Chemical Reactions

Chapter 17

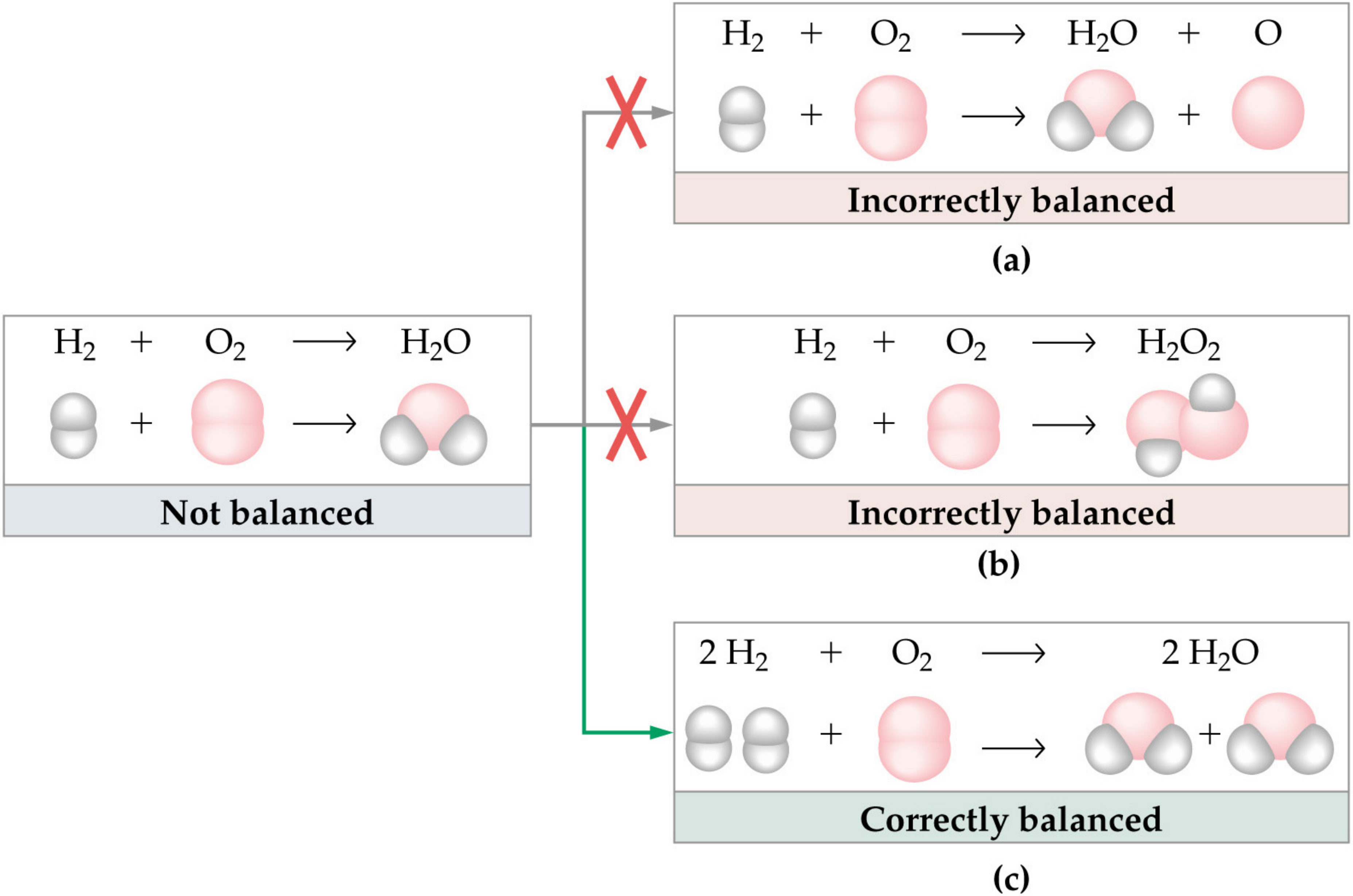
Chemical Equations

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

- 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


$H_2 + O_2 \longrightarrow H_2O$
Not balanced
$H_2 + O_2 \longrightarrow H_2O + O$
Incorrectly balanced
(a)
$H_2 + O_2 \longrightarrow H_2O_2$
Incorrectly balanced
(b)
$2\,H_2 + O_2 \longrightarrow 2\,H_2O$
Correctly balanced
(c)

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

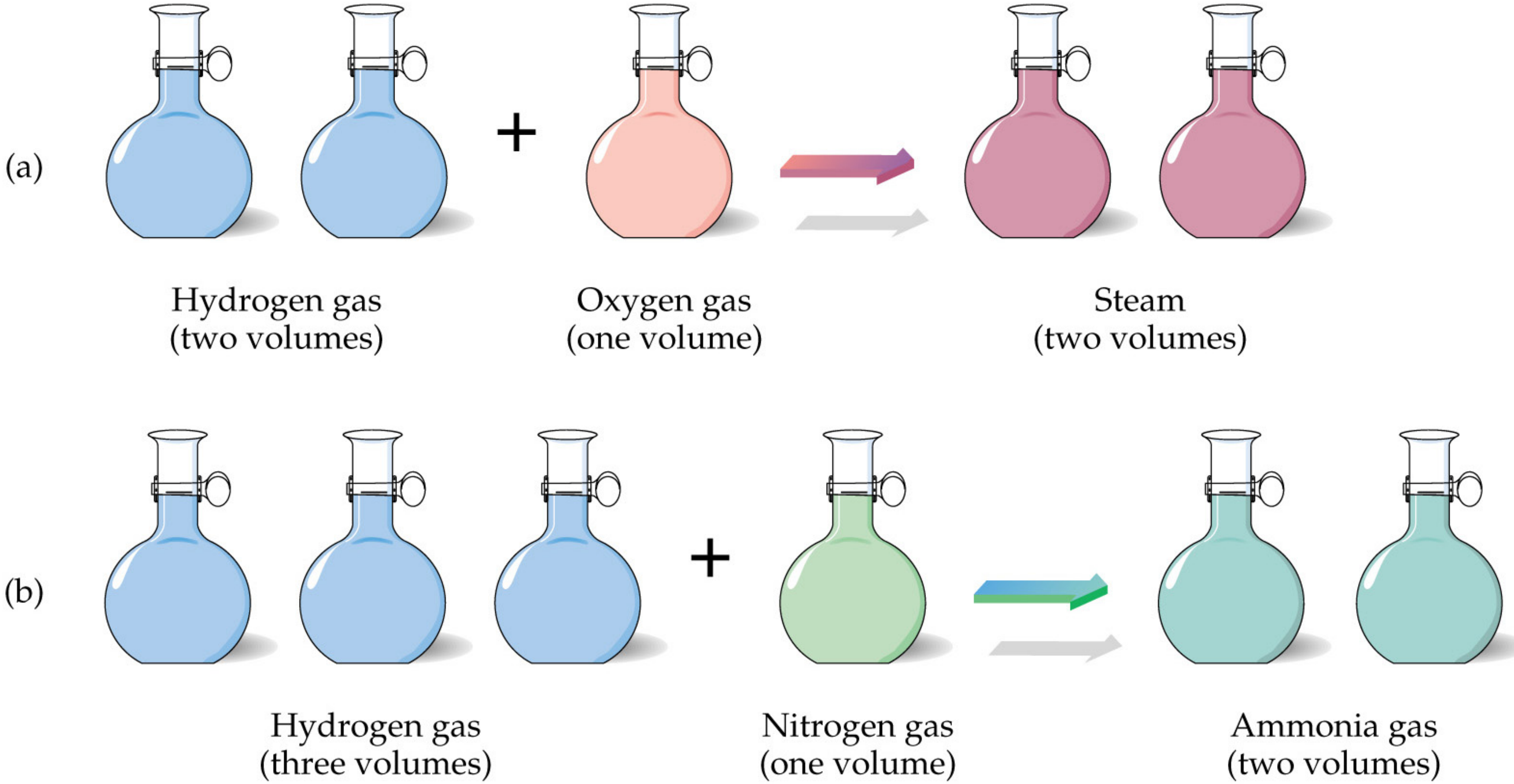
Balance the following chemical equation, the combustion of methane

$$CH_4 + O_2 \rightarrow$$

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


(a)
Hydrogen gas
(two volumes)
Oxygen gas
(one volume)
Steam
(two volumes)
(b)
Hydrogen gas
(three volumes)
Nitrogen gas
(one volume)
Ammonia gas
(two volumes)

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
- $0.5\ \text{L} \times \dfrac{5\ \text{L}\ O_2}{1\ \text{L Propane}} = 2.5\ \text{L Oxygen}$

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 $\frac{\text{g}}{\text{mole}}$
- Round atomic weight of H to 1 $\frac{\text{g}}{\text{mole}}$

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

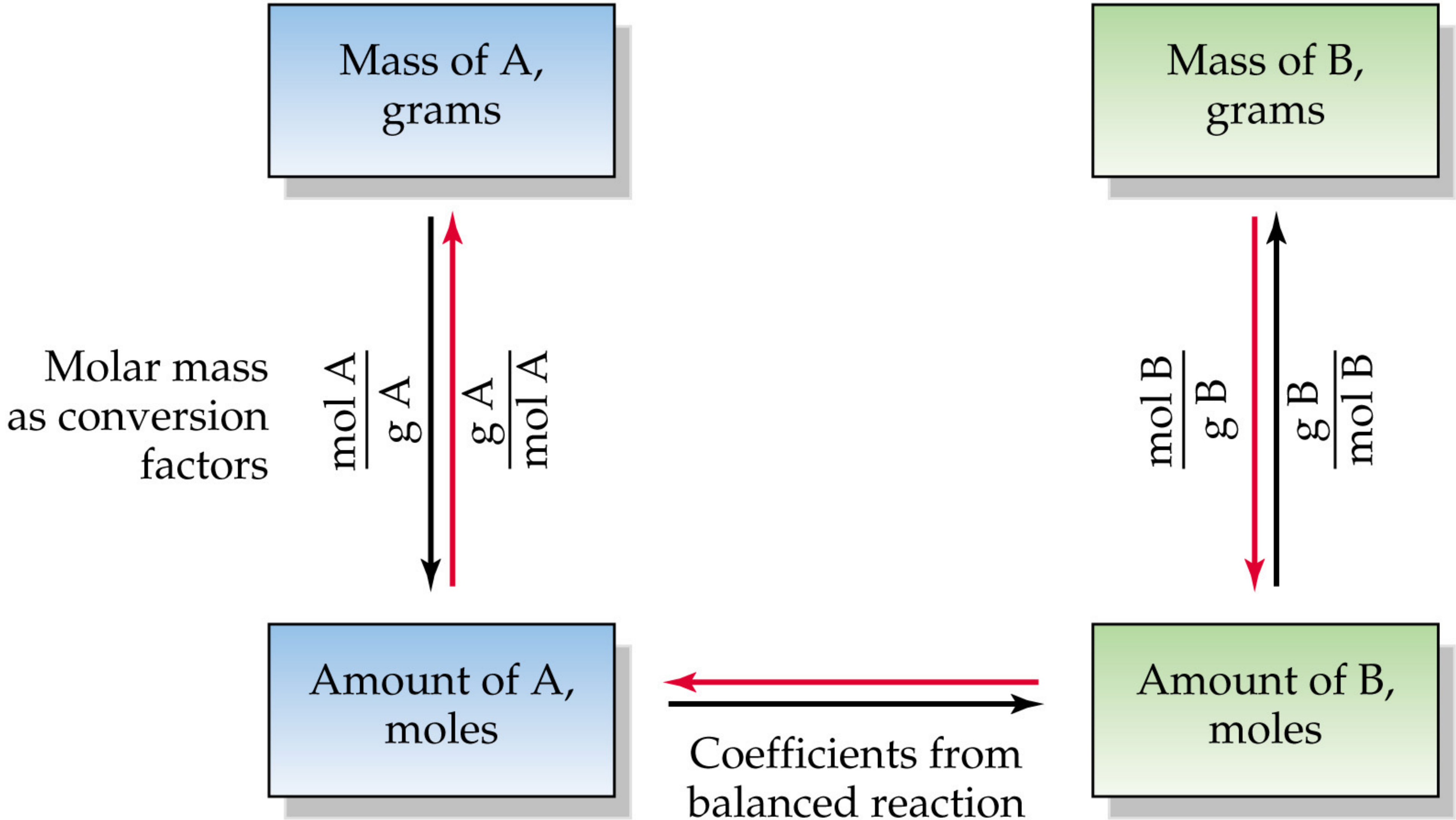
- 176 g of CO_2 = Number of moles?
- Molar mass of CO_2 = 44 $\frac{\text{g}}{\text{mole}}$
- Divide 176 g by 44 $\frac{\text{g}}{\text{mole}}$
- Same as multiply by reciprocal

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

- Now the grams cancel =)

Problem 5 in class

132 g of propane is how many moles?



Mass of A, grams
Mass of B, grams
Molar mass as conversion factors
mol A / g A
g A / mol A
mol B / g B
g B / mol B
Amount of A, moles
Amount of B, moles
Coefficients from balanced reaction

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?

$$32\,\mathrm{g}\,\mathrm{SO_2} \cdot \frac{1\,mole}{64\,\mathrm{g}} = 0.5\,moles\,\mathrm{SO_2}$$

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

$$32\,\mathrm{g\,SO_2} \cdot \frac{1\,mole}{64\,\mathrm{g}} = 0.5\,moles\,\mathrm{SO_2}$$

Set up proportion

- 32 grams SO_2
- How many grams O_2 used?

with the unknown on top (the O_2)

$$\frac{?\,g\,O_2}{[\qquad]} = \frac{[\qquad]}{[\qquad]}$$

Problem 6 $C + O_2 \rightarrow CO_2$

Is it balanced?

Molar ratio 1:1:1

4 grams oxygen

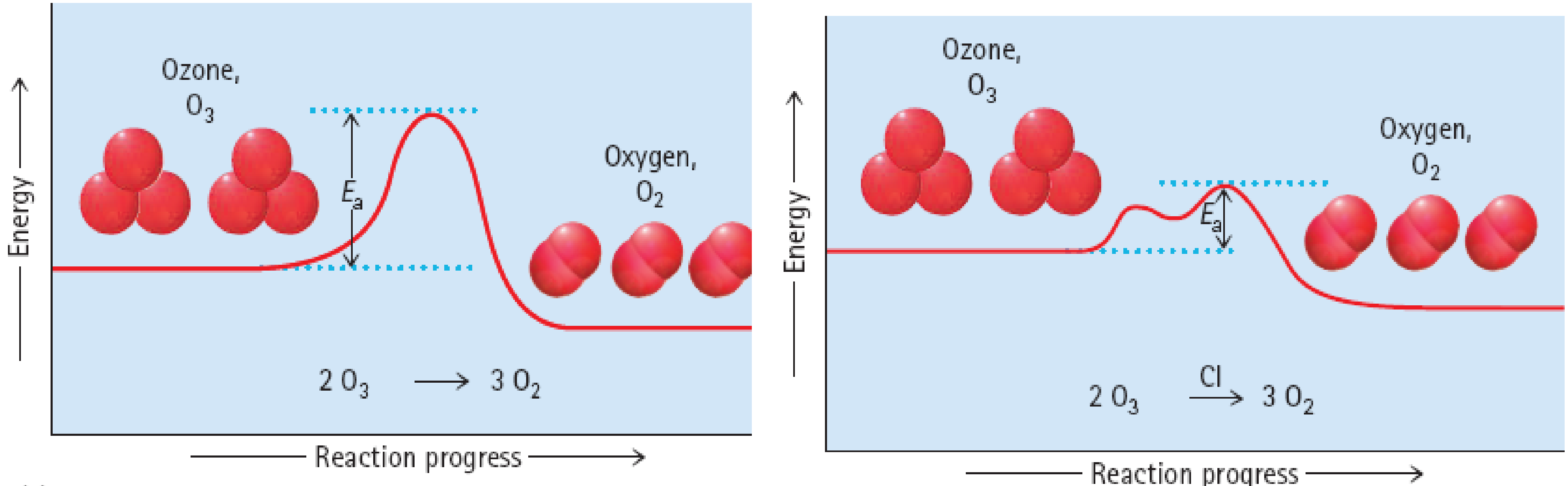
- Grams carbon consumed?
- Grams carbon dioxide produced?

Reaction Speed

Collision of molecules required for it to occur

- Increase concentration
- Increase temperature
- Catalyst can facilitate reaction

Chlorine catalyst



(a) Without catalyst

(b) With chlorine catalyst

Energy of reactions

- Release energy
- EXOTHERMIC
- Methane combustion

- Consume energy
- ENDOTHERMIC
- Formation of water