pm 216 pm	**95 pm 136 pm**	
	r ≈ 311 pm	**r ≈ 231 pm**	

NaI –688 kJ/mol < NaF –904 kJ/mol < Li_2O –2925 kJ/mol < Al_2O_3 –15,916 kJ/mol