STOICHIOMETRY

- By combining our abilities to balance equations and do simple unit conversions, we can now complete simple stoichiometry problems (mole to mole) and more complicated ones (mass to mass)

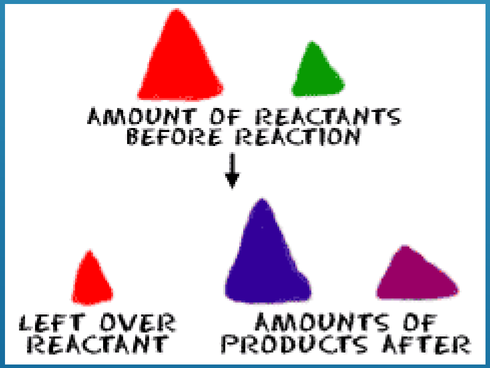
STOICHIOMETRY

Mass, Particle and Mole Relationships

- **Stoichiometry** is the study of quantitative relationships between the amounts of reactants used and amounts of products formed by a chemical reaction.
- Stoichiometry is based on the law of conservation of mass.

STOICHIOMETRY

- Stoichiometry problems consist of:
- Determining amt. of product if you know amt. of reactant
- Determining amt. of reactant needed to produce a certain amount of product.



- As an example, let's consider a ham sandwich
- To make a ham sandwich, here is the equation:
- 1 H(am) + 2 B(read) + 1 L(ettuce) → 1 HB_2L (also known as a Ham Sandwich)

STOICHIOMETRY

- If you had 4 slices of ham, 6 pieces of lettuce, and 7 slices of bread, how many ham sandwiches could you make?

(remember 1 H + 2 B + 1 L → 1 HB_2L)

STOICHIOMETRY

- How about how many pieces of bread would you need to make 14 ham sandwiches?

STOICHIOMETRY

Using Stoichiometry

- All stoichiometric calculations begins with a balanced chemical equation.

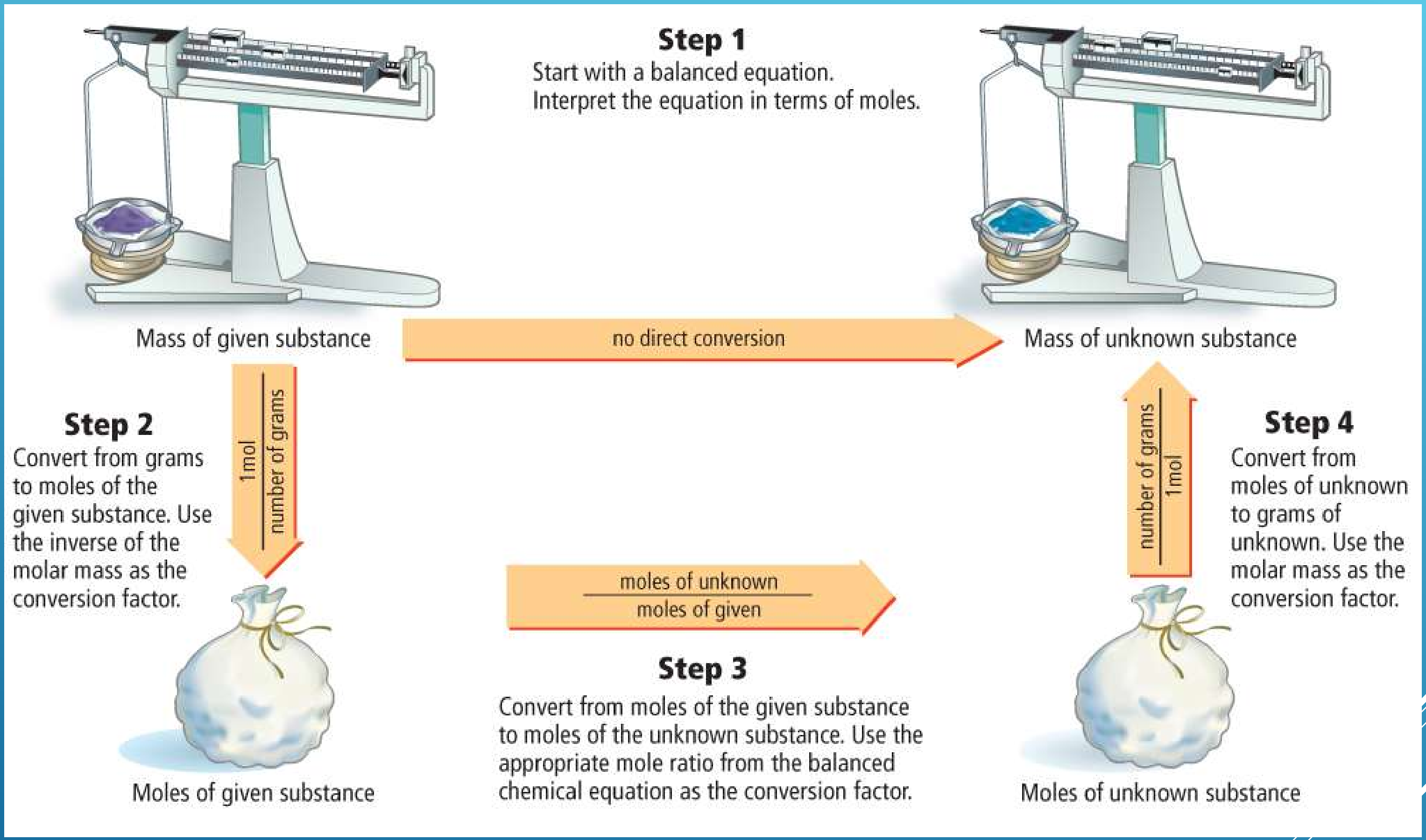
$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Particle and Mole Relationships (cont.)

Table 11.1 Relationships Derived from a Balanced Chemical Equation

$4Fe(s)$	+	**$3O_2(g)$**	→	**$2Fe_2O_3(s)$**
iron	+	oxygen	→	iron(III) oxide
4 atoms Fe	+	3 molecules O_2	→	2 formula units Fe_2O_3
4 mol Fe	+	3 mol O_2	→	2 mol Fe_2O_3
223.4 g Fe	+	96.00 g O_2	→	319.4 g Fe_2O_3
319.4 g reactants			→	319.4 g products

Using Stoichiometry (cont.)



Particle and Mole Relationships (cont.)

- A **mole ratio** is a ratio between the numbers of moles of any two substances in a balanced equation.
- Refer to **coefficients** in the balanced equation to determine the mole ratio.

Using Stoichiometry (cont.)

- Steps to solve mole-to-mole, mole-to-mass, and mass-to-mass stoichiometric problems

1. Complete Step 1 by writing the balanced chemical equation for the reaction.
2. To determine where to start your calculations, note the unit of the given substance.

- If mass (in grams) of the given substance is the starting unit, begin your calculations with Step 2.
- If amount (in moles) of the given substance is the starting unit, skip Step 2 and begin your calculations with Step 3.

Using Stoichiometry (cont.)

3. The end point of the calculation depends on the desired unit of the unknown substance.
   - If the answer must be in moles, stop after completing Step 3.
   - If the answer must be in grams, stop after completing Step 4.

STOICHIOMETRY

- We will solve these problems using the factor label method, which we've used for other conversions.

Givenunits to units to

units fromunits from

SAMPLE PROBLEM:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

How many moles of iron III oxide will be produced if 11 moles of iron react with excess oxygen?

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

How many moles of iron III oxide will be produced if 112 grams of iron reacts with excess oxygen?

SAMPLE PROBLEM

- $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
- If I use 145 g of oxygen, with an excess of iron, how many grams of iron III oxide will be produced?

SAMPLE PROBLEM

- Let's return to the ham sandwich example.

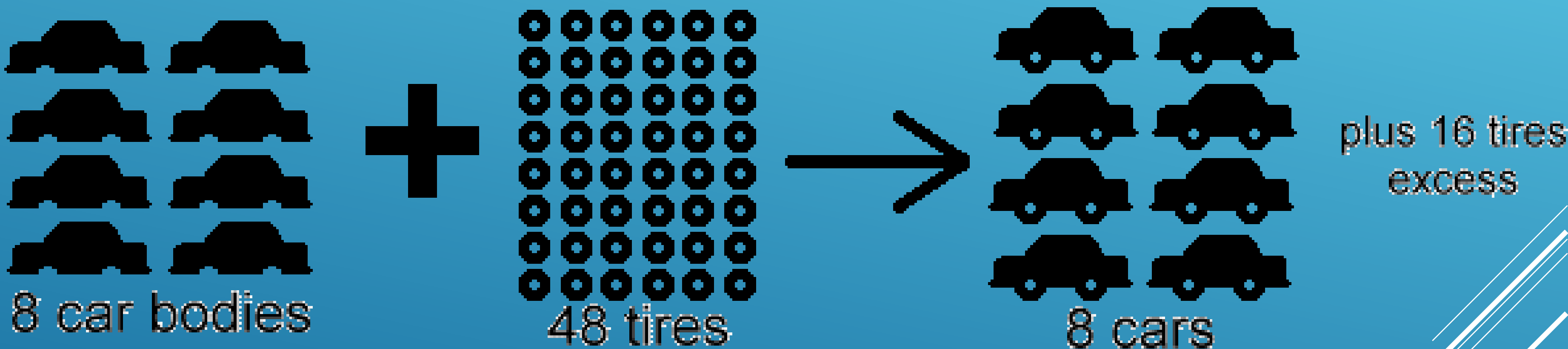
(remember 1 H + 2 B + 1 L → 1 HB_2L)

- If you have 4 pieces of ham, 6 pieces of lettuce, and 7 slices of bread, how many leftover pieces of ham and lettuce will you have?
- This is known as a limiting reactant problem

LIMITING AND EXCESS REACTANTS

LIMITING AND EXCESS REACTANTS

- Here's another example:

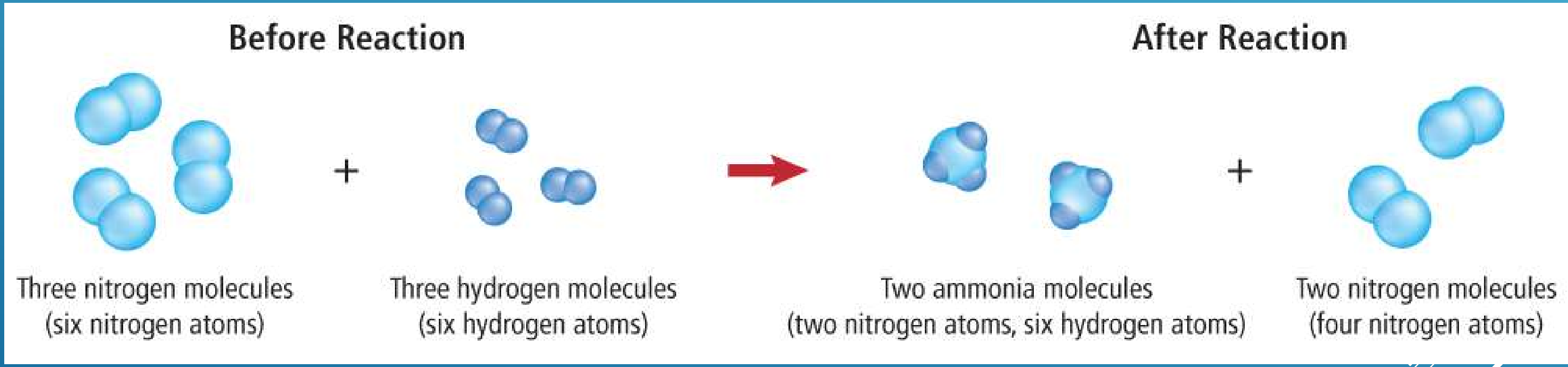


Why do reactions stop?

- Reactions proceed until one of the reactants is used up and one is left in excess.
- The **limiting reactant** limits the extent of the reaction and, thereby, determines the amount of product formed.
- The **excess reactants** are all the leftover unused reactants.

Why do reactions stop? (cont.)

- Determining the limiting reactant is important because the amount of the product formed depends on this reactant.



- Once the limiting reactant has been determined, you can use it to calculate how much of the other reactants will be consumed, and how much of the products will be produced.
- To determine how much will be left over, simply subtract the consumed/produced amounts from the available amounts.

LIMITING AND EXCESS REACTANTS

Calculating the Product when a Reactant is Limiting

- $S_8(l) + 4Cl_2(g) \rightarrow 4S_2Cl_2(l)$
- 200.0g S_8 and 100.0g Cl_2
- Determine which is the limiting reactant

Calculating the Product when a Reactant is Limiting (cont.)

- Calculating the amount of product formed

Calculating the Product when a Reactant is Limiting (cont.)

- Determine the amount of the excess reactant

Calculating the Product when a Reactant is Limiting (cont.)

- Using an excess of a reactant can speed up the reaction.
- Using an excess of a reactant can drive a reaction to completion.

How much product? (cont.)

- The **theoretical yield** is the maximum amount of product that can be produced from a given amount of reactant.
- The **actual yield** is the amount of product actually produced when the chemical reaction is carried out in an experiment.
- The **percent yield** of a product is the ratio of the actual yield expressed as a percent.

- You can also use stoichiometry calculations to determine percent yield in a reaction.
- The amount that you actually get may be more or less than the amount that you would predict in a stoichiometry problem.
- If you divide the actual yield by the theoretical yield (predicted), you can determine the % yield.

PERCENT YIELD

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Percent Yield in the Marketplace

- Percent yield is important in the cost effectiveness of many industrial manufacturing processes.
- Laboratory reactions do not always produce the calculated amount of products.
- Reactants stick to containers.
- Competing reactions form other products.