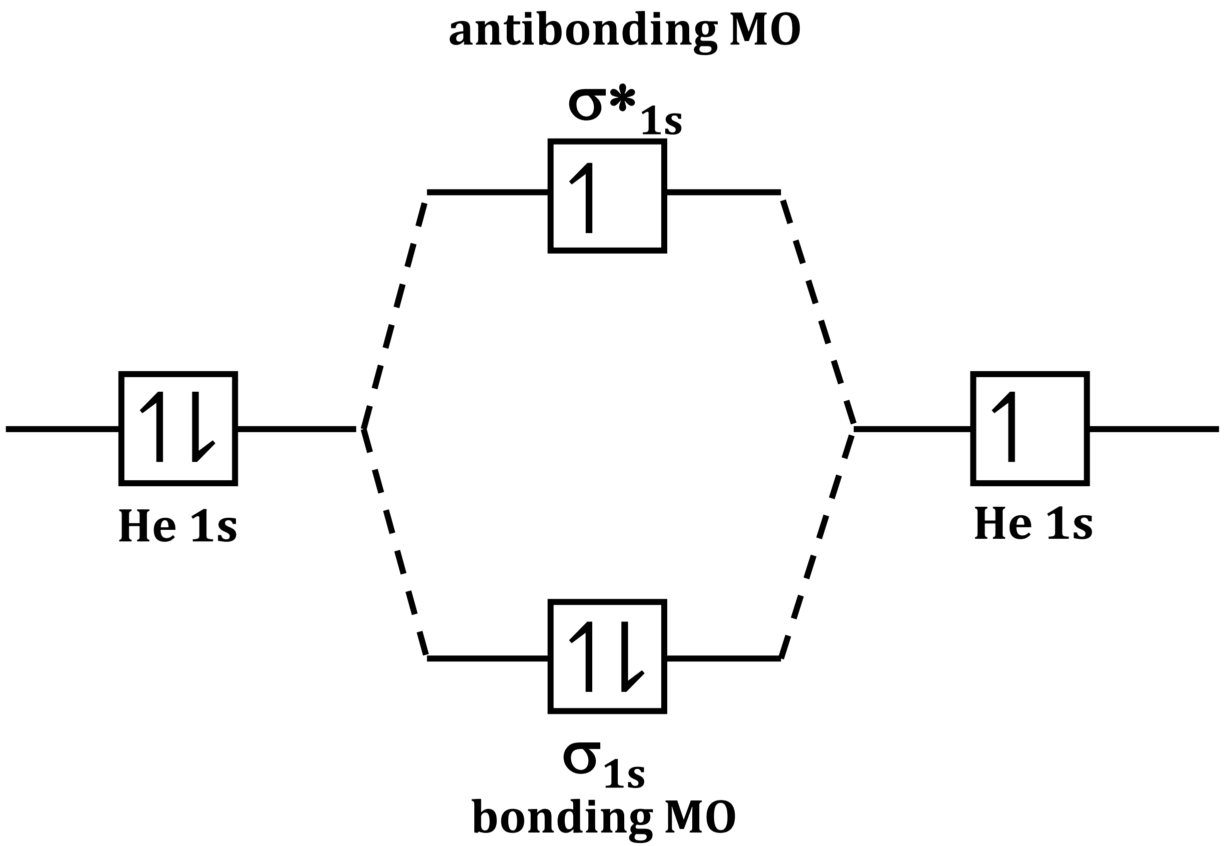
Announcements for Thursday, 24OCT2024

- Week 8 Homework Assignments available on eLearning
  - Graded and Timed Quiz 8 – “Bonding + review” due **Monday, 28OCT2024, at 6:00 PM (EDT)**
- **Exam 2 Conflict Exam Requests due by Friday, 25OCT2024, 11:59 PM (EDT)**
  - for students having Rutgers sanctioned classes and activities during the Exam 2 period (Wednesday, 30OCT2024, 7:45 PM – 9:05 PM)

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

Try This On Your Own

- Draw a molecular orbital diagram for He_2^+ and determine whether the molecule exists.



Bond Order = ½ (2 – 1) = ½

the He–He bond **can** form and He_2^+ **exists**.

MO Diagrams for *Heteronuclear* Diatomic Molecules – **Period 2**

cyanide ion: CN^{-}

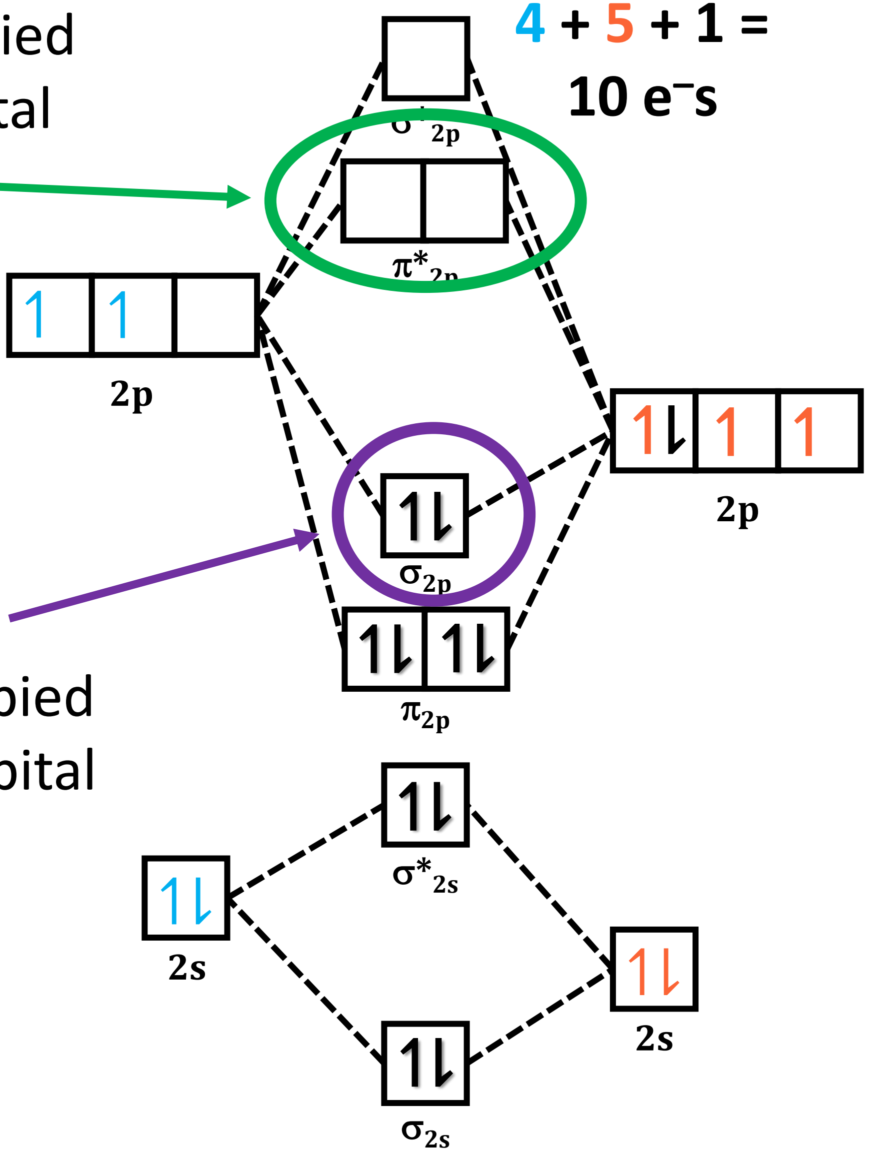
C: [He] $2s^2\ 2p^2$

N: [He] $2s^2\ 2p^3$

4 + 5 + 1 =

10 e⁻s

Lowest **U**noccupied
Molecular **O**rbital
(LUMO)



(HOMO)
Highest **O**ccupied
Molecular **O**rbital

Bond Order = ½ (6 – 0) = 3

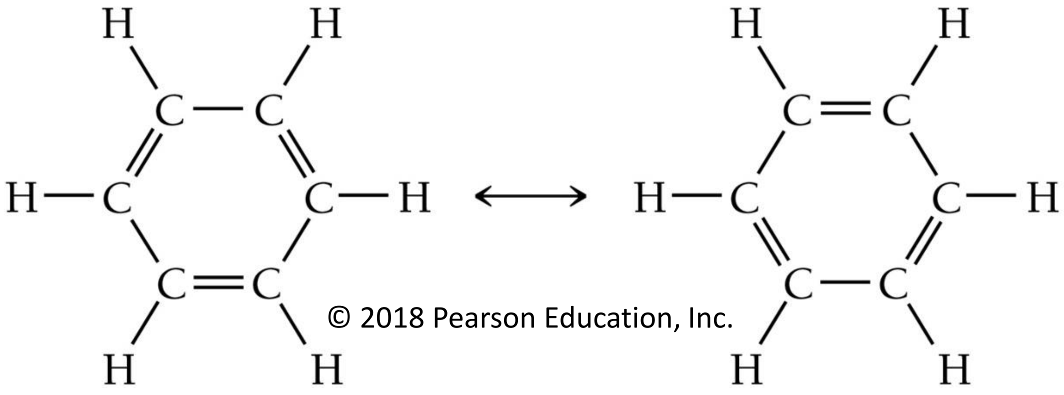
exactly what Lewis and VB theories predict

MO Theory – Polyatomic Molecules
electron delocalization

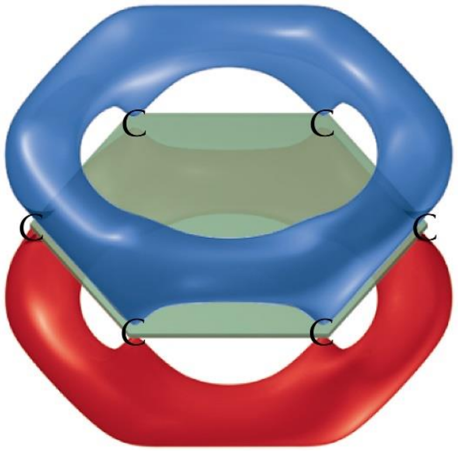
- with the help of computers, MO theory can be applied to polyatomic molecules, giving greater insight into their structures and properties

- electron delocalization
  - an important contribution from MO theory

- benzene (C_6H_6)
  - highly symmetrical molecule
  - planar
  - six identical C–C bonds



2 resonance forms of benzene



lowest energy π bonding MO of benzene

Practical skills related to MO theory

- you should be able to construct MO diagrams for homonuclear and heteronuclear diatomic species and use the diagrams to determine bond order, relative bond strengths/lengths and paramagnetism
  - for example, determine if the species NO^+ is paramagnetic
  - for example, choose the species with the higher bond order between Li_2 and Be_2

Exam II only covers Chapter 3.6 – Chapter 6.5

The following material will **NOT** be on Exam II

Chapter 7: Chemical Reactions and Chemical Quantities

Some questions we'll try to answer

- What are chemical changes and how do they differ from physical changes?
- How do we correctly represent chemical reactions?
- What numerical relationships are expressed within a balanced chemical equation?
- How can we use balanced reaction coefficients as conversion factors?
- What is a limiting reactant and what role does it play in a chemical reaction?
- How can we use a conversion factor approach to identify limiting reactant and do stoichiometry in general?
- What is reaction yield and what factors impact reaction yields?
- What are some common chemical reactions that you should be familiar with?

Chemical vs. Physical Changes

- **chemical change =** atoms rearrange to form new substances with different compositions and properties
  - fermenting grape juice into wine
  - rusting of iron
  - tarnishing of silver
- **physical change =** the form of the substance changes but the composition and identity does not
  - phase changes like melting, freezing, boiling, etc.
- Both physical and chemical changes can be represented by chemical equations

Writing Chemical Equations

- **chemical equation =** a shorthand way of representing a chemical reaction

Reactants $\boxed{\rightarrow}$ **Products**

- states of reactants/products
  - (s), (ℓ), (g), and $\boxed{\text{(aq)}}$
- changing names into chemical formulas (Chapter 4)
  - don't forget about diatomic elements such as hydrogen (H_2), oxygen (O_2), nitrogen (N_2), etc.

<u>necessary skill is writing chemical equations from words:</u>

- copper solid reacts with aqueous nitric acid (HNO_3) to form aqueous copper(II) nitrate, nitrogen monoxide gas and water
  - **$Cu(s) + HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + NO(g) + H_2O(\ell)$**
- nitrogen gas and hydrogen gas reacts to form ammonia gas
  - **$N_2(g) + H_2(g) \rightarrow NH_3(g)$**

Balancing Chemical Equations

$$N_2(g) + H_2(g) \longrightarrow NH_3(g)$$

Does this give the full picture?

- Atoms are not created or destroyed during chemical reactions
  - number and types of atoms on both sides of the arrow must be the same
- Balance by changing ***coefficients*** only!
  - NEVER by changing subscripts (…that would change the compound)
- balance atoms that occur as free elements last
- when present on both sides of the reaction, balance a polyatomic ion as single unit
- express coefficients in lowest whole-numbers
  - the coefficients can be thought of on two levels: atomic vs. macroscopic
- the balanced coefficients will act as important **conversion factors**

Writing Balanced Chemical Equations – Examples

- Write the balanced equation when aqueous solutions of sodium phosphate and lead(II) nitrate are mixed together forming aqueous sodium nitrate and solid lead(II) phosphate

$$2\ Na_3PO_4(aq) + 3\ Pb(NO_3)_2(aq) \rightarrow 6\ NaNO_3(aq) + Pb_3(PO_4)_2(s)$$

- Write the balanced equation for the complete combustion of hexane (C_6H_{14})

$$2\ C_6H_{14}(\ell) + 19\ O_2(g) \rightarrow 12\ CO_2(g) + 14\ H_2O(g)$$

Try These On Your Own

Write **balanced** chemical equations for the following reactions:

Liquid dichlorine heptoxide is added to water to form liquid perchloric acid ($HClO_4$).

When aqueous solutions of aluminum sulfate and sodium hydroxide are mixed, aqueous sodium sulfate and solid aluminum hydroxide are formed.

Solid aluminum carbide (Al_4C_3), when mixed with water, produces solid aluminum hydroxide and methane (CH_4) gas.

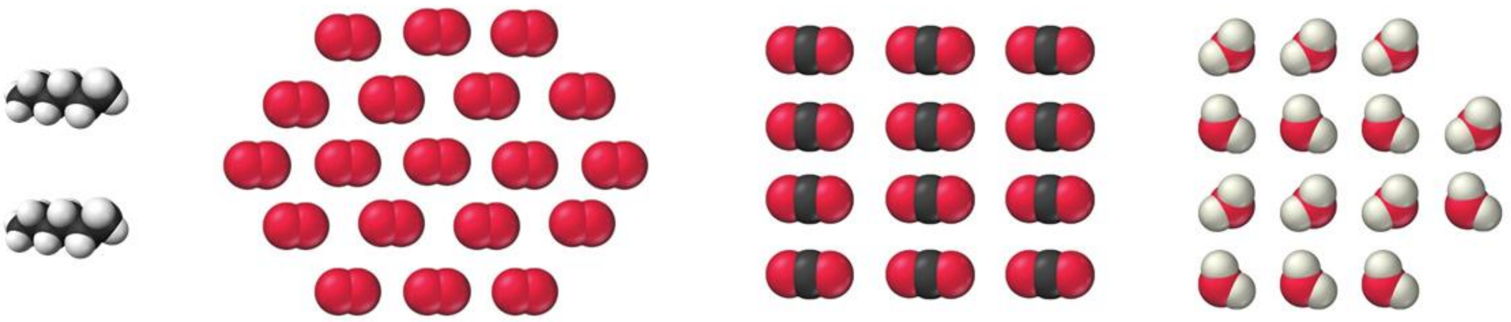
Rust (i.e., iron(III) oxide) forms when iron is exposed to oxygen in the air.

Complete combustion of liquid propanol ($CH_3CH_2CH_2OH$) yields carbon dioxide and water vapor.

Reaction Stoichiometry

- **stoichiometry =** the numerical relationships between chemical amounts in a balanced chemical equation
- compound stoichiometry introduced in Chapter 4
  - using chemical formulas, subscripts, and molar masses as conversion factors
  - example: how many total atoms in 25.0 g $C_6H_{12}O_6$?
- using ***balanced reaction coefficients*** as conversion factors

$$\mathbf{2}\ C_6H_{14}(\ell) + \mathbf{19}\ O_2(g) \longrightarrow \mathbf{12}\ CO_2(g) + \mathbf{14}\ H_2O(g)$$



- **2** *molecules* of C_6H_{14} reacts with **19** *molecules* of O_2 to yield **12** *molecules* of CO_2 and **14** *molecules* of H_2O
- **2 moles** of C_6H_{14} reacts with **19 moles** of O_2 to yield **12 moles** of CO_2 and **14 moles** of H_2O

2 mol C_6H_{14} : 19 mol O_2 : 12 mole CO_2 : 14 mol H_2O (the source of many conversion factors!)

RECALL CH 4: Compound Stoichiometry Calculations

- How many hydrogen atoms are in 88.0 ng glucose ($C_6H_{12}O_6$)?

starting unit				**ending unit**
mass glucose (ng)	$\longrightarrow$	$\longrightarrow$	$\longrightarrow$	# of hydrogen atoms

$$88.0\ \text{ng glucose} \times \frac{1\ \text{g}}{10^9\ \text{ng}} \times \frac{1\ \text{mol glucose}}{180.16\ \text{g}} \times \frac{6.022 \times 10^{23}\ \text{glucose molecules}}{1\ \text{mol glucose}} \times \frac{12\ \text{hydrogen atoms}}{1\ \text{glucose molecule}} =$$

molar mass glucose

from chemical formula

3.53×10^{15} H atoms

Reaction Stoichiometry Illustrated

$$N_2(g) + 3\ H_2(g) \longrightarrow 2\ NH_3(g)$$

What mass of nitrogen gas is needed to completely react with 12.5 moles hydrogen gas?

starting units: **moles H_2**(g) → → → ending units: **grams** N_2(g)

$$12.5 \text{ moles } H_2 \times \frac{\mathbf{1\ mol\ N_2}}{\mathbf{3\ mol\ H_2}} \times \frac{28.02\ g}{1\ mol\ N_2} = 117\ g\ N_2$$

molar mass N_2

from balanced equation

What mass of ammonia will be produced?

starting units: **moles H_2**(g) → → → ending units: **grams** NH_3(g)

$$12.5 \text{ moles } H_2 \times \frac{\mathbf{2\ mol\ NH_3}}{\mathbf{3\ mol\ H_2}} \times \frac{17.03\ g}{1\ mol\ NH_3} = 142\ g\ NH_3$$

molar mass NH_3

from balanced equation

Try This On Your Own

Ammonium nitrite (NH_4NO_2) is an unstable solid that readily decomposes into nitrogen gas and water vapor. How many molecules of gas will be produced by the decomposition of 100. g of ammonium nitrite?

Reaction Stoichiometry – Try These On Your Own

Electrolysis of water leads to the formation of hydrogen and oxygen gases according to the reaction $H_2O(\ell) \rightarrow H_2(g) + O_2(g)$. How many *moles* of water must be electrolyzed to generate 0.231 *moles* of oxygen gas?

What mass of oxygen is needed to completely combust 5.00 *moles* hexane (C_6H_{14})?

Consider the reaction $2\ N_2(g) + 5\ O_2(g) \rightarrow 2\ N_2O_5(g)$. What masses of nitrogen gas and oxygen gas are needed to produce 100.0 g N_2O_5? MM N_2O_5 = 108.02 g/mol

The complete decomposition of ClF_3 into Cl_2 and F_2 produced 142 g $Cl_2(g)$. <u>How many molecules</u> of fluorine gas was produced in the same reaction?