Senior High School

Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Physical Science

First Quarter - Module 6

Stoichiometry

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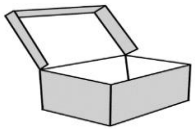


What I Need to Know

Stoichiometry is the calculation of quantities of reactants and products in chemical reactions. The concept of stoichiometry can be observed in the Law of Conservation of Mass where the total mass of the reactants must be equal the total mass of the products. In other words:

- If the amounts of the separate reactants are known, then the amount of the product can be calculated.
- If one reactant has a known quantity and the quantity of the product can be determined, then the amount of the other reactant used can also be calculated.

The module is divided into 3 lessons, namely:

- Lesson 1 – Molar Mass
- Lesson 2 – Mass of Reactants and Products
- Lesson 3 – Percentage Yield

Moreover, in this lesson you will learn concepts and do practice activities that will help you to do the following prior to the main lesson;

- write balanced chemical equations and find stoichiometric ratios of the reactants and products;
- calculate the amount of substances used and produced in a chemical reaction; and
- calculate the percent yield of a reaction;

Finally, we will **determine the limiting reactant in a reaction and calculate the amount of product formed. S11/12PS-IIIh-27**

What I Know

Read the question carefully and encircle the letter of the correct answer.

1. What is the molecular mass of potassium phosphate?
   A. 69 g/mol B. 85 g/mol C. 112 g/mol D. 212 g/mol

2. The unit of molar mass is _____.
   A. grams B. grams/mole C. mole D. moles/gram

3. What is the molecular mass of $AuCl_3$?
   A. 35 g/mol B. 197 g/mol C. 303 g/mol D. 1232 g/mol

4. Which among the choices would have more atoms?
   A. 1 mole of Li
   B. 1 mole of Au
   C. 1 mole of Si
   D. None, all are equal

5. What is the mass of 2.50 mol of oxygen gas (O_2)?
   A. 16 g B. 32 g C. 40 g D. 80 g

6. How many molecules of water are in 5.2 moles of water?
   A. 5.2 C. 8.638×10^{-24}
   B. 6.02×10^{23} D. 3.1304×10^{24}

7. What should be the molar ratio to balance the chemical equation of:
   $H_2 + O_2 \rightarrow H_2O$?
   A. 2: 1: 2 B. 0: 2: 2 C. 2: 2: 2 D. 2: 0: 2

8. Which of the following pertains to chemicals that are created in a chemical reaction?
   A. Producers B. Products C. Reactants D. Reactors

9. How many moles of oxygens are in $2(NO_3)$?
   A. 1 B. 2 C. 3 D. 6

10. What coefficients would balance this equation?
   $Fe + Cl_2 \rightarrow FeCl_3$
   A. 2, 3, 2 B. 3, 2, 2 C. 1, 1, 2 D. 4, 2, 2

11. How many aluminum atoms are in $2Al_2O_3$?
   A. 2 B. 6 C. 4 D. 8

12. Which four coefficients are required to balance the equation?
   $\_CuO + \_H_2 \rightarrow \_Cu + \_H_2O$
   A. 2, 1, 2, 1 B. 1, 1, 1, 1 C. 2, 1, 1, 1 D. 1, 2, 2, 1

13. Which four coefficients are required to balance the equation below?
   $\_CH_4 + \_O_2 \rightarrow \_CO_2 + \_H_2O$
   A. 1, 1, 1, 2 B. 1, 2, 2, 1 C. 1, 1, 1, 1 D. 1, 2, 1, 2

14. In most chemical reactions the amount of product obtained is _____.
   A. more than the percentage yield C. more than the theoretical yield
   B. less than the theoretical yield D. equal to the theoretical yield

15. When two substances react to form products, the reactant which is used up is called the _____.
   A. catalytic reagent C. excess reagent
   B. determining reagent D. limiting reagent

Lesson 1 Molar Mass

What's In

Molecular Mass and Formula Mass

Before we proceed to the more complex computations, it is necessary that we recall how to calculate molecular mass (for covalent) or the formula mass (for ionic) of compounds. It is simply calculated by adding together the atomic mass of each atom in its chemical formula. The units is expressed as **g/mol** or **amu** (atomic mass unit)

(Note: Your Periodic table would be significant on this module in cases you are not fond of the atomic masses of elements.)

Let us look at the following examples:

Table 1.1. Examples of Molecular Mass

Example 1: Nitrogen	Example 2: Carbon Dioxide
Nitrogen exists as molecules. Each molecule of nitrogen (N_2) consists of two nitrogen atoms (N) Number of Atoms : 2 Atomic Mass of Nitrogen : 14 Molecular Mass : 2 x 14 = **28**	One molecule of carbon dioxide (CO_2) consists of one carbon atom (C) and two oxygen atoms (O) Number of Atoms of Carbon : 1 Atomic Mass of Carbon : 12 Number of Atoms of Oxygen : 2 Atomic Mass of Oxygen : 16 Molecular Mass: (1 x 12) + (2 x 16) = **44**

For more samples of computations molecular and formula mass, refer to the table 1.2 below:

Table 1.2. More examples of Molecular Mass

Molecule/ Substance	Formula	Number of Atoms	Calculation of the Mass (g/mol)
Ammonia	NH_3	1 N ; 3 H	(1 X 14) + (3 X 1) = 17
Water	H_2O	2 H ; 1 O	(2 X 1) + (1 X 16) = 18
Ethanol	C_2H_5OH	2 C ; 6 H ; 1 O	(2 X 12) + (6 X 1) + (1 X 16) = 46
Calcium carbonate	$CaCO_3$	1 Ca ; 1 C ; 3 O	(1 X 40) + (1 X 12) + (3 X 16) = 100
Magnesium sulphate	$MgSO_4$	1 Mg ; 1 S ; 4 O	(1 X 24) + (1 X 32) + (4 X 16) = 120

What's New

Activity 1.1

Solve for the molecular/formula mass of the following compounds. Write your solutions and answers of a separate sheet of paper.

1. What is the molecular mass of glucose ($C_6H_{12}O_6$)?
2. What is the molecular mass of sucrose ($C_{12}H_{22}O_{11}$)?
3. What is the molecular mass of sulphuric acid (H_2SO_4)?
4. What is the formula mass of potassium sulphide (K_2S)?
5. What is the formula mass of calcium hydroxide ($Ca(OH)_2$)?
6. What is the formula mass of magnesium oxide (MgO)?

What Is It

Molar Mass and Moles

As atoms are very small, we deal with a very large number of atoms in this chemistry part of Physical Science. The **SI unit for the amount of substance is denoted as mole (mol), given the symbol "n".**

The number of moles of substances can be calculated using this formula:

$$\text{Number of Moles (n)} = \frac{\text{Mass of a substance in grams (m)}}{\text{Atomic Mass } (A_r) \text{ or Molecular Mass } (M_r)}$$

The actual number of particles in a mole has been experimentally determined to be 6.02×10^{23} particles representing atoms, molecules, and ions or formula units, this is known as the Avogadro's number. Therefore:

- a mole of copper (Cu) has 6.02×10^{23} atoms
- a mole of water (H_2O) has 6.02×10^{23} molecules, and
- a mole of sodium chloride (NaCl) has 6.02×10^{23} formula units

$$\text{Number of Moles (n)} = \frac{\text{Number of Particles}}{6.02 \times 10^{23}}$$

Now that you have been presented by the relevant formulas, let us look at more examples:

1. Find the number of moles of 88g carbon dioxide (CO_2)

It can be solved like this:

$$\text{Number of moles } CO_2 = \frac{88 \text{ grams } CO_2}{44 \text{ grams/mol } CO_2}$$

$$= 2 \text{ moles } CO_2$$

or like this:

$$88 \text{ grams } CO_2 = \frac{1 \text{ mole } CO_2}{44 \text{ grams } CO_2}$$

$$= 2 \text{ moles } CO_2$$

2. How many moles of sodium chloride are in 175.5g sodium chloride (NaCl)?

It can be solved like this:

$$\text{Number of Moles NaCl} = \frac{178.5 \text{ grams NaCl}}{58.5 \text{ grams/ mol NaCl}}$$

$$= 3 \text{ mol NaCl}$$

or like this:

$$178.5 \text{ grams NaCl} = \frac{1 \text{ mole NaCl}}{58.5 \text{ grams NaCl}}$$

$$= 3 \text{ moles NaCl}$$

3. Convert 2.01×10^{23} magnesium atom to mole of magnesium atoms.

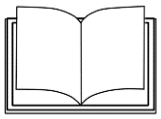
$$\text{Number of Moles (Mg)} = \frac{2.01 \times 10^{23}}{6.02 \times 10^{23}}$$

$$= 0.334 \text{ mole of Mg atom}$$

4. How many grams are there in 3.3 moles of Magnesium Fluoride (MgF_2)?

$$\text{g of Magnesium Sulfide } (MgF_2) = 3.3 \text{ mol} \times 62 \text{ g/mol}$$

$$= 204.6 \text{ g } MgF_2$$



What's More

Activity 1.2

Compute the right answer to the following problems.

1. How many iron atoms are there in 0.6 mol of iron?

2. Calculate the mass of a 0.8 mol of sulphur dioxide (SO_2).

3. How many moles are in 420g of copper (II) sulphate ($CuSO_4$)?

4. What is the amount in moles of a 36.5g of silver nitrate ($AgNO_3$)?

5. How many hydrogen atoms are there in three moles of hydrogen gas?

What I Have Learned

Here are the things worth to remember:

The molar mass is also known as molecular weight, is the sum of the total mass in grams of all the atoms that make up a mole of a particular molecule. The unit used to measure is grams per mole.

- Find the atomic mass of the individual elements
- Count the atoms each element
- Find the molar mass

What I Can Do

Activity 1.3

The following are some of the chemicals used in daily life. Complete the table below by solving the molar masses of the following common chemicals.

Number	Common Name of Chemical	Molecular Formula	Molar Mass
1	Baking powder	$NaHCO_3$	
2	Alcohol	C_2H_6O	
3	Bleaching Powder	$NaOCl$	
4	Moth balls	$C_6H_4C_{l2}$	
5	Chalk	$CaCO_3$	

Assessment

Read the question carefully and encircle the letter of the correct answer.

1. What is the molecular mass of calcium nitrate ($Ca(NO_3)_2$)?
   A. 116.1 g/mol B. 102.1 g/mol C. 150.1 g/mol D. 164.1 g/mol

2. What is the molecular mass of magnesium fluoride (MgF_2)?
   A. 43.3 g/mol B. 62.3 g/mol C. 67.6 g/mol D. 92.9 g/mol

3. How many moles are in 32.3 grams of carbon dioxide (CO_2)?
   A. 0.73 moles C. 44.01 moles
   B. 32.3 moles D. 1421.52 moles

4. What is the mass of 2.50 mol of oxygen gas (O_2)?
   A. 16 g B. 32 g C. 40 g D. 80 g

5. How many moles are in 36.0 g of Be?
   A. 0.25 mol B. 4.0 mol C. 45.0 mol D. 320 mol

6. What is the mass of one mole of $AuCl_3$?
   A. 96 g B. 130 g C. 232.5 g D. 303.5 g

7. How many moles of atoms in a container are in 6.02 x 10^{24} molecules of water?
   A. 1 B. 10 C. 30 D. 60

8. Comparing an 88 g of carbon dioxide (CO_2) to an 88 g of propane (C_3H_8) it contains _____.

A. less atoms
B. more molecules
C. the same number of atoms
D. the same number of molecules

9. How many moles of atoms are present in sulfuric acid, H_2SO_4?

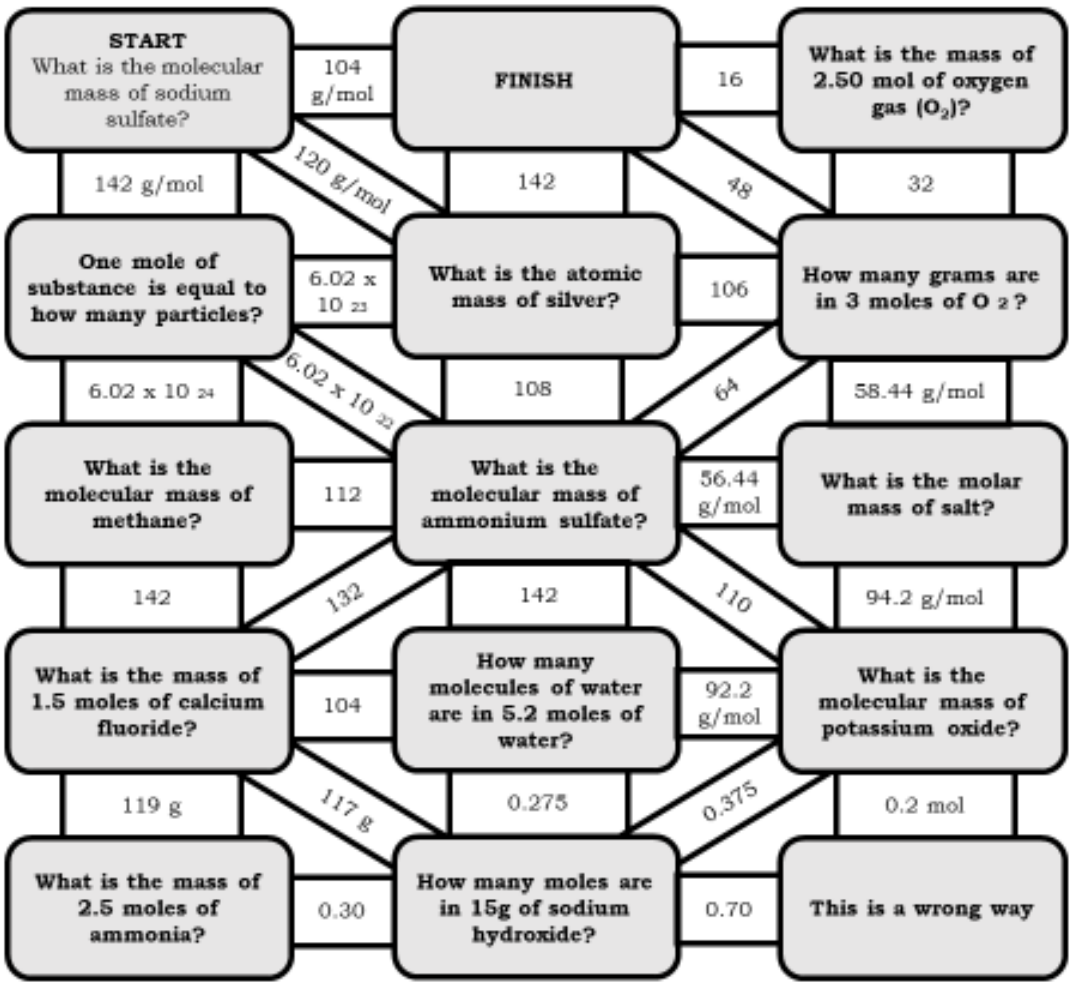
A. 7 B. 14 C. 21 D. 49

10. What is the molecular mass of potassium oxide?

A. 90.2 g/mol B. 92.4 g/mol C. 102.4 g/mol D. 116.0 g/mol

Additional Activities

Read the question at **START** and follow the correct path that contains the right answer. Keep going until you reach the **FINISH**. Hint: the correct path has 9 questions.



Lesson 2 Mass of Reactants and Products

What's In

Review of Balancing Chemical Equations

Before we proceed to the concept of mass of reactants and products, it is necessary that you know how to balance chemical equations. This is for the reason of: every chemical reaction problem you must deal with must be balanced.

Consider the reaction below:

- A hydrogen gas (H_2) reacts with oxygen gas (O_2) to form water (H_2O)

Word Equation : hydrogen + oxygen → water

Chemical Formula Equation : $H_2 + O_2 \rightarrow H_2O$

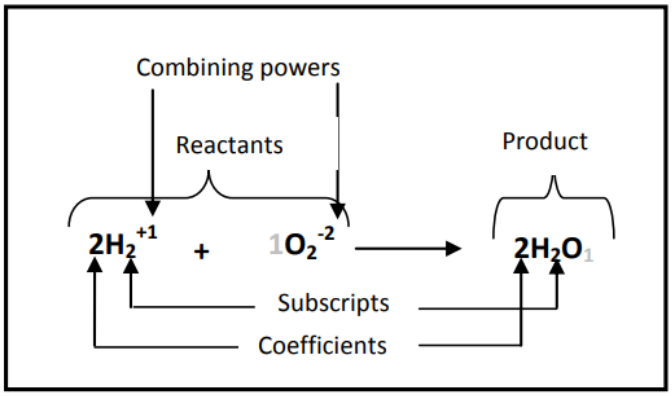


Figure 2.1. Parts of a Chemical Equation

Balanced Chemical Equation : $2H_2 + O_2 \rightarrow 2H_2O$

Now, let us try doing another example of balancing chemical equations by following the steps presented.

Sample Chemical Equation:

$$CH_4 + O_2 \rightarrow CO_2 + H_20$$

1. **Write down the number of atoms per element.** Do this separately for both reactant and product side of the equation. Look at the subscripts next to each atom to find the number of atoms in the equation.

	CH_4 + 0_2 → CO_2 + H_20	
☑	1	- C - 1
✗	4	- H - 2
✗	2	- O - 2 + 1 = 3

Figure 2.2. Writing down the atoms per element

(Take note that in balancing chemical equations, you can add or change coefficients, but you must never alter the subscripts.)

2. **Add a coefficient.** A coefficient of 2 is placed on the product side- that is, of water (H_2O) to balance the hydrogen from the product(right) side, with the 4 hydrogen atoms on the reactant (left) side.

	CH_4 + 0_2 → CO_2 + **2**H_20	
☑	1	- C - 1
☑	4	- H - 2 **(2)** = 4
✗	2	- O - 2 + 1**(2)** = 4

Figure 2.3. Adding coefficients and adjusting the number of atoms

3. **Address the remaining unbalanced atoms by adding coefficients that would balance the chemical equation**. A coefficient of 2 is placed on one of the reactants- the oxygen (O_2) to balance the atoms of oxygen to the product side.

	CH_4 + **2**0_2 → CO_2 + **2**H_20	
☑	1	- C - 1
☑	4	- H - 2 (2) = 4
☑	2**(2)** = 4	- O - 2 + 1(2) = 4

Figure 2.4. Further adding coefficients and adjusting the number of atoms

What's New

Activity 2.1

Balance the following chemical reactions by writing the correct coefficients.

1. ____$SiCl_4$ + ____H_2O → ____SiO2 + ____HCl

2. ____Fe + ____H_2S0_4 → ____$Fe_2(SO_4)_3$ + ____H_2

3. ____Fe_2O_3 + ____CO → ____Fe + ____CO_2

4. ____NaBr + ____Cl_2 → ____NaCl + ____Br_2

5. ____$Mg(OH)_2$ + ____HCl → ____$MgCl_2$ + ____H_2O

What Is It

Masses of reactant and product given the mass of one reactant

As a recall, let us note the following concepts that you have learned:

- You learned how to construct a balanced chemical equation.
- Your learned that a chemical equation represents the actual atoms or molecules that takes part on a reaction.

From a balanced chemical equation, we are now going to calculate the amount of reactants required and the amount of products formed as well.

Let us consider this chemical reaction:

A reaction occurred between zinc and hydrochloric acid. The products formed are zinc chloride and hydrogen gas.

- Writing down the word equation:

  zinc + hydrochloric acid → zinc chloride + hydrogen gas

- Writing down the chemical formula equation:

  Zn + HCl → $ZnCl_2$ + H_2

- Using graphical illustration of particles:

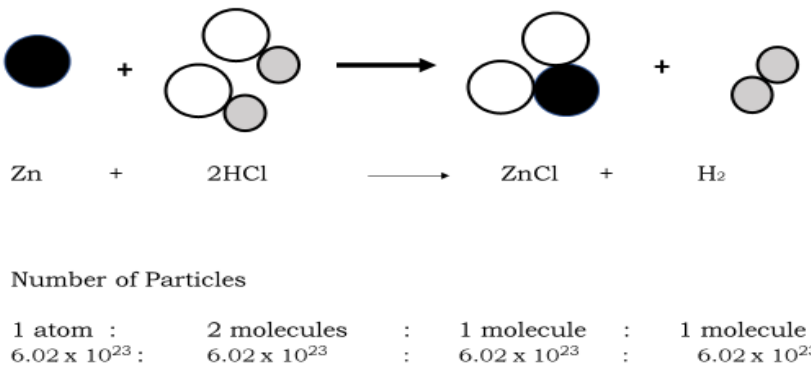


Figure 2.6. Graphic Illustration of a Chemical Equation

- Writing down the balanced chemical equation:

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

- Writing the balanced equation in terms of mole ratio:

1 mole: 2 moles : 1 mole: 1 mole

The above interpretations show that the mole ratio is proportional to the number of atoms or molecules taking part in a chemical reaction. **Therefore, we can say that the number of atoms or molecules taking part in a chemical reaction can be converted into moles.**

The equation can be interpreted as:

1 mole of zinc *reacting with* ***2 moles of hydrochloric acid*** *will produce* ***1 mole of zinc chloride*** *and* ***1 mole of hydrogen****.*

The following step by step examples show how chemical calculations are carried out.

Sample Problem 1:
A magnesium reacts with dilute hydrochloric acid according to the equation of:

magnesium + hydrochloric acid → magnesium chloride + hydrogen gas

In an experiment, 2 g of magnesium ribbon is chemically reacted with excess hydrochloric acid.

a. How many moles of magnesium have reacted?
b. What mass of magnesium chloride would be formed?

Solution:

- **Step 1:** Balance the chemical equation

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

- **Step 2:** Write the molar ratio

1 mol Mg : 2 mol HCl **:** 1 mol $MgCl_2$: 1 mol H_2

Verbal Interpretation:

1 mole of magnesium reacts with 2 moles of hydrochloric acid will produce 1 mol of magnesium chloride and 1 mole of hydrogen gas.

- **Step 3:** Using the molecular mass and molar ratio, convert to the asked unit.
    a. Question: How many moles of magnesium have reacted?

It can be solved like this: *or like this:*

$$\text{Moles of Magnesium} = \frac{2 \text{ grams Mg}}{24 \text{ grams/mol Mg}} \qquad 2 \text{ grams Mg} = \frac{1 \text{ mol Mg}}{24 \text{ grams Mg}}$$

$$= 0.0833 \text{ moles Mg} \qquad = 0.0833 \text{ mol Mg}$$

b. Question: What mass of magnesium chloride would be formed?

$$2 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24 \text{ g Mg}} \times \frac{1 \text{ mol MgCl}}{1 \text{ mol Mg}}$$

$$= 0.0833 \text{ mol Mg}$$

Sample Problem 2:
A nitric oxide reacts with oxygen and produces nitrogen dioxide:

$$NO + O_2 \rightarrow NO_2$$

a. How many moles of NO_2 are formed by the reaction of 0.56 moles of O_2?
b. How many grams of NO_2 are formed by the reaction of 144 moles of

Solution:

- **Step 1:** Balance the chemical equation

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

- **Step 2:** Write the molar ratio

$$2 \text{ mol NO} : 1 \text{ mol } O_2 : 2 \text{ mol } NO_2$$

- **Step 3:** Using the molecular mass and molar ratio, convert to the asked unit.

1. QUESTION: How many moles of NO_2 are formed by the reaction of 0.56 moles of O_2?

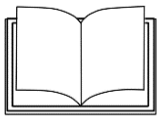
$$0.56 \text{ mol } O_2 \times \frac{2 \text{ mol } NO_2}{1 \text{ mol } O_2}$$

$$= 1.12 \text{ mol } NO_2$$

2. QUESTION: How many grams of NO_2 are formed by the reaction of 144 moles of NO?

$$144 \text{ g NO} \times \frac{1 \text{ mol NO}}{30 \text{ g NO}} \times \frac{2 \text{ mol } NO_2}{2 \text{ mol NO}} \times \frac{46 \text{ g } NO_2}{1 \text{ mol } NO_2}$$

$$= \quad 220.8 \text{ g } NO_2$$



What's More

Activity 2.2

Solve the following chemical reactions:

1. Calculate the amount of barium chloride ($BaCl_2$) needed to prepare 50.0g of barium sulphate ($BaSO_4$).

barium chloride + sodium sulphate → barium sulphate + sodium chloride

$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + NaCl$

2. A reaction occurs between sodium chloride (NaCl) solution and silver nitrate solution ($AgNO_3$). If a SHS student has 5.85 g of sodium chloride (NaCl), how many grams silver nitrate ($AgNO_3$) would he need for all the sodium chloride (NaCl) to be used up?

sodium chloride + silver nitrate → silver chloride + sodium nitrate

$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

What I Have Learned

Here are your takeaways from this specific lesson:

- We want the equation to accurately represent what happens in an actual chemical reaction.
- A balanced chemical equation obeys the Law of Conservation of Mass, which is a major principle in science.
- A balanced chemical equation lets up predict the amount of reactants needed and the amount of products formed.

And keep in mind these things when doing calculations:

- Make sure that the chemical equation is balanced.
- To get molar ratios, use the coefficients on the left side of the compounds.

- Check to make sure you use the appropriate atomic masses and molecular mass before proceeding.

What I Can Do

Activity 2.3

Answer the following statements in an explanatory form.

1. Why is it important to understand the relationship between reactants and products in a chemical reaction?

2. How is the mass of reactants and products used in the field of medicine?

Assessment

Read the question carefully and encircle the letter of the correct answer.

1. What should be the three quantities to balance the chemical equation below?

_Ca + _Cl_2 → _$CaCl_2$

A. 1, 1, 2 B. 2, 2, 1 C. 1, 2, 1 D. 1, 1, 1

2. In Fe + Cl_2 → $FeCl_3$, what coefficients would balance the equation?

A. 2, 3, 2 B. 3, 2, 2 C. 1, 1, 2 D. 4, 2, 2

3. What should be the molar ratio to balance the equation below?

_CuO + _H_2 → _Cu + _H_2O

A. 2: 1: 2: 1 B. 1: 1: 1: 1 C. 2: 1: 1: 1 D. 1: 2: 2: 1

4. How much aluminum is in $2Al_2O_3$?

A. 2 B. 4 C. 6 D. 8

5. For the reaction $2KClO_3 \rightarrow 2KCl + 3O_2$, how many moles of oxygen are produced when 3 moles of $KClO_3$ decompose completely?

A. 1 mol B. 2.5 mol C. 3.0 mol D. 4.5 mol

6. Consider the following reaction:

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2\,(g) + 10H_2O$$

How many moles CO_2 of are produced by the complete combustion of 58 g of butane (C_4H_{10})?

A. 2 B. 4 C. 6 D. 8

7. What does the law of conservation of mass state?
   A. The total mass of the reactions equals the total mass of the products.
   B. The total mass of the reactants is greater than the total mass of the products.
   C. The total mass of the reactions is less than the total mass of the products.
   D. Mass can be created but not destroyed.

8. Aluminum reacts with oxygen to produce aluminum oxide.

$$\mathbf{4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3}$$

If 5.0 moles of Al react with excess O_2, how many moles of Al_2O_3 can be formed?

A. 1.0 mol B. 2.0 mol C. 2.5 mol D. 5.0 mol

9. What mass of oxygen is consumed by the complete combustion of 23.0 grams of ethylene?

$$\mathbf{C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O}$$

A. 2.46 g B. 8.75 g C. 26.2 g D. 60.5 g

10. How many moles of nitric oxide can be made from the reaction of 3.80 mol NH_3 with 5.15 mol O_2?

$$\mathbf{4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O}$$

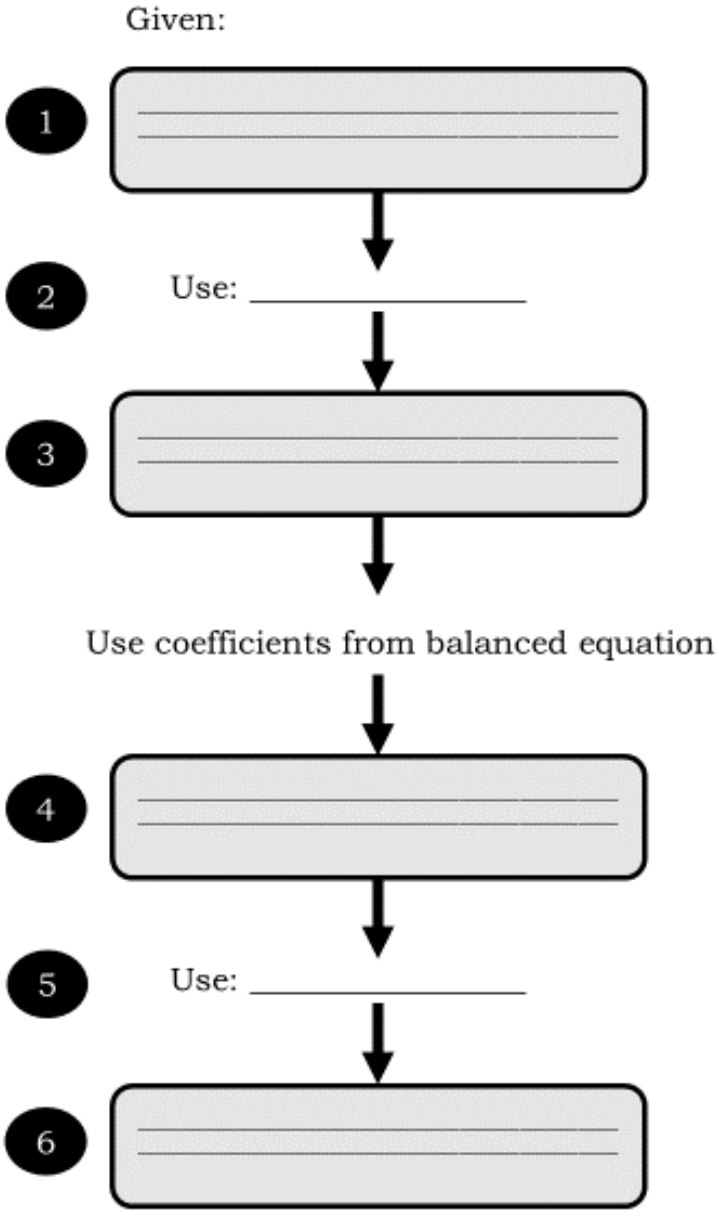
A. 3.80 mol
B. 4.12 mol
C. 5.15 mol
D. 6.44 mol

Additional Activities

Complete the concept map below by filling up the blank spaces with the appropriate concepts using the linking words/phrases as guide on how these concepts are related to each other.

Concepts:

Molar mass of substance A	Moles of substance B
Molar mass of substance B	Grams of substance A
Moles of substance A	Grams of substance A



Lesson 3 Percentage Yield

What's In

Limiting and Excess Reactant

Imagine you are disinfecting your entire house, but you only have a small amount of disinfectant as it was used weeks before. Of course, it would be impossible to clean your entire household with that just amount. As there is insufficiency in your disinfectant, chemists would say that the disinfectant is the limiting reactant.

Let us look at the actual definitions:

- **Limiting reactant** - the reactant that is completely used up in a reaction It is called so because it determines or limits the amount of products formed.
- **Excess reactants** - reactants that are not used up.

To further understand the concept, let us observe this given scenario:

A scientist conducted three experiments using different molar ratios of the reactants- the hydrogen and the chlorine to form hydrogen chloride or hydrochloric acid (HCl).

$$H_2 + Cl_2 \rightarrow 2HCl$$

1 mole : 1 mole : 2 moles

The results he obtained are the following:

- In experiment 1, the ratio of the number of moles of reactant molecules used is the same as the balanced chemical equation.

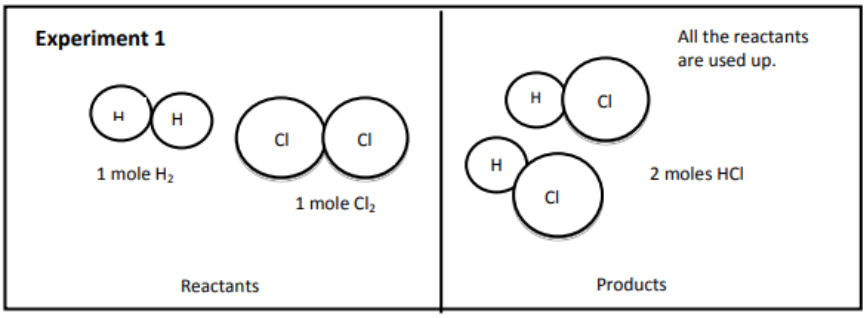


Figure 3.1. Sample Experiment 1

- In experiments 2 and 3 however, the ratio of the number of moles of reactant molecules used is different from the chemical equation.

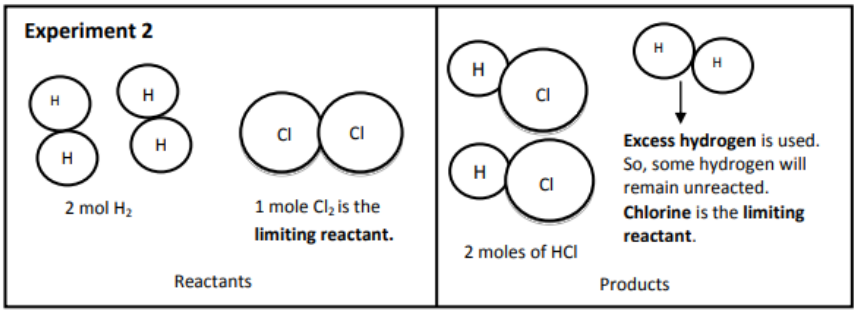


Figure 3.2. Sample Experiment 2

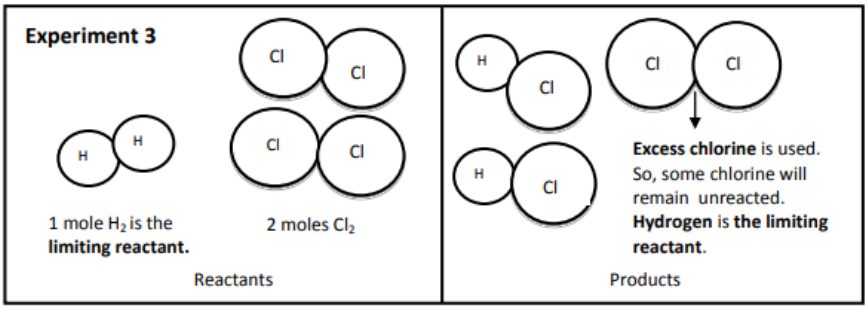


Figure 3.3. Sample Experiment 3

For any chemical reaction, it is possible to calculate the exact quantities of reactants that are required and products that are formed from a balanced chemical equation. Reactions should be carried out using exact quantities of reactants to minimize wastes.

Now let us try to incorporate calculations on the topic.

Sample Problem 1:

Zinc reacts with hydrochloric acid. If 0.05 mol of zinc is added to 0.075 mol of hydrochloric acid:

a. identify the limiting reactant.
b. calculate the amount in moles of the excess reactant that will remain unreacted.

$$\underset{1\text{ mol}}{Zn} + \underset{2\text{ mol}}{2HCl} \rightarrow \underset{1\text{ mol}}{ZnCl_2} + \underset{1\text{ mol}}{H_2}$$

Solution:

According to the balanced equation, 1 mol of zinc (Zn) reacts with 2 mol of hydrochloric acid (HCl). Therefore:

a.

$$0.05 \text{ mol Zn} \times \frac{2 \text{ mol HCL}}{1 \text{ mol Zn}}$$

$$= 1 \text{ mol HCL}$$

$$0.075 \text{ mol HCl} \times \frac{1 \text{ mol Zn}}{2 \text{ mol HCL}}$$

$$= 0.0375 \text{ mol Zn}$$

Since 0.05 mol of zinc is used, the zinc must be in excess and **hydrochloric acid is the limiting reactant.**

b. The amount of zinc which remains unreacted is:

$$= 0.05 \text{ mol Zn} - 0.0375 \text{ mol Zn}$$

$$= 0.0125 \text{ mol Zn}$$

Sample Problem 2:

Ethene ($C2H_4$) burns in oxygen (O_2) to form carbon dioxide (CO_2) and water (H_2O). Specifically, 1 mole of ethane (C_2H_4) is burnt in 5 moles of oxygen (O_2).

a. Which gas is the excess reactant?
b. Calculate the amount in moles of the excess gas.
c. Calculate the amount in moles of carbon dioxide produced.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + H_2O$$

1 mol : 3 mol : 2 mol : 1 mol

Solution:

a. 1 mol C_2H_4 reacts with 3 mol O_2

$$1 \text{ mol } C_2H_4 \times \frac{3 \text{ mol } O_2}{1 \text{ mol } C_2H_4}$$

$$= 3 \text{ mol } O_2$$

However, 5 moles of oxygen were used, therefore, **oxygen gas is the excess reactant.**

b. The amount of oxygen gas remaining:

$$= 5 \text{ mol } O_2 - 3 \text{ mol } O_2$$

$$= 2 \text{ mol } O_2$$

c. The amount of carbon dioxide produced:

$$1 \text{ mol } C_2H_4 \times \frac{2 \text{ mol } CO_2}{1 \text{ mol } C_2H_4}$$

$$= \quad 2 \text{ mol } O_2$$

What's New

Activity 3.1

Solve the chemical reaction problem below:

1. A solution containing 20 g of sodium chloride (NaCl) is reacted with a solution containing 20 g of silver nitrate according to the equation:

$$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$$

a. What is the molar mass of NaCl, $AgNO_3$, AgCl, and $NaNO_3$?

b. Which is the limiting reactant, and which is the excess reactant?

c. What mass of silver chloride will precipitate?

d. What mass of excess reactant will remain unreacted at the end of the reaction?

Percentage and Theoretical Yield

Calculations based on chemical equations give the theoretical yield of product to be expected from a reaction.

- **Theoretical yields -** the amount of products calculated from the complete reaction of the limiting reactant.
- **Actual yields -** the amount of products that are actually produced in a reaction.
- **Percent Yield -** used to determine how efficient a given reaction is.

Often, the actual yield is almost always less than the calculated yield of the product. The reason may be that some products have remained in a solution or has not been weighed with the final yield.

The percentage yield of a product is shown in a relationship of:

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

Let us try doing some calculations based on the given relationship:

Sample Problem 1:

A grade 12 student calculates that a certain reaction will yield 7.0 g of salt. His product weighs 6.3 g. What percentage yield has he obtained?

Solution:

$$\text{Percentage Yield} = \frac{6.3}{7.0} \times 100$$

$$= 90\ \%$$

Sample Problem 2:

If 1.92 g of magnesium (Mg) is heated in excess oxygen (O), 3.0 g of magnesium oxide (MgO) will be obtained. Calculate the percentage yield of magnesium oxide (MgO).

$$Mg + O_2 \rightarrow MgO$$

Solution:

1. Balance the equation

$$2Mg + O_2 \rightarrow 2MgO$$

2. Calculate for the mass of magnesium oxide using the 1.92g of magnesium (Mg) given.

$$1.92\ \text{g Mg} \times \frac{1\ \text{mol Mg}}{24\ \text{g Mg}} \times \frac{2\ \text{mol MgO}}{2\ \text{mol Mg}} \times \frac{40\ \text{g MgO}}{1\ \text{mol MgO}}$$

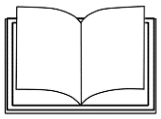
$$= \quad 3.2\ \text{g MgO}$$

3. Find the percentage yield, using the actual amount of magnesium oxide (MgO) obtained which is 3.0 g MgO.

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

$$\text{Percentage Yield} = \frac{3.0\ \text{g MgO}}{3.2\ \text{g Mgo}} \times 100$$

$$\text{Percentage Yield} = 93.8\ \%$$



What's More

Activity 3.2

Solve the percentage yield of the problems below:

1. 28 g of nitrogen (N_2) is reacted with a hydrogen (H_2) and 3.4g of ammonia (NH_3) has been formed. What is the percentage yield obtained?

nitrogen + hydrogen → ammonia

$N_2 + H_2 \rightarrow NH_3$

2. If 25 g of CaO is treated with 98.5 g H_3PO_4 and $Ca_3(PO_4)_2$ is obtained, calculate the percent yield?

$CaO + H_3PO_4 \rightarrow CA_3(PO_4)_2 + H_20$

What I Have Learned

Why is it important to identify the limiting reactant, excess reactant, and the percentage yield?

- In chemical industries, large amounts of chemicals are required to manufacture a specific product. To get the maximum yield of a product at the minimum production cost, they need to know the limiting reactant. This ensures that the limiting reactant or chemical is utilized very well.
- In a most realistic setting, the excess reactants on the other hand are recycled, to reduce the production costs.

What I Can Do

Activity 3.3

Write **TRUE** if the given statement is true and write **FALSE** if it says otherwise. Write your answer before the number.

1. The presence of moisture and other environmental factors in the product does not affect determination of actual yield.
2. The product must be pure to determine actual yield.
3. The excess reagent is always present because of incomplete reactions.
4. Excess reagent is calculated from mole data presented.
5. A balanced equation is necessary for percentage yield calculations.

Assessment

Read the question carefully and encircle the letter of the correct answer.

1. What is the mass of hydrogen formed when 25 grams of aluminum reacts with excess hydrochloric acid?

$$2Al + 6HCl \rightarrow Al2Cl_6 + 3H_2$$

A. 0.41 g B. 1.2 g C. 1.8 g D. 2.8g

2. In most chemical reactions, the amount of the product obtained is _____.
   A. more than the percentage yield
   B. less than the theoretical yield
   C. more than the theoretical yield
   D. equal to the theoretical yield

3. If the percentage yield is results to 100%, then _____.
   A. there was no limiting reactant
   B. the actual yield is equal to the theoretical yield
   C. the actual yield is less than the theoretical yield
   D. the actual yield is greater than the theoretical yield

4. The reactant which is used up when two substances react to form products is called the _____.
   A. limiting reagent
   B. determining reagent
   C. catalytic reagent
   D. excess reagent

5. Which statement is true if 12 mol CO and 12 mol FeO are allowed to react?

3CO + FeO -> 2Fe + 3CO

   A. The limiting reagent is Fe O and 24 mol Fe will be formed.
   B. The limiting reagent is CO and 3.0 mol CO will be formed.
   C. The limiting reagent is CO and 8.0 mol Fe will be formed.
   D. The limiting reagent is Fe O and 36 mol CO will be formed

6. For the reaction represented below, if you start with 500 g of sulfur trioxide, how many grams of sulfuric acid (H_2SO_4) can you produce?

$SO_3 + H_2O \rightarrow H_2SO_4$

A. 312.2 g B. 766.3 g C. 612.5 g D. 1021.8 g

7. What is the percentage yield if 500 g of sulfur trioxide react with excess water to produce 575 g of sulfuric acid (H_2SO_4)?

$SO_3 + H_2O \rightarrow H_2SO_4$

A. 91.2% B. 82.7% C. 88.3% D. 93.9%

8. What is a limiting reactant?
   A. The reactant that makes the product.
   B. The substance that is in excess that does not get used up as a reactant.
   C. The reactant that is used up last and prevents more product from being made.
   D. The reactant that is used up first and prevents more product from being made.

9. If 2.5 moles of zinc react with 6.0 moles of hydrochloric acid in the equation below, what is the limiting reactant?

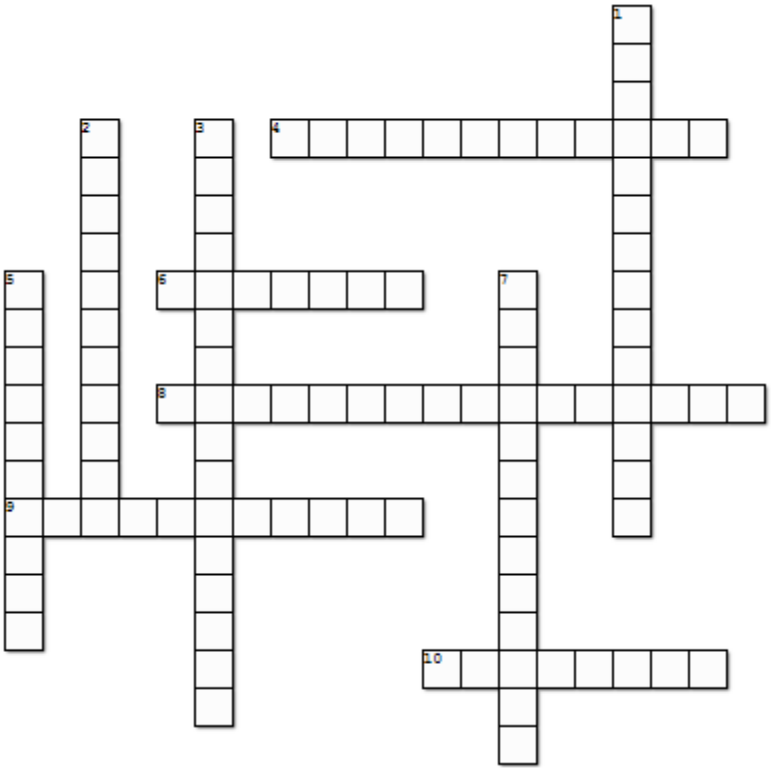
$Zn + 2HCl = ZnCl_2 + H_2$

A. Zn B. HCl C. ZnCl D. ZnH

10. Reagent A was used in a reaction. At the end of the reaction, no reagent A remained. Reagent A is the _____.
    A. excess reagent
    B. insufficient reagent
    C. limiting reagent
    D. restricted reagent

Additional Activities

Complete the puzzle by using the clues below to fill in the correct words connected to the concepts of molar mass, mass of reactants and products, and percentage yields.



Across	Down
4. used to determine how efficient a given reaction is. 6. the new substances produced in a chemical reaction 8. the reactant that is completely used up in a reaction 9. the amount of products that are actually produced in a reaction. 10. the entity that is rearranged to form products	1. reactant that is not used up. 2. the numbers in front of the formulas 3. the amount of products calculated from the complete reaction of the limiting reactant. 5. states the proportions of reactants and products that are used and formed in a chemical reaction. 7. calculated by adding together the atomic mass of each atom in its chemical formula

Posttest

Read the question carefully and encircle the letter of the correct answer.

1. What is the molecular mass of potassium phosphate?
   A. 69 g/mol B. 85 g/mol C. 112 g/mol D. 212 g/mol

2. The unit of molar mass is _____.
   A. grams B. grams/mole C. mole D. moles/gram

3. What is the molecular mass of $AuCl_3$?
   A. 35 g/mol B. 197 g/mol C. 303 g/mol D. 1232 g/mol

4. Which among the choices would have more atoms?
   A. 1 mole of Li C. 1 mole of Si
   B. 1 mole of Au D. None, all are equal

5. What is the mass of 2.50 mol of oxygen gas (O_2)?
   A. 16 g B. 32 g C. 40 g D. 80 g

6. How many molecules of water are in 5.2 moles of water?
   A. 5.2 B. 6.02×10^{23} C. 8.638×10^{-24} D. 3.1304×10^{24}

7. What should be the molar ratio to balance the chemical equation of $\mathbf{H_2 + O_2 \rightarrow H_2O?}$
   A. 2: 1: 2 B. 0: 2: 2 C. 2: 2: 2 D. 2: 0: 2

8. Which of the following pertains to chemicals that are created in a chemical reaction?
   A. Producers B. Products C. Reactants D. Reactors

9. How many moles of oxygens are in $2(NO_3)$?
   A. 1 B. 2 C. 3 D. 6

10. What coefficients would balance this equation? $\mathbf{Fe + Cl_2 \rightarrow FeCl_3}$
   A. 2, 3, 2 B. 3, 2, 2 C. 1, 1, 2 D. 4, 2, 2

11. How many aluminum atoms are in $2Al_2O_3$?
   A. 2 B. 6 C. 4 D. 8

12. Which four coefficients are required to balance the equation?
   $\mathbf{\_CuO + \_H_2 \rightarrow \_Cu + \_H_2O}$
   A. 2, 1, 2, 1 B. 1, 1, 1, 1 C. 2, 1, 1, 1 D. 1, 2, 2, 1

13. Which four coefficients are required to balance the equation below?
   $\mathbf{\_CH_4 + \_O_2 \rightarrow \_CO_2 + \_H_2O}$
   A. 1, 1, 1, 2 B. 1, 2, 2, 1 C. 1, 1, 1, 1 D. 1, 2, 1, 2

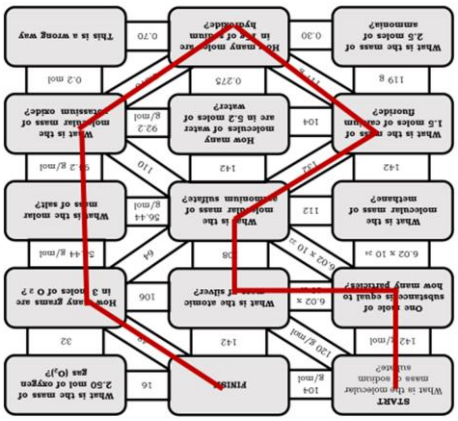
14. In most chemical reactions the amount of product obtained is _____.
   A. more than the percentage yield C. more than the theoretical yield
   B. less than the theoretical yield D. equal to the theoretical yield

15. When two substances react to form products, the reactant which is used up is called the _____.

A. catalytic reagent
B. determining reagent
C. excess reagent
D. limiting reagent

Answer Key

Lesson 1



Additional Activities

Activity 1.3

1. 87 g/mol
2. 46 g/mol
3. 74 g/mol
4. 147 g/mol
5. 100 g/mol

What I Can Do

Activity 1.2

1. 3.612×10^{23} Fe atoms
2. 51.2 g SO_2
3. 2.625 mol $CuSO_4$
4. 0.215 mol $AgNO_3$
5. 3.612×10^{24} H atoms

What's More

Activity 1.1

1. 180 g/mol
2. 342 g/mol
3. 98 g/mol
4. 110 g/mol
5. 74 g/mol
6. 40 g/mol

What's New

Lesson 2

What's New

Activity 2.1

1. $SiCl_4 + 2H_2O \rightarrow SiO2 + 4HCl$
2. $2Fe + 3H_2S0_4 \rightarrow Fe_2(SO_4)_3 + 3H_2$
3. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
4. $2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$
5. $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

What's More

Activity 2.2

1. 0.21 mol $BaSO_4$
2. 170 g $AgNO_3$

What I Can Do

Activity 2.3

1. Answers may vary
2. Answers may vary

Additional Activities

1. Grams of substance A
2. Molar Mass of substance A
3. Mole of substance A
4. Mole of substance B
5. Molar mass of substance B
6. Grams of substance B

Lesson 3

What's New

Activity 3.1

1. a. NaCl = 58 g/mol
   AgNO = 170 g/mol
   AgCl = 143 g/mol
   b. chloride (NaCl) is in excess. Silver nitrate ($AgNO_3$) is the limiting reactant.
   c. 16.93 g AgCl
   d. 6.903 g NaCl

What's More

Activity 3.2

1. 95 %

What Can I Do

Activity 3.3

1. true
2. false
3. true
4. true
5. true

Additional Activities

1. Excess reactant
2. Coefficient
3. Theoretical yield
4. Percent yield
5. Molar ratio
6. Product
7. Molecular mass
8. Limiting reactant
9. Actual Yield
10. Reactant

References

(1) Commons,C.Heinemann Chemistry two.1991.Malcolm Parsons.ISBN 0 86462 428 X.

(2) Leong, O. H., and C. L. Sian Dr. 2007. Chemistry Expression An inquiry Approach ' O ' Level Special. Express. Utopia Press Pte.Ltd. ISBN 981 -271-162-7

(3) Regan, S., L. Bramley, T. Gemellano, D. Wilson and S. Wiseman. 2004. Chemistry A Contextual Approach. Heinemann Queensland Science project

(4) Wilkinson,J.W.1990. World of Chemistry. The Macmillan Company of Australia Pty.Ltd. ISBN 0732901731.

(5) Tan Tin Toon, Chen Ling Kwong, et.al. G.C.E.'O' Level Chemistry Matters. 2011. Marshall Cavendish International (Singapore) Private Limited. ISBN 978-981-01-6463-8.

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