Chemical Reactions

Chapter 17

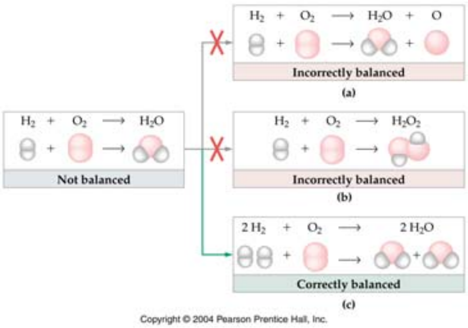
Chemical Equations

- $C + O_2 \rightarrow CO_2$
- $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$

- Reactants on left, products on right
- Each are balanced because same number of atoms of reactants as products
- Some equations show the phase of the substances also: solid, liquid, gas

Balancing Chemical Equations

- Molecules of reactants and products shown—
  - Cannot change the molecule
  - Can change how many of them
- Cannot add or delete reactants or products
- Balanced—equal number of same atoms on each side



Balancing Tips

- Never change the molecular formula of reactants or products
- Count atoms in reactant and products
- Always add whole molecules, not parts
- Start by balancing atoms in compounds
- Save element reactants or products for last—to make up any imbalance

Rusting of Iron

- $Fe + O_2 \rightarrow Fe_2O_3$ not balanced
- start with oxygen
- $Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$
- next do iron
- $4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$

Problem 1 in class

Balance the following equation, on the worksheet provided. (Put your name on the back of the sheet, please.)

$$N_2 + \quad H_2 \rightarrow \quad NH_3$$

Combustion of propane

- $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
- fix hydrogen first—it's in two compounds
- $C_3H_8 + O_2 \rightarrow CO_2 + 4\,H_2O$
- need more carbon product
- $C_3H_8 + O_2 \rightarrow 3\,CO_2 + 4\,H_2O$
- Do oxygen last, because it is single
- $C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$

Problem 2 in class

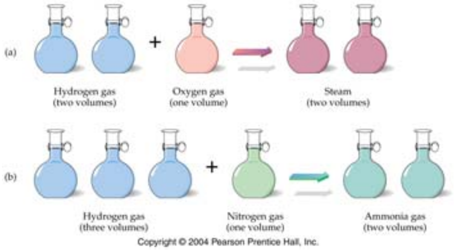
Balance the following chemical equation, the combustion of methane

$$CH_4 + O_2 \rightarrow$$

Methane oxygen

Volume Relationships

- Equal volumes of gases at the same temperature and pressure have the same number of molecules
- Gases react in small whole number quantities
- Avogadro's hypothesis: chemicals react in consistent, small whole number ratios



Combustion of propane

$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

- What volume of oxygen is needed to burn 0.5 L of propane?
- Ratio of Oxygen molecules to propane molecules is 5:1
- $0.5\ L \times \frac{5\ L\ O_2}{1\ L\ Propane} = 2.5\ L$ Oxygen

Problem 3 in class

- Combustion of propane

  $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

Calculate how much CO_2 is produced when 2 L of propane is burned

Atomic vs. Molecular Weight

- Atomic weight on periodic table is average of natural abundance of isotopes
- Atomic mass is the number of nucleons in a particular atom—specified by isotope
- Molecular mass is the mass of one mole of molecules
  - One atomic mass number of grams
  - 6.0221367×10^{23} molecules

Calculate Molecular Mass

- O atomic weight 15.9996 (round to 16 for this class)
- O-16 atomic mass 16 u
- Molecular oxygen O_2 atomic mass 32 u
- Molecular O_2 molecular mass 32 g/mole
- CO_2 molecular mass
  - C=12 g/mole, O_2=32 g/mole
  - CO_2=12+32=44 g/mole

Problem 4 in class

- Calculate the molar mass of propane C_3H_8
- Round atomic weight of C to 12 $\frac{g}{mole}$
- Round atomic weight of H to 1 $\frac{g}{mole}$

Grams calculated from Moles

- Can find the molar mass of substance
  - Na=23 $\frac{g}{mole}$
  - $\frac{1}{4}$ mole of Na
- Multiply molar mass times moles
- 23 $\frac{g}{mole}$ x 0.250 moles = 5.75 g

Moles calculated from Grams

- 176 g of CO_2 = Number of moles?
- Molar mass of CO_2 = 44 $\frac{g}{mole}$
- If you multiply,
  - 176 g x 44 $\frac{g}{mole}$ results in units of $\frac{g^2}{mole}$
  - you get a unit mess
- **UNITS** alert you that you made an error
- **KEEP UNITS WITH NUMBERS!!**

Moles calculated from Grams

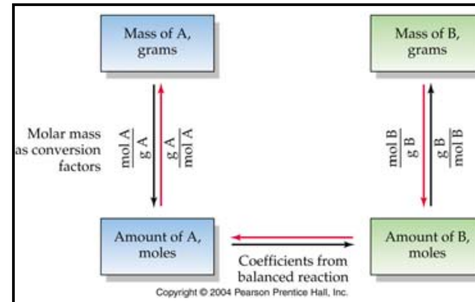
- 176 g of CO_2 = Number of moles?
- Molar mass of CO_2 = 44 $\frac{g}{mole}$
- Divide 176 g by 44 $\frac{g}{mole}$
- Same as multiply by reciprocal

$$176 \text{ g} \times \left(\frac{1 \text{ mole}}{44 \text{ g}}\right) = 4 \text{ moles } CO_2$$

- Now the grams cancel =)

Problem 5 in class

132 g of propane is how many moles?



To convert between grams and moles

- Make sure equation is balanced
- So you know the molar ratios of them
- Find molar mass of them
- ~~Set up proportions for moles and grams~~

Proportions

- Mathematical device to compare ratios
- Cross-multiply to solve
- Correctly organized
- Be sure you keep same:same in columns and rows

Proportions to find grams and moles

- Correctly organized

Example $\frac{\text{moles of a}}{\text{moles of b}} = \frac{g \text{ of a}}{g \text{ of b}}$

or $\frac{\text{moles of a}}{g \text{ of a}} = \frac{\text{moles of b}}{g \text{ of b}}$

- cross-multiply to solve

Proportions

- Correctly organized
- It doesn't matter how you write the first ratio, as long as you label the numbers
- Try to put unknown on the top—easier to solve
- The second ratio needs to match the first

Problem $NO + O_2 \rightarrow NO_2$

- 64 grams O_2
- How many grams NO_2 produced?

First: Balance Equation

$$2NO + O_2 \rightarrow 2NO_2$$

Problem $2NO + O_2 \rightarrow 2NO_2$

- 64 grams O_2
- How many grams NO_2 produced?

Balance Equation
Determine molar ratios of them 1:2
Find molar mass of each component
NO_2=46 g, O_2=32 g, (NO=30 g)

Problem $2NO + O_2 \rightarrow 2NO_2$

- 64 grams O_2
- How many grams NO_2 produced?

Molar mass of each: O_2=32 g, NO_2=46 g

How many moles is 64 grams O_2?
One mole

Problem $2NO + O_2 \rightarrow 2NO_2$

- 64 grams O_2
- How many grams NO_2 produced?
- Molar mass of each O_2=32 g, NO_2=46 g

Molar ratios O_2:NO_2 is 1:2
Two mole of O_2
So four moles of NO_2 is produced
How many grams is that?
4 mol x 46 g/mol = 184 grams

Problem

$$H_2S + O_2 \rightarrow SO_2 + H_2O$$

- 32 grams SO_2
- How many grams O_2 used?

Problem

- 32 grams SO_2
- How many grams O_2 used?

$$H_2S + O_2 \rightarrow SO_2 + H_2O$$

- Balance first

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

- Then determine molar ratios
- 2 SO_2 to 3 O_2

Problem

- 32 grams SO_2
- How many grams O_2 used?

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

- Find molar masses
  - SO_2 = 32 + 32 = 64 g/mol SO_2
  - O_2 = (2x1) +16 = 32 g/mol O_2
  - H_2O= (2x1) +16 = 18 g/mol H_2O
  - H_2S = (2x1) +32 = 34 g/mol H_2S

Problem

- 32 grams SO_2
- How many grams O_2 used?

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

- 32 g SO_2 needs how many grams O_2?
- How many moles is 32 g SO_2?

$$32\text{ g SO}_2 \cdot \frac{1\,mole}{64\text{ g}} = 0.5\,moles\,\text{SO}_2$$

Problem

- 32 grams SO_2
- How many grams O_2 used?

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

- How many moles O_2 is needed?
- 0.5 moles SO_2 in 2:3 ratio with O_2
- 0.75 moles O_2

$$32\text{ g SO}_2 \cdot \frac{1\,mole}{64\text{ g}} = 0.5\,moles\,\text{SO}_2$$

Set up proportion

- 32 grams SO_2
- How many grams O_2 used?

with the unknown on top (the O_2)

$$\frac{?\text{ g O}_2}{[\quad]} = \frac{[\quad]}{[\quad]}$$

Problem 6 $C + O_2 \rightarrow CO_2$

Is it balanced?
Molar ratio 1:1:1
4 grams oxygen

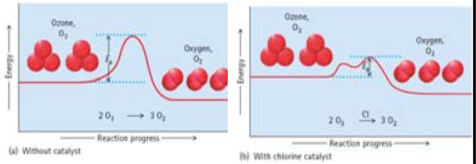
- Grams carbon consumed?
- Grams carbon dioxide produced?

Reaction Speed

Collision of molecules required for it to occur

- Increase concentration
- Increase temperature
- Catalyst can facilitate reaction

Chlorine catalyst



Energy of reactions

- Release energy
- EXOTHERMIC
- Methane combustion

- Consume energy
- ENDOTHERMIC
- Formation of water