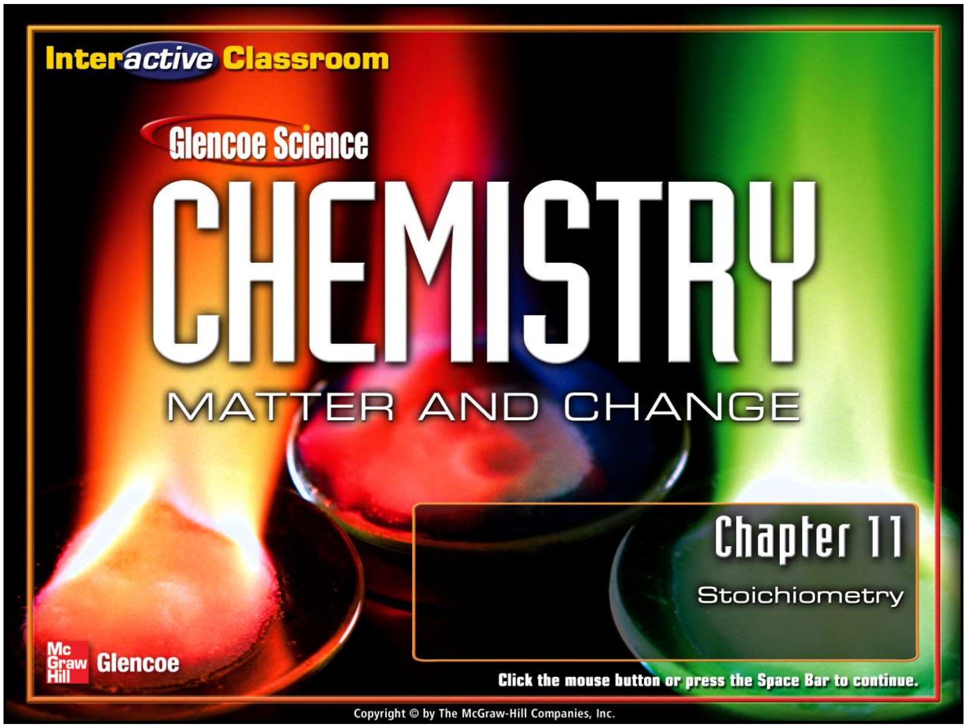

Stoichiometry

Click a hyperlink or folder tab to view the corresponding slides.

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Section 11.1 Defining Stoichiometry

Objectives

- **Describe** the types of relationships indicated by a balanced chemical equation.
- **State** the mole ratios from a balanced chemical equation.

Review Vocabulary

reactant: the starting substance in a chemical reaction

New Vocabulary

stoichiometry

mole ratio

MAIN Idea **The amount of each reactant present at the start of a chemical reaction determines how much product can form.**

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Particle and Mole Relationships

- Chemical reactions stop when one of the reactants is used up.
- **Stoichiometry** is the study of quantitative relationships between the amounts of reactants used and amounts of products formed by a chemical reaction.

Particle and Mole Relationships (cont.)

- Stoichiometry is based on the law of conservation of mass.
- The mass of reactants equals the mass of the products.

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Particle and Mole Relationships (cont.)

$$CO_{2(g)} + 3H_{2(g)} \rightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

We can interpret any balanced chemical equation in four (4) different ways. By

- Particles
- Moles
- Mass
- Volume at STP (for gases)

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Particle and Mole Relationships (cont.)

$$CO_{2(g)} + 3H_{2(g)} \rightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

Particles

- The coefficients tell how many representative particles of each species (substance) are in the balanced equation.
- 1 molecule of CO_2
- 3 molecules of H_2
- 1 molecule of CH_3OH
- 1molecule of H_2O

Particle and Mole Relationships (cont.)

$$CO_{2(g)} + 3H_{2(g)} \rightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

Moles

- Coefficients tell how many moles of each species (substance) are involved in the reaction.
- 1 mole of CO_2
- 3 moles of H_2
- 1 mole of CH_3OH
- 1mole of H_2O

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Particle and Mole Relationships (cont.)

$$CO_{2(g)} + 3H_{2(g)} \rightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

Mass

- Mass of reactants = mass of products
- Law of conservation of mass

50.7 g = 50.7g

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Particle and Mole Relationships (cont.)

$$CO_{2(g)} + 3H_{2(g)} \rightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

Volume at STP (for gases only)

Molar volume = 22.4L/mol of any gas

- 22.4L CO_2
- 3(22.4L) = 67.2L H_2
- 22.4L CH_3OH
- 22.4L H_2O

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

Concepts In Motion
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Particle and Mole Relationships (cont.)

- A **mole ratio** is a ratio between the numbers of moles of any two substances in a balanced equation.
- The number of mole ratios that can be written for any equation is $(n)(n – 1)$ where n is the number of species in the chemical reaction.

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Section 11.1 Assessment

CheckPoint

Which of the following is a correct mole ratio for the following equation?

$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$

A. 2 mol Al : 3 mol Br

B. 3 mol Br_2 : 2 mol Al

C. 2 mol $AlBr_3$: 1 mol Br_2

D. 2 mol Br : 2 mol Al

0%	0%	0%	0%
A	B	C	D

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Section 11.1 Assessment

CheckPoint

How many mole ratios can be written for the following reaction?

$4H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

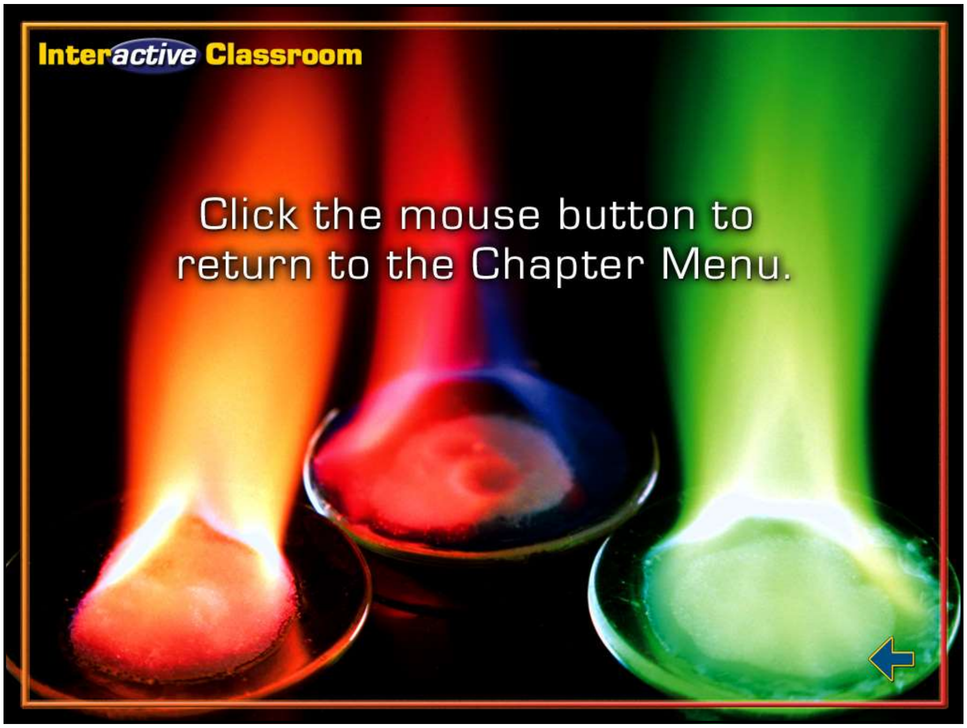
A. 6

B. 4

C. 3

D. 2

0%	0%	0%	0%
A	B	C	D



Section 11.2 Stoichiometric Calculations

Objectives

- **List** the sequence of steps used in solving stoichiometric problems.
- **Solve** stoichiometric problems.

Review Vocabulary

chemical reaction: a process in which the atoms of one or more substances are rearranged to form different substances

MAIN Idea **The solution to every stoichiometric problem requires a balanced chemical equation.**

Using Stoichiometry

- All stoichiometric calculations begins with a balanced chemical equation.

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

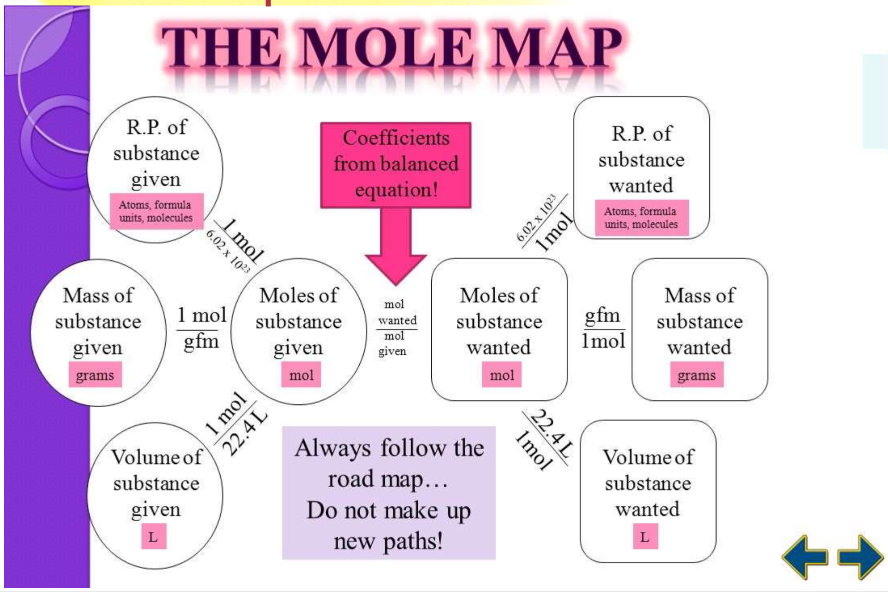
Using Stoichiometry (cont.)

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.
3. The end point of the calculation depends on the desired unit of the unknown substance.

Follow the "Mole Map" to solve stoichiometry problems…

The Mole Map



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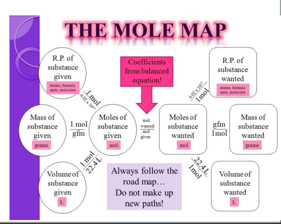
Examples:

How many moles of ammonia are produced by 2.8 mol of hydrogen?

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$



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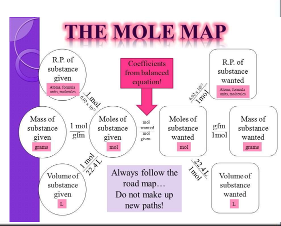
Examples:

What mass of ammonia, NH_3, can be produced from 5.00 moles of H_2 according to the equation:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$



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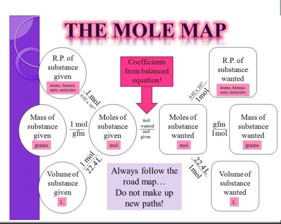
Examples:

Ammonia is produced in a reaction between nitrogen gas and hydrogen gas. How many litres of H_2 gas are needed to react with 4.2×10^{23} molecules of N_2 at STP?

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$



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Section 11.2 Assessment

CheckPoint

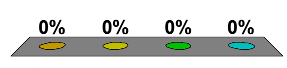
A chemical reaction equation must be _____ in order to make stoichiometric calculations.

A. measured

B. controlled

C. balanced

D. produced



Section 11.2 Assessment

CheckPoint

How many moles of CO_2 will be produced in the following reaction if the initial amount of reactants was 0.50 moles?

$$2NaHCO_3 \rightarrow Na_2CO + CO_2 + H_2O$$

A. 0.25

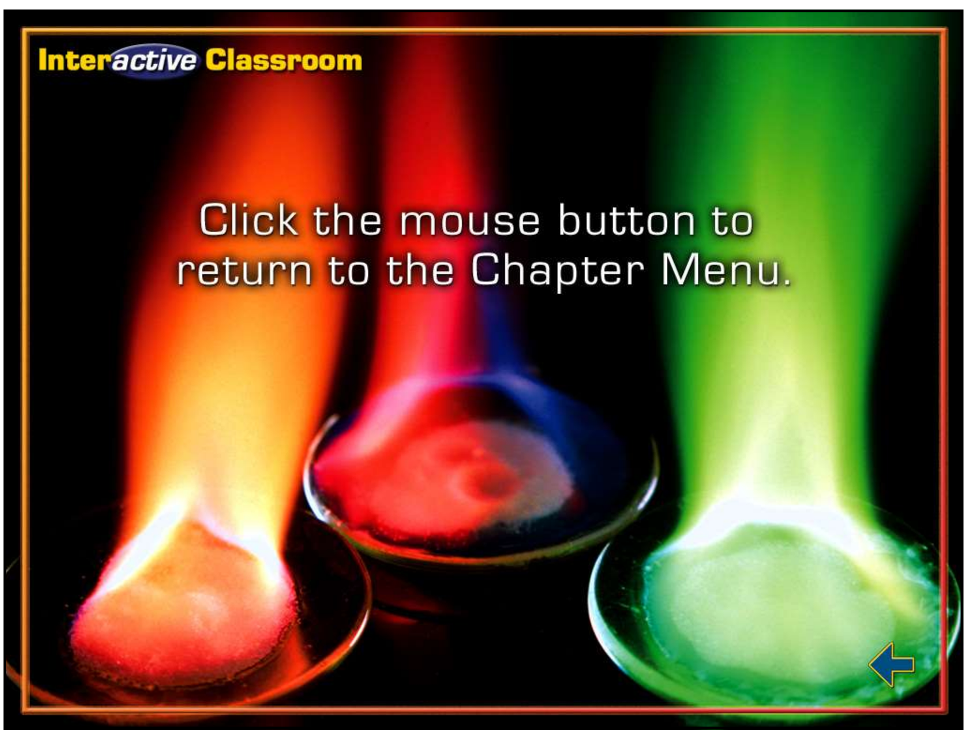
B. 0.3

C. 0.5

D. 1.0

0% 0% 0% 0%

A B C D



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Section 11.3 Limiting Reactants

Objectives

- **Identify** the limiting reactant in a chemical equation.
- **Identify** the excess reactant, and calculate the amount remaining after the reaction is complete.
- **Calculate** the mass of a product when the amounts of more than one reactant are given.

Review Vocabulary

molar mass: the mass in grams of one mole of any pure substance

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Section 11.3 Limiting Reactants (cont.)

New Vocabulary

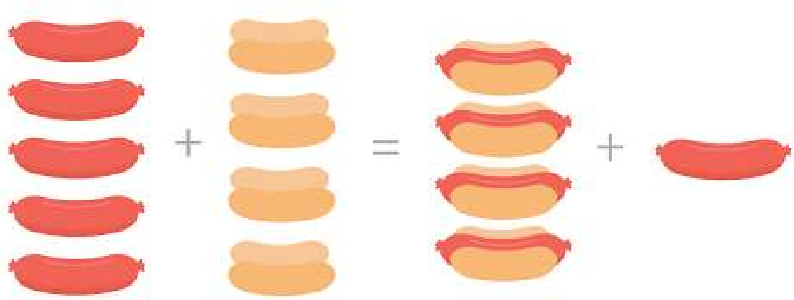
limiting reactant

excess reactant

MAIN Idea **A chemical reaction stops when one of the reactants is used up.**

Why do reactions stop? An example…

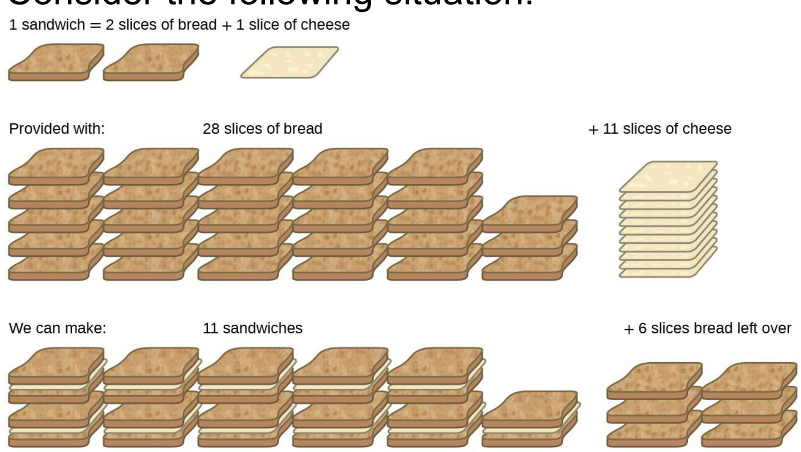
Consider the following situation:



Why did hotdog production stop?

Why do reactions stop? Another example…

Consider the following situation:



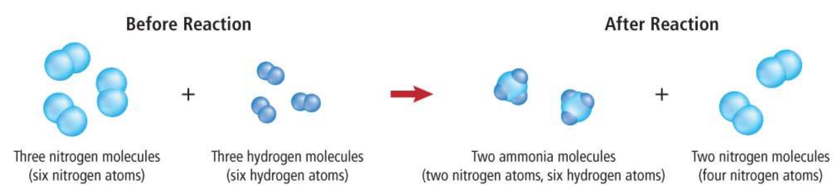
Why did they stop making sandwiches?

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.



Concepts In Motion
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Calculating the Product when a Reactant is Limiting

- $S_8(l) + 4Cl_2(g) \rightarrow 4S_2Cl_4(l)$
- 200.0g S and 100.0g Cl_2
- Which is the limiting reactant

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

- Determine the amount of product formed

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

How much excess reactant is left over?

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

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

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Section 11.3 Assessment

CheckPoint

The mass of the final product in a chemical reaction is based on what?

A. the amount of excess reactant

B. the amount of limiting reactant

C. the presence of a catalyst

D. the amount of O_2 present

0% 0% 0% 0%
A B C D

Section 11.3 Assessment

CheckPoint

What is the excess reactant in the following reaction if you start with 50.0g of each reactant?

$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$

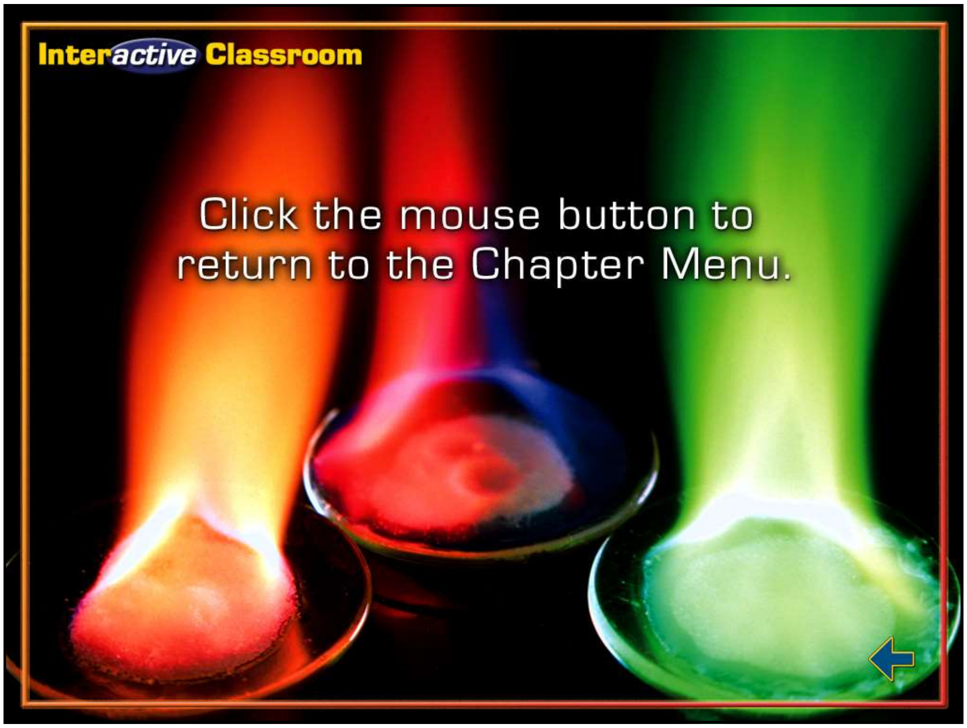
A. O_2

B. P_4

C. Both are equal.

D. unable to determine

0% 0% 0% 0%
A B C D



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Section 11.4 Percent Yield

Objectives

- **Calculate** the theoretical yield of a chemical reaction from data.
- **Determine** the percent yield for a chemical reaction.

Review Vocabulary

process: a series of actions or operations

New Vocabulary

theoretical yield

actual yield

percent yield

MAIN Idea **Percent yield is a measure of the efficiency of a chemical reaction.**

How much product?

- Laboratory reactions do not always produce the calculated amount of products.
- Reactants stick to containers.
- Competing reactions form other products.

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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.

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

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- Calcium carbonate is decomposed by heating, as shown in the following equation

$$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$$

- What is the theoretical yield of CaO if 24.8 g $CaCO_3$ is heated?
- What is the percent yield if 13.1 g CaO is produced?

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- The theoretical yield can be calculated using the mass of the reactant (mole ratio)

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- Percent yield can then be calculated using the equation, now that you know the theoretical and are given the actual yield or experimental yield

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

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- When 84.8 g of iron (III) oxide reacts with an excess of carbon monoxide, 54.3 g of iron is produced

- What is the percent yield of this reaction?

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- You are given the actual yield; you now must calculate the theoretical yield

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Percent Yield in the Marketplace

- Percent yield is important in the cost effectiveness of many industrial manufacturing processes.

Section 11.4 Assessment

CheckPoint

The amount of product that can be produced from a given amount of reactants based on stoichiometric calculations is:

A. actual yield

B. percent yield

C. theoretical yield

D. stoichiometric yield

0% 0% 0% 0%
A B C D

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Section 11.4 Assessment

CheckPoint

You calculate the theoretical yield of a chemical reaction starting with 50.0g of reactant is 25.0g of product. What is the percent yield if the actual yield is 22.0g of product?

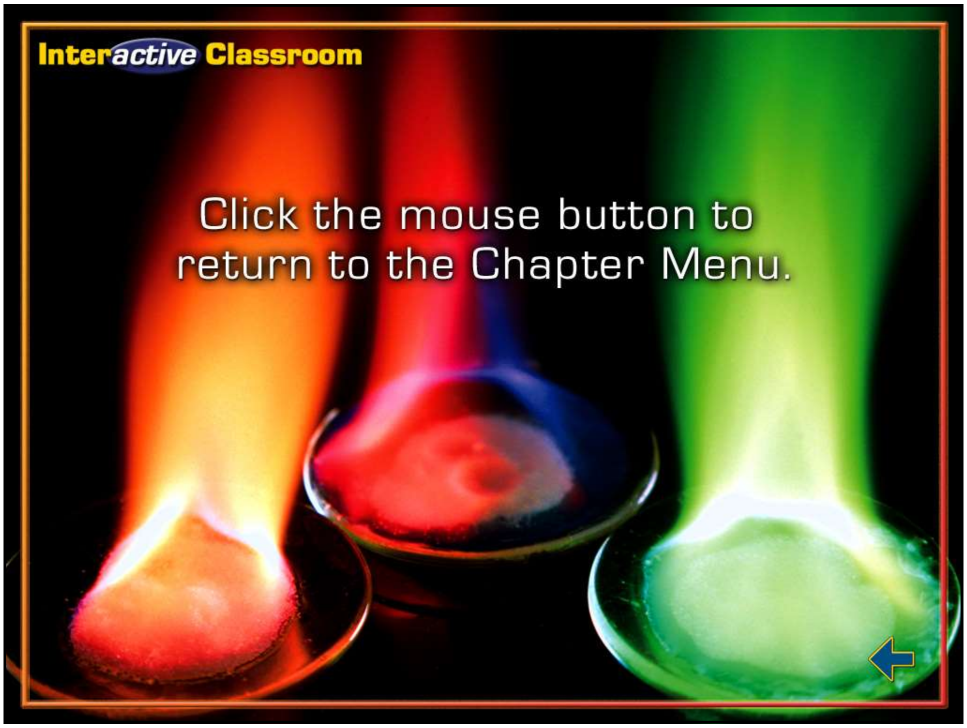
A. 88%

B. 44%

C. 50%

D. 97%

0% 0% 0% 0%
A B C D



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CHAPTER 11

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Study Guide Section 11.1 Defining Stoichiometry

Key Concepts

- Balanced chemical equations can be interpreted in terms of moles, mass, and representative particles (atoms, molecules, formula units).
- The law of conservation of mass applies to all chemical reactions.
- Mole ratios are derived from the coefficients of a balanced chemical equation. Each mole ratio relates the number of moles of one reactant or product to the number of moles of another reactant or product in the chemical reaction.

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Study Guide Section 11.2 Stoichiometric Calculations

Key Concepts

- Chemists use stoichiometric calculations to predict the amounts of reactants used and products formed in specific reactions.
- The first step in solving stoichiometric problems is writing the balanced chemical equation.
- Mole ratios derived from the balanced chemical equation are used in stoichiometric calculations.
- Stoichiometric problems make use of mole ratios to convert between mass and moles.

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Study Guide Section 11.3 Limiting Reactants

Key Concepts

- The limiting reactant is the reactant that is completely consumed during a chemical reaction. Reactants that remain after the reaction stops are called excess reactants.
- To determine the limiting reactant, the actual mole ratio of the available reactants must be compared with the ratio of the reactants obtained from the coefficients in the balanced chemical equation.
- Stoichiometric calculations must be based on the limiting reactant.

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Study Guide Section 11.4 Percent Yield

Key Concepts

- The theoretical yield of a chemical reaction is the maximum amount of product that can be produced from a given amount of reactant. Theoretical yield is calculated from the balanced chemical equation.
- The actual yield is the amount of product produced. Actual yield must be obtained through experimentation.
- Percent yield is the ratio of actual yield to theoretical yield expressed as a percent. High percent yield is important in reducing the cost of every product produced through chemical processes.

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

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What law are all stoichiometric calculations based on?

A. law of definite proportions

B. law of conservation of mass

C. law of conservation of energy

D. none of the above

0% 0% 0% 0%

A B C D

CHAPTER 11

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CheckPoint

The mole ratios can be determined only if what?

A. all the reactants are present in equal amounts

B. the reactants do not have coefficients

C. the products do not have coefficients

D. the equation is balanced

0% 0% 0% 0%

A B C D

CHAPTER 11

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CheckPoint

If the following reaction yields 5 mol $NaAu(CN)_2$, how many moles of Au were present as reactants? (Assume all other reactants are in excess).

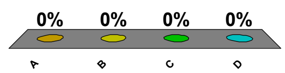
$4Au(s) + 8NaCN(aq) + O_2 + 2H_2O(l) \rightarrow 4NaAu(CN)_2(aq) + 4NaOH(aq)$

A. 1

B. 4

C. 5

D. 20



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In the following reaction, how many moles of NaCN are required to react with 5 mol of Au?

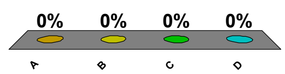
$4Au(s) + 8NaCN(aq) + O_2 + 2H_2O(l) \rightarrow 4NaAu(CN)_2(aq) + 4NaOH(aq)$

A. 3

B. 5

C. 8

D. 10



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In the following reaction, what mass of NaOH is produced if 5.0 moles of NaAu are also produced in the reaction?

$4Au(s) + 8NaCN(aq) + O_2 + 2H_2O(l) \rightarrow 4NaAu(CN)_2(aq) + 4NaOH(aq)$

A. 20 g

B. 50 g

C. 200 g

D. 400 g

0% 0% 0% 0%

A B C D

CHAPTER 11 Resources

Standardized Test Practice

CheckPoint

The SI base unit of amount is ____.

A. the gram

B. the kilogram

C. the mole

D. Avogadro's number

0% 0% 0% 0%

A B C D

CHAPTER 11

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Standardized Test Practice

CheckPoint

Zinc reacts with iodine in a synthesis reaction: $Zn + I_2 \rightarrow ZnI_2$. What is the theoretical yield of ZnI_2, if 1.912 mol of zinc is used?

A. 6.103 g

B. 61.03 g

C. 610.3 g

D. 0.6103 g

0% 0% 0% 0%

A B C D

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Standardized Test Practice

CheckPoint

In a chemical reaction, the statement that matter is neither created nor destroyed is based on what?

A. mole ratio

B. law of conservation of mass

C. Avogadro's number

D. law of definite proportions

0% 0% 0% 0%

A B C D

Chapter 11 — Resources

Standardized Test Practice

CheckPoint

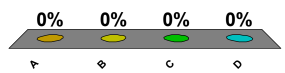
Which is not a product that must be produced in a double replacement reaction?

A. water

B. heat

C. precipitates

D. gases



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Standardized Test Practice

CheckPoint

The _____ is the maximum amount of product that can be produced from a given amount of reactant.

A. theoretical yield

B. actual yield

C. limiting reactant

D. excess reactant