Announcements for Wednesday, 09OCT2024

- Tomorrow's Office Hours are Extended to go until 4:00 PM
- Exam 1 should be available for reviewing through ***Gradescope*** by tomorrow
- Application deadline for transfer into Chem 133 is **Thursday, 10OCT2024**
  - if you got $\leq$ 44% on the first exam, you should ***strongly*** consider transferring as Chem 161 will only get harder as the semester progresses
  - see Canvas announcement from Oct 8 and "Transfer to Chemistry 133" module for more details and application directions

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

Try These On Your Own

- What is the molar mass of glucose ($C_6H_{12}O_6$)? 180.16 g/mol
- How many hydrogen atoms are in 88.0 ng glucose? 3.53×10^{15} hydrogen atoms
- How many molecules in 5.21 g glucose? 1.74×10^{22} molecules of glucose
- A sample of glucose contains 5.55×10^{24} carbon atoms. What amount of glucose, in moles, is there? 1.54 moles glucose
- What amount of oxygen atoms, in moles, is in 25.0 g glucose? 0.833 moles of oxygen atoms
- How many atoms in total are in 100.0 g glucose? 8.02×10^{24} atoms

Try This On Your Own

- Calculate the mass percent composition of all elements in 255 g of chromium(III) phosphate trihydrate

irrelevant information!

$$CrPO_4 \cdot 3H_2O$$

$$1 \text{ mole } CrPO_4 \cdot 3H_2O = 52.00 + 30.97 + 112.0 + 6.048 = 201.02 \text{ g/mol}$$

$$\text{mass \% Cr} = \frac{52.00\text{ g}}{201.02\text{ g}} \times 100\% = 25.87\% \text{ Cr by mass}$$

$$\text{mass \% P} = \frac{30.97\text{ g}}{201.02\text{ g}} \times 100\% = 15.41\% \text{ P by mass}$$

$$\text{mass \% O} = \frac{112.0\text{ g}}{201.02\text{ g}} \times 100\% = 55.71\% \text{ O by mass}$$

$$\text{mass \% H} = \frac{6.048\text{ g}}{201.02\text{ g}} \times 100\% = 3.01\% \text{ H by mass}$$

100% total

Determining Molecular Formula from Empirical Formula and Molar Mass

- remember that a compound's molecular formula is a whole-number multiple of its empirical formula

molecular formula = empirical formula × *n* *(n = 1, 2, 3…)*

glucose: $C_6H_{12}O_6$ $CH_2O \times 6$

- because of this, the molar mass of compound is also a whole-number multiple of the compound's empirical molar mass:

$$\mathrm{n} = \frac{\textit{molecular}\ \text{molar mass}}{\textbf{empirical}\ \text{formula mass}}$$

Determining Molecular Formula from Empirical Formula and Molar Mass (continued)

glucose: CH_2O × *n* → $C_6H_{12}O_6$ where *n* = 6

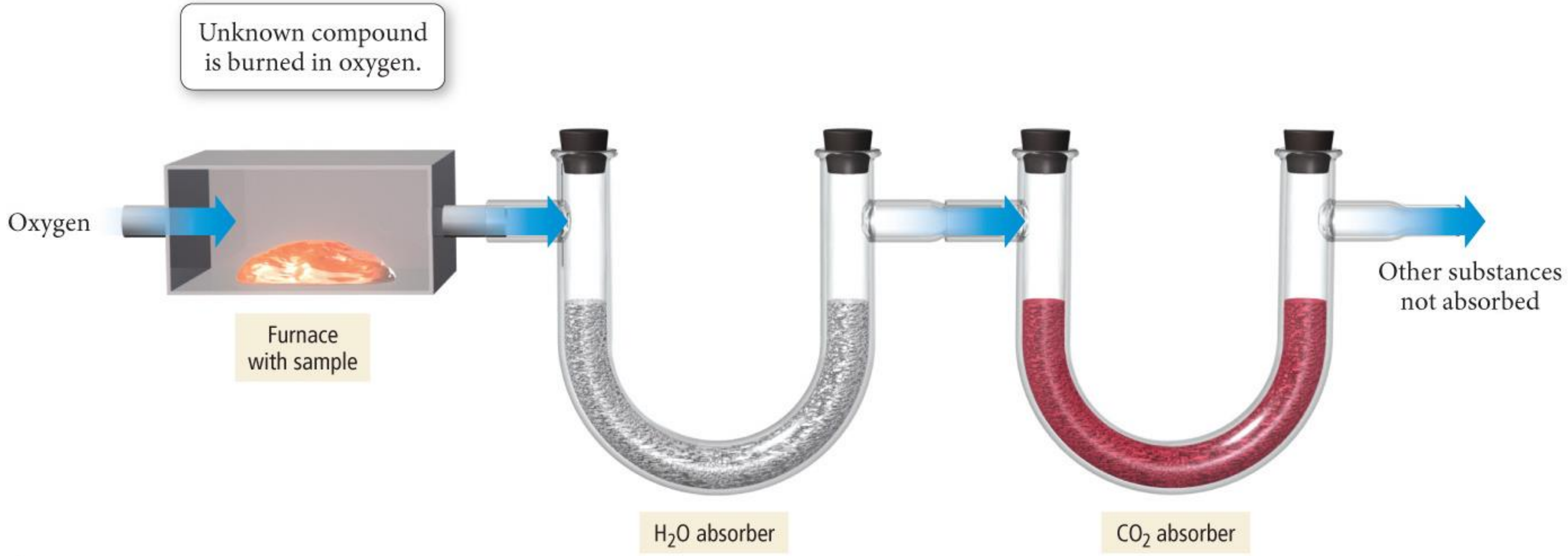
$$n = \frac{\textbf{\textit{molecular}}\ \textbf{molar mass}}{\textbf{empirical}\ \text{molar mass}}$$

$$= \frac{(6 \times 12.01) + (12 \times 1.008) + (6 \times 16.00)}{12.01 + (2 \times 1.008) + 16.00} = \frac{180.16}{30.026} = 6$$

- empirical formula and molar mass must be established separately

Determining Empirical Formula by Combustion Analysis

completely reacting an unknown compound with ***oxygen gas (O_2(g))***
and recording the masses of known products



Combustion Analysis

- ***completely*** reacting an unknown compound with ***oxygen gas (O_2(g))*** and recording the masses of known products

$C_XH_Y + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$ **vs.** $C_XH_YO_Z + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

??

- working our way backwards from the mass of products to the number of atoms present in the original compound
- all atoms need to be accounted for
- start with known mass of sample to be combusted and form CO_2 and H_2O.

mass CO_2 ⟶ moles CO_2 ⟶ moles C from compound

mass H_2O ⟶ moles H_2O ⟶ moles H in H_2O ⟶ moles H from compound

mass O compound = total mass – mass C – mass H ⟶ moles O from compound

Combustion Analysis

- Complete combustion of 1.23 g of a compound containing C, H, and O yields 1.74 g CO_2 and 1.07 g H_2O. In a separate experiment, the formula mass of the compound is determined to be 62.07 amu. Provide the molecular formula of this compound.

$$1.74\ g\ CO_2 \times \frac{1\ mole\ CO_2}{44.01\ g} \times \frac{1\ mole\ C\ atoms}{1\ mole\ CO_2} = 0.0395\ moles\ C \times \frac{12.01\ g\ C}{1\ mole\ C} = 0.474\ g\ C$$

$$1.07\ g\ H_2O \times \frac{1\ mole\ H_2O}{18.02\ g} \times \frac{2\ mole\ H\ atoms}{1\ mole\ H_2O} = 0.1188\ moles\ H \times \frac{1.008\ g\ H}{1\ mole\ H} = 0.120\ g\ H$$

$$1.23\ g\ compound - 0.474\ g\ C - 0.120\ g\ H = 0.636\ g\ O \times \frac{1\ moles\ O}{16.00\ g\ O} = 0.0397\ mol\ O$$

$$C_{\frac{0.0395}{0.0395}}\ H_{\frac{0.1188}{0.0395}}\ O_{\frac{0.0397}{0.0395}}$$

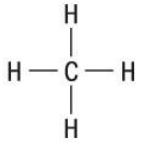
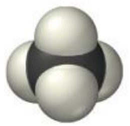
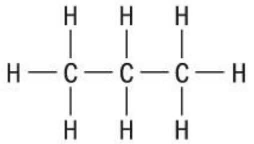
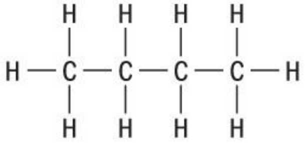
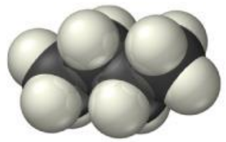
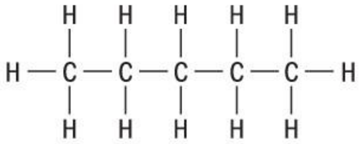
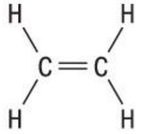
$$n = \frac{molar\ mass}{EF\ mass} = \frac{62.07}{(1)(12.01) + (3)(1.008) + (1)(16.00)} = \frac{62.07}{31.03} = \mathbf{2}$$

$$C_1\ H_3\ O_1 \longrightarrow \underset{\text{empirical formula}}{CH_3O} \xrightarrow{n\,=\,2} \underset{\text{molecular formula}}{C_2H_6O_2}$$

Organic Compounds

- organic compounds = compounds composed of carbon, hydrogen, and often other nonmetals (O, N, S, P, F, Cl, Br, I)
- the key element is carbon
  - able to make four bonds (i.e., tetravalent) and can bond to itself to form long chains
- **hydrocarbon =** organic compound containing only carbon and hydrogen

TABLE 4.5 **Common Hydrocarbons**

Name	Molecular Formula	Structural Formula	Space-filling Model
Methane	CH_4		
Propane	C_3H_8		
n-Butane*	C_4H_{10}		
n-Pentane*	C_5H_{12}		
Ethene	C_2H_4		
Ethyne	C_2H_2		

Functional Groups

- **groups of atoms** that have a characteristic influence on the shape and reactivity of a hydrocarbon containing the functional group
- molecules having the same functional group are categorized into the same organic family
  - compounds in the same family exhibit similar chemical behaviors
- R = a generic carbon-containing group
- be able to identify **alcohols, carboxylic acids,** and **amines**

Family	General Formula	Example
Alcohols	R—OH	CH_3CH_2OH
Carboxylic acids	R—C(=O)—OH	H_3C—C(=O)—OH
Amines	R—N(R)—R	H_3CH_2C—N(H)—H

Determining Empirical and Molecular Formulas

- What is the empirical formula of a compound that is composed of 5.00×10^{24} hydrogen atoms, 5.00×10^{24} bromine atoms, and 2.00×10^{25} oxygen atoms?
- 60.00 g of a compound containing only sulfur and oxygen contains 24.03 g sulfur. What is the empirical formula of this compound?
- Determine the empirical formula of a compound that is 21.95% sulfur by mass and 78.05% fluorine by mass.
- Determine the ***molecular*** formula of a compound that is 65.19% arsenic by mass, 34.81% oxygen by mass , and has a molar mass of 459.68 g/mol.
- Combustion analysis of 12.01 g of an organic compound containing only carbon, hydrogen, and oxygen produces 14.08 g CO_2 and 4.32 g H_2O. Determine the compound's empirical formula.

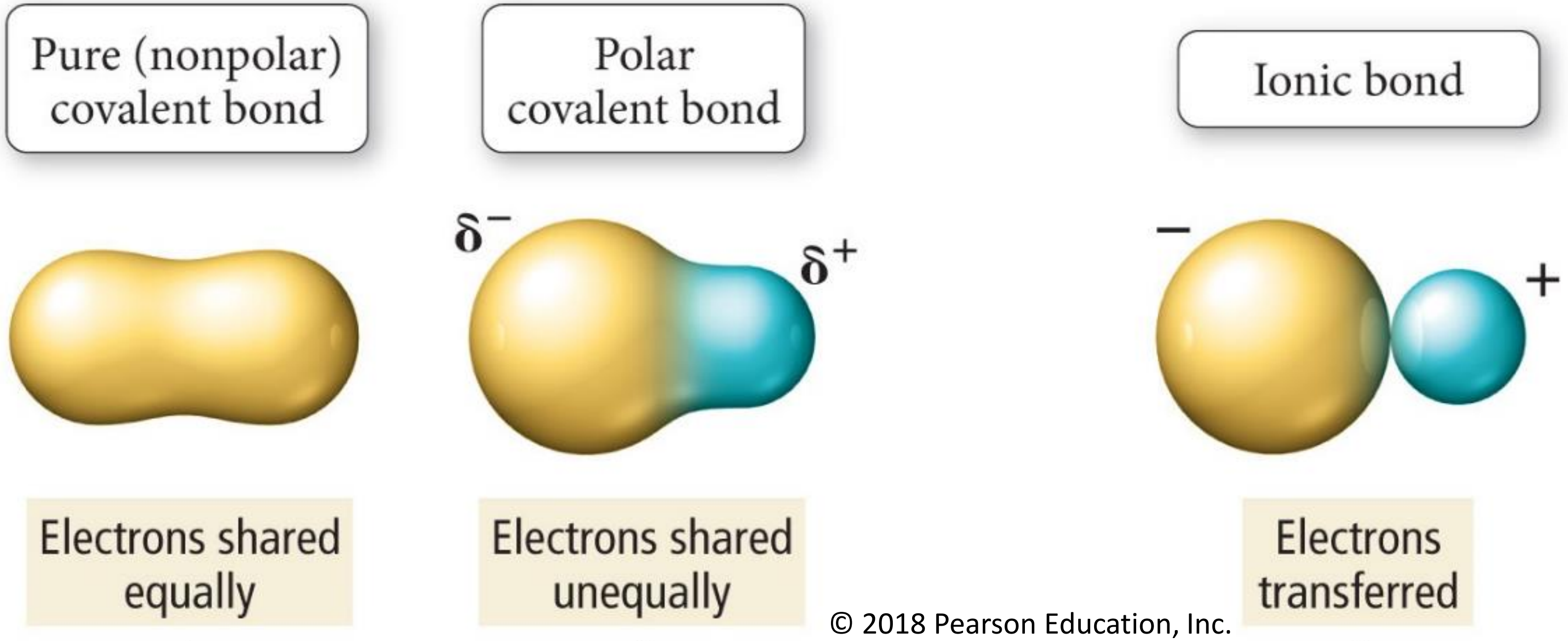
Chapter 5: Chemical Bonding I

Some questions we'll try to answer

- How evenly are electrons in a bond shared and what property of an atom dictates this behavior?
- How can we represent the structures of molecules and polyatomic ions?
- What does it mean when a species exhibits resonance?
- What criteria is used to establish "the best" Lewis structure(s) of a molecule or polyatomic ion?
- How do bonds differ in their length and in their strength?
- How can the shape of a species be established from its Lewis structure?
- What is molecular polarity and how can you determine if a molecule exhibits a net dipole moment?

The Continuum of Bonding

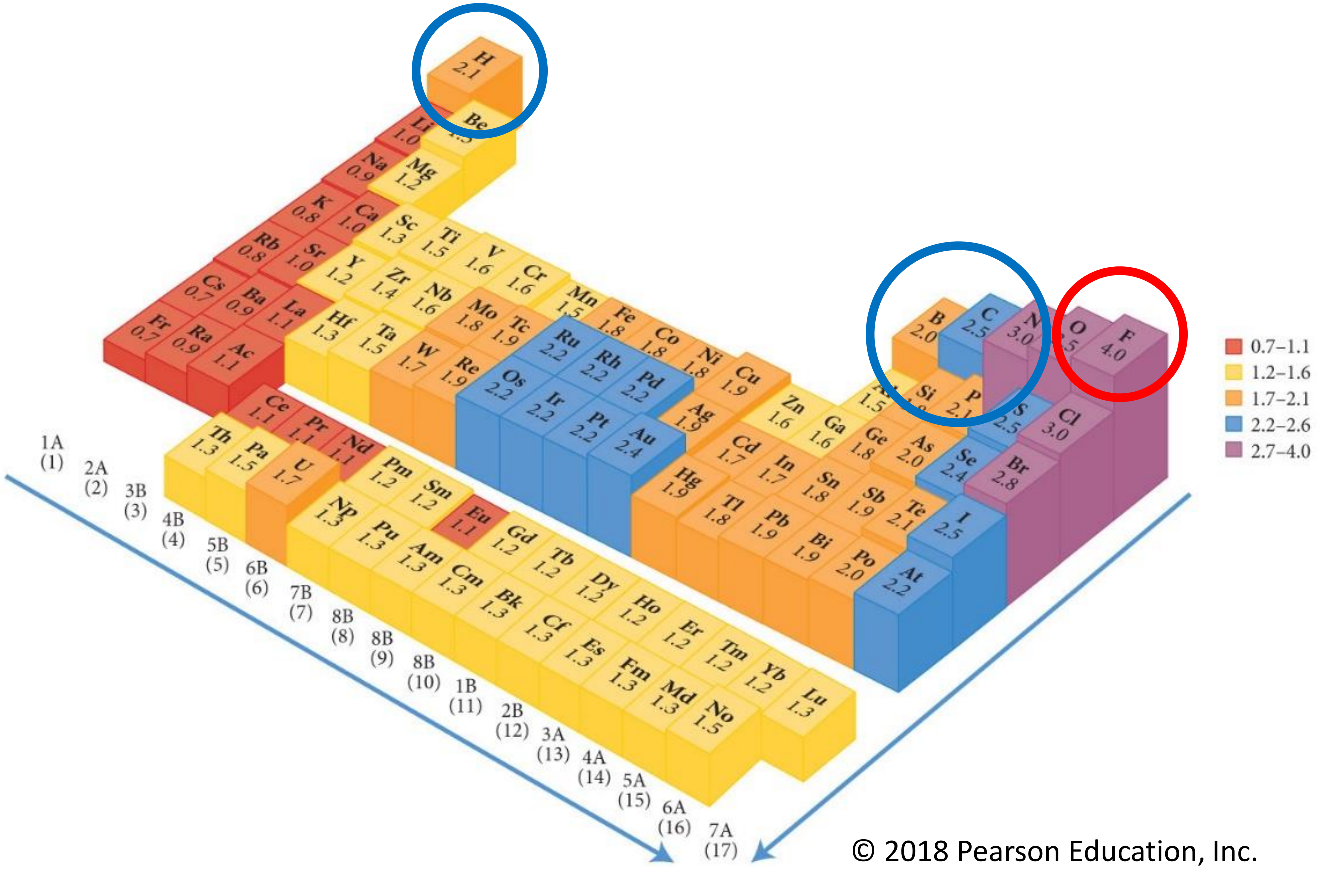
- The distinction between covalent bonding and ionic bonding is not always well defined
- Covalent bonds and ionic bonds represent two ends of the spectrum



- What specifically dictates the position of a bond on this continuum?

Electronegativity

- the ability of an atom to attract **bonding electrons** to itself
  - not to be confused with electron affinity
- electronegativity increases left-to-right across a period
- electronegativity decreases going down a group
  - F is most electronegative, followed by O and then N and Cl
  - H is located between B and C
  - noble gases are not assigned electronegativities as they don't readily bond to other atoms (except Xe, Kr, and recently Ar)
  - main group metals tend to have low electronegativities



- Impacts several behaviors/properties about a molecule
  - molecular polarity
  - formal charges
  - oxidation numbers
  - the ability to form H-bonds
  - acid strength

Covalent Bonds: Polar vs. Nonpolar Bonds

- electrons can be shared evenly or unevenly
  - the evenness of sharing dictates polarity
- the evenness of sharing depends on the electronegativity **difference (ΔEN)** between the atoms participating in the bond
  - greater ΔEN = more polar bond
  - think about the electronegativity trend
- the bonding spectrum can be arbitrarily divided into specific regions based on ΔEN

TABLE 5.1 The Effect of Electronegativity Difference on Bond Type

Electronegativity Difference (ΔEN)	Bond Type	Example
Small (0–0.4)	Covalent	Cl_2
Intermediate (0.4–2.0)	Polar covalent	HCl
Large (2.0+)	Ionic	NaCl