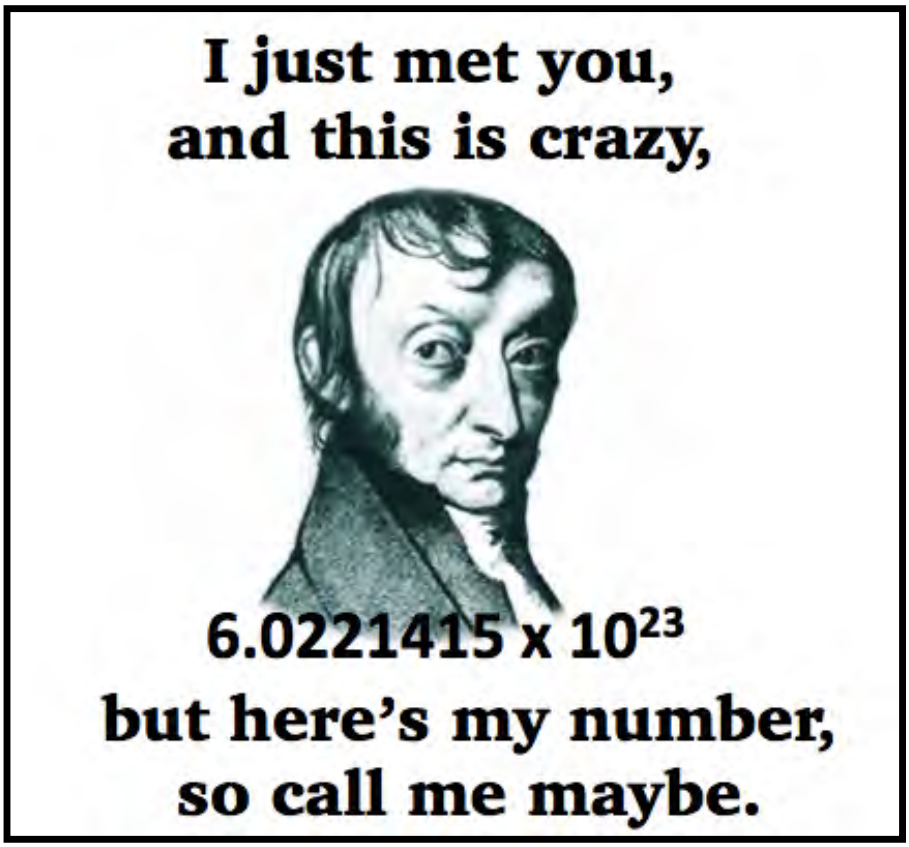
Name:

Regents Chemistry: Dr. Shanzer

Practice Packet

Chapter 10: Chemical Calculations



Chapter 10 : Chemical Calculations Vocabulary

1. **Mole** – a quantity of 6.02×10^{23} units of a substance; the amount of a substance equal to the sum of the atomic masses in grams; Avogadro's number
2. **Formula mass (FM)** – the sum of the atomic masses of a substance in a.m.u.
3. **Gram formula mass (GFM)** – the sum of the atomic masses of a substance in grams
4. **Coefficient** – the integer that appears in front of an element, molecule, or compound indicating the number of moles present
5. **Subscript** – the integer to the lower right of an element which indicates the number of atoms present in the compound
6. **Species** – the individual products and reactants in a chemical reaction
7. **Law of conservation of mass** – in any chemical reaction, mass can neither be created nor destroyed; the mass of the reactants must be equal to the mass of the products
8. **Law of conservation of energy** – in any chemical reaction, energy can neither be created nor destroyed; the energy of the reactants must be equal to the energy of the products
9. **Balanced equation** – a chemical equation in which the number of moles of each element on the reactants side is equal to the number of moles of each element on the products side
10. **Synthesis reaction** – a chemical reaction in which two or more substances combine to form a compound

    Ex: $A + B \rightarrow AB$
11. **Decomposition reaction** – a chemical reaction in which a compound is broken down into simpler substance

    Ex: $AB \rightarrow A + B$
12. **Single-replacement reaction -** a chemical reaction in which a metal replaces a metal OR a nonmetal replaces a nonmetal within a compound

    Ex: $A + BC \rightarrow AC + B$
13. **Double-replacement reaction -** a chemical reaction in which a metal replaces a metal AND a nonmetal replaces a nonmetal within two compounds; two compounds "trade" elements

    Ex: $AB + XY \rightarrow AY + XB$
14. **Molecular formula** – formula for a compound which provides the number and identity of the atoms of each element present

    Ex: $C_6H_{12}O_6$
15. **Empirical formula** – formula for a compound which provides the simplest ratio of the elements present

    Ex: The empirical formula for the molecule $C_6H_{12}O_6$ is CH_2O
16. **Percent mass** – **% composition by mass** = $\frac{\text{mass of part}}{\text{mass of whole}} \times 100$

Gram Formula Mass

Video Lesson 10.1

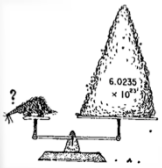
Objectives

- Describe how to calculate formula mass and gram formula mass
- Distinguish between the atomic mass of an element and its molar mass.

Stoichiometry

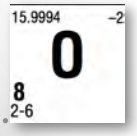
- The study of the quantitative relationships in chemical reactions.

IN OTHER WORDS … HOW MUCH?



Quick Review

- What are the units we use for the mass of atoms
  - ANS: Atomic mass units (amu) or (u)
- What is the mass of one atom of oxygen?
  - ANS: 15.9994 amu or u



Gram Formula Mass

- Formula mass
  - The mass of an atom, molecule or compound in **ATOMIC MASS UNITS (amu) or (u)**
  - EX. Formula mass of a hydrogen atom is 1.00794 amu
- Gram Formula Mass
  - The mass of one MOLE of an atom, molecule or compound in **GRAMS (g/mol)**
  - EX. GFM of hydrogen is 1.00794 g/mol

Example 1: Calculating Formula Mass

What is the formula mass of K_2CO_3?

K = 39.1 x 2 = 78.2
C = 12.0 x 1 = 12.0
O = 16.0 x 3 = + 48.0

138.2 amu

Example 2: Calculating Gram Formula Mass

What is the formula mass of K_2CO_3?

K = 39.1 x 2 = 78.2
C = 12.0 x 1 = 12.0
O = 16.0 x 3 = + 48.0
138.2 g/mol

Example 3: Calculating Gram Formula Mass

What is the gram formula mass of NH_3?

N = 1 x 14.0 = 14.0
H = 3 x 1.0 = + 3.0
17.0 g/mol

Example 4: Calculating Gram Formula Mass

- What is the gram formula mass of $Mg(OH)_2$

Mg = 1 x 24.3 = 24.3
O = 2 x 16.0 = 32.0
H = 2 x 1.0 = 2.0
+
58.3 g/mol

Percent Composition

Chemistry 200
Video Lesson 10.2

Objective:

How do we determine the difference between a Hydrate and Anhydrous?

How do we calculate the percent composition by mass for a hydrate or anhydrous using the percent composition formula?

Hydrate -

H_2O molecule(s) attached to an ionic crystal.

We calculate the gram formula mass as a separate unit.

ex: $CaSO_4 \bullet 2H_2O$

Anhydrous - ionic substances without H_2O

Percent Composition

Imagine a big bucket w/ 100 pieces of fruit in it. If the bucket has 25 apples, 30 oranges, 20 pears & 25 bananas, what percentage of the bucket consists of pears?

$$\frac{20 \text{ pears}}{100 \text{ pieces}} \times 100 = 20\%$$

Percent Composition can also be applied to the masses of elements in a compound using the following formula:

$$\% \text{ composition by mass} = \frac{\text{mass of part}}{\textbf{mass of whole}} \times 100$$

ex: What % of oxygen is in $KClO_3$?

GFM → K 1 atom 1 x 39.1 g/mol = 39.1
Cl 1 atom 1 x 35.5 g/mol = 35.5
O 3 atoms 3 x 16.0 g/mol = 48.0
122.6 g/mol

$$\% \text{ Oxygen} = \frac{48.0}{122.6} \times 100 = \mathbf{39.2\%}$$

What is the % of water in $Na_2Cr_2O_7 \bullet 10H_2O$

Na = 23.0 g/mole x 2 atoms --> 46.0g/mol
Cr = 52.0 g/mole x 2 atoms --> 104.0g/mol
O = 16.0 g/mole x 7 atoms --> 112.0g/mol
H_2O = 18.0 g/mole x 10 atoms → 180.0g/mol
442.0 g/mol

$$\% \text{ of } H_2O = \frac{180.0 \text{g/mol}}{442.0 \text{ g/mol}} \times 100 = \mathbf{40.7\ \%\ H_2O}$$

The Mole

Video Lesson 10.3

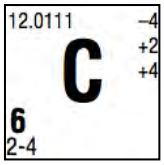
Objectives

- Define Avogadro's number as it relates to a mole of a substance.
- Describe how the mass of a mole of a compound is calculated.

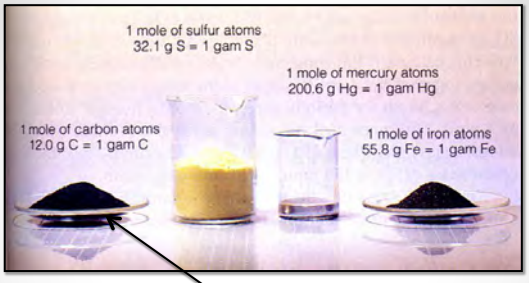
THE MOLE CONCEPT

- A mole is a chemistry unit of measure

12 bagels or 1 dozen



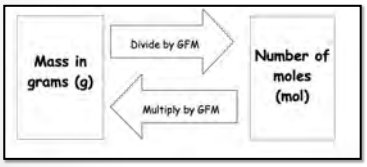
6.02×10^{23} atoms of C or 1 mole



Or 6.02×10^{23} atoms/particles of Carbon

USING MOLES

Mole Calculations	number of moles = $\frac{\text{given mass (g)}}{\text{gram-formula mass}}$



MOLE CALCULATION EXAMPLE #1

How many moles are in 39.0 grams of LiF?

Step 1:

Li = 1 x 7.0 = 7.0
F = 1 x 19.0 = 19.0

26.0 g/mol

Step 2: Solve for Moles

$$\text{\# of moles} = \frac{\text{given mass (g)}}{\text{GFM (g/mol)}}$$

$$\text{Moles} = \frac{39.0\ g}{26.0\ g/mol}$$

Moles = 1.50 mol

CONVERTING MOLES TO GRAMS EXAMPLE #2

What is the mass of 4.50 moles of KOH?

K = 1 x 39.1 = 39.1
O = 1 x 16.0 = 16.0
H = 1 x 1.0 = +1.0
56.1 g/ mol

$$\text{number of moles} = \frac{\text{given mass}}{\text{gram-formula mass}}$$

$$4.50 \text{ mol} = \frac{g}{56.1 \text{ g/mol}} \qquad g = 252.5g$$

Mole to Mole Ratios

Chemistry 200
Video Lesson 10.4

Objective:

How do we determine a new mole ratio in a reaction when the molar amount of a reactant or product is changed?

20 Cookies =

1cup-flour, 4 eggs, 2 tsp-salt, 3oz-butter, 12oz-choc chips

30 Cookies =

1.5cup-flour, 6 eggs, 3 tsp-salt, 4.5oz-butter, 18oz-choc chips

10 Cookies =

.5 cup-flour, 2 eggs, 1 tsp-salt, 1.5oz-butter, 6oz-choc chips

Mole to Mole ratios

In problems involving chemical reactions, the relative amounts of reactants & products are represented by the coefficients. Coefficients represent both the basic unit & mole ratios in balanced equations. The ratio is like a recipe for the reaction. The ratio tells how many moles of each species are necessary for the balanced reaction

We can use the **Mole Ratios** btwn elements & molecules in a chemical equation to make predictions about how they will react in nature by applying the following procedure:

****Ratios must be moles to moles,**
NOT grams to grams or grams to moles**

1. Put boxes around the 2 substances that are referred to in the question
2. Set up a proportion using the mole ratios of the 2 substances:
   a. Place the numbers in the chemical equation on the bottom part of the ratio
   b. Place the numbers in the word problem on the top of the ratio

Combustion of butane

$$2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$$

3.55 moles of C_4H_{10} will yield how many moles of CO_2?

$$\frac{3.55 \text{ moles } C_4H_{10}}{2 \text{ moles } C_4H_{10}} = \frac{x \text{ moles } CO_2}{8 \text{ moles } CO_2}$$

Solve for x --> cross multiply

$2(x) = 8(3.55)$ $\quad x = \frac{28.4}{2}$

$\boxed{x = 14.2 \text{ moles of } CO_2}$

$4Al + 3O_2 \rightarrow 2Al_2O_3$

What information do we know about the above equation?

Qualitative - Aluminum, Oxygen & Aluminum Oxide

Quantitative - 4 moles of Aluminum, 3 moles of Oxygen & 2 moles of Aluminum Oxide

Empirical & Molecular Formulas

Chemistry 200
Video Lesson 10.5

Objective:

How do we determine the molecular formula for a substance if given the empirical formula and gram formula mass?

Empirical & Molecular Formulas

Empirical Formula – The lowest whole number ratio of atoms in a compound. For example, C_6H_6 would have an empirical formula of CH. $C_6H_{12}O_6$ would have an empirical formula of CH_2O. An empirical formula can also be the same as the molecular formula, as in the case of H_2O.

Molecular Formula – A molecular formula represents the true formula of a substance. Unlike ionic formulas that need to be simplified, a molecular compound like dinitrogen tetroxide (N_2O_4) would not be simplified because that is the molecular formula.

Other examples would include N_2O, CO_2, C_3H_6, etc. If we were to represent these examples as empirical formulas, C_3H_6 could be simplified while the others are already empirical formulas.

Determining an empirical formula from a molecular formula

To convert a molecular formula into an empirical formula:

- Find the largest common multiple of all the subscripts in a formula
- Divide each subscript by that common multiple to create an empirical formula.

$$\frac{C_6H_9O_3}{3} = \mathbf{C_2H_3O}$$

$$\frac{C_6H_{14}}{2} = \mathbf{C_3H_7}$$

Determining a molecular formula from an empirical formula

- Converting an empirical formula into a molecular formula is a little trickier since we do not know the common multiple.
- Consider the empirical formula CH_2. This empirical formula can yield many molecular formulas including CH_2, C_2H_4, C_3H_6, C_4H_8 etc.

To convert an empirical formula into a molecular formula, use the following steps:

1. Determine the molecular mass of the empirical formula.
2. Divide the molecular mass **(GFM)** of the molecular formula by the molecular mass of the empirical formula. This represents the common multiple.
3. Multiply each subscript in the empirical formula by this common multiple to obtain the molecular formula.

Determine the molecular formula of a substance that has a molecular mass of 84.0 g/mole & an empirical formula of CH_2

Molecular mass of CH_2 (empirical formula)

C --> 1 atom x 12.0 g/mole = 12.0 g/mole

H --> 2 atoms x 1.0 g/mole = 2.0 g/mole

14.0 g/mole

$$\frac{\text{Molecular mass of molecular formula}}{\text{Molecular mass of empirical formula}}$$

$$\frac{84.0 \text{ g/mole}}{14.0 \text{ g/mole}} = 6$$

Molecular formula = CH_2 x 6 = $\boxed{\mathbf{C_6H_{12}}}$

Sketch Notes

Video 10.1: Gram Formula Mass

Chemical Formula	Gram Formula Mass
1. $MgBr_2$	
2. KCl	
3. $FeCl_2$	
4. CrF_2	
5. Al_2S_3	
6. PbO	
7. TiI_4	
8. Mg_3P_2	
9. $SnCl_2$	
10. $HgCl_2$	
11. H_2SO_4	

Name:

Gram Formula Mass

____ 1. The sum of the atomic masses of the atoms in one molecule of $C_3H_6Br_2$ is called the

1) formula mass
2) isotopic mass
3) percent abundance
4) percent composition

____ 2. The gram-formula mass of NO_2 is defined as the mass of

1) one mole of NO_2
2) one molecule of NO_2
3) two moles of NO
4) two molecules of NO

____ 3. What is the gram-formula mass of $Ca_3(PO_4)_2$?

1) 248 g/mol
2) 263 g/mol
3) 279 g/mol
4) 310. g/mol

____ 4. The gram formula mass of NH_4Cl is

1) 22.4 g/mole
2) 28.0 g/mole
3) 53.5 g/mole
4) 95.5 g/mole

____ 5. The gram-formula mass of $(NH_4)_2CO_3$ is

1) 46.0 g
2) 64.0 g
3) 78.0 g
4) 96.0 g

____ 6. What is the gram-formula mass of $Fe(NO_3)_3$?

1) 146 g/mol
2) 194 g/mol
3) 214 g/mol
4) 242 g/mol

____ 7. What is the gram-formula mass of $(NH_4)_3PO_4$?

1) 112 g/mol
2) 121 g/mol
3) 149 g/mol
4) 242 g/mol

____ 8. A 1.0-mole sample of krypton gas has a mass of

1) 19 g 2) 36 g 3) 39 g 4) 84 g

____ 9. The molar mass of $Ba(OH)_2$ is

1) 154.3 g
2) 155.3 g
3) 171.3 g
4) 308.6 g

____ 10. What is the gram formula mass of $Ca_3(PO_4)_2$?

1) 196 g
2) 214 g
3) 245 g
4) 310. g

Video 10.2: Percent Composition
Complete the following calculations. Show all work and units. Round GFM to nearest tenth.

1. What is the percent by mass of magnesium in $Mg_3(PO_4)_2$?

2. What percentage of Na_2SO_4 is oxygen by mass?

3. What is the percent of nitrogen by mass in ammonium nitrate?

4. What is the percent by mass of water in $Al(ClO_3)_3 \bullet 6H_2O$?

5. Calculate the % of hydrogen in nitroglycerine {$C_3H_5N_3O_9$}.

6. What percentage of $CaSO_4 \bullet 2H_2O$ is water by mass?

7. Calculate the percent composition of oxygen in glycerol {$C_3H_5(OH)_3$}.

8. Calculate the percent aluminum in aluminum oxide.

9. Calculate the percent of phosphorus in sodium phosphate?

10. Calculate the percent by mass of water in $CuNO_3 \bullet 5H_2O$?

Video 10.3

M<u>oles and Molar Mass:</u> Find the gram formula mass of the following: (Show all work)

1. CO_2
2. FeS
3. NaCl
4. $Al_2(CO_3)_3$
5. H_2SO_4
6. $Al_2(SO_3)_3$
7. Fe_2O_3
8. $Ca(OH)_2$
9. NH_3
10. H_2O_2
11. $NaHCO_3$
12. $C_6H_{12}O_6$
13. MgO
14. $SrSO_4 \cdot 3H_2O$

<u>Moles</u>: Find the number of moles in the following measurements: (Show your work)

Using the mole formula convert the following from grams to moles. An example is provided. Round to the nearest hundredth.

Example: Convert 15.0 g of $CaCl_2$ to moles.

Step 1: Calculate gram formula mass	Step 2: Plug into mole equation
Ca = 1 x 40.08 = 40.08	moles = grams/GFM
Cl = 2 x 35.45 = 70.90	moles = 15.0 g/110.98 g
110.98 grams/mol	moles = 0.140 moles

1. 900. grams $C_6H_{12}O_6$
2. 24.5 grams H_2SO_4
3. 192 grams SiO_2
4. 450. grams of $ZnCl_2$
5. 22 grams of CO_2
6. 20. grams of Fe_2O_3
7. 3.40 grams of H_2O_2
8. 840. grams of $NaHCO_3$

Now solve for the mass given the moles. (Show your work)

Using the mole formula convert the following from moles to grams. An example is provided. Round to the nearest hundredth.

Example: Convert 2.5 moles of $CaCl_2$ to grams

Step 1: Calculate gram formula mass	Step 2: Plug into mole equation moles = grams/GFM
Ca = 1 x 40.08 = 40.08	2.5 moles = g/110.98 g
Cl = 2 x 35.45 = 70.90	grams = 277.5 grams
110.98 grams/mol	

1. 2.00 moles of $C_6H_{12}O_6$
2. 5.00 moles of $SrSO_4 \cdot H_2O$
3. 0.250 moles of CH_4
4. 0.100 moles of NH_3
5. 12.0 moles of SiO_2
6. 0.330 moles of FeS
7. 1.50 moles of MgO
8. 0.500 moles of $ZnCl_2$

Moles

____ 1. Which sample contains a mole of atoms?

1) 23 g Na 2) 24 g C
3) 42 g Kr 4) 78 g K

____ 2. What is the total mass of 2.0 moles of $H_2(g)$?

1) 1.0 g 2) 2.0 g 3) 3.0 g 4) 4.0 g

____ 3. What is the mass in grams of 2.0 moles of NO_2?

1) 92 2) 60. 3) 46 4) 30.

____ 4. What is the total number of moles in 80.0 grams of C_2H_5Cl (gram-formula mass = 64.5 grams/mole)?

____ 5. The number of moles of molecules in a 12.0-gram sample of Cl_2 is

1) $\frac{12.0}{35.5}$ mole 2) $\frac{12.0}{71.0}$ mole
3) 12.0 moles 4) 12.0×35.5 moles

____ 6. What is the total mass of oxygen in 1.00 mole of $Al_2(CrO_4)_3$?

1) 192 g 2) 112 g
3) 64.0 g 4) 48.0 g

____ 7. What is the total mass in grams of 0.75 moles of SO_2?

1) 16 g 2) 24 g 3) 32 g 4) 48 g

____ 8. The total number of moles represented by 20 grams of $CaCO_3$ is

1) 1 2) 2 3) 0.1 4) 0.2

____ 9. What is the mass in grams of 1.00 mole of O_2 gas?

1) 11.2 2) 16.0 3) 22.4 4) 32.0

____ 10. What is the total mass of iron in 1.0 mole of Fe_2O_3?

1) 160 g 2) 112 g
3) 72 g 4) 56 g

Video 10.4: Mole to Mole Ratios

Determine the molar amount using mole to mole ratios for the following reactions

1. Given the reaction: $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

   What is the maximum number of moles of H_2O that can be produced when 2.0 moles of NH_3 are completely reacted?

2. Given the reaction: $2KClO_3 \rightarrow 2KCl + 3O_2$

   What is the total number of moles of potassium chlorate needed to produce 6.0 moles of O_2?

3. Given the reaction: $2C_2H_2 + 5O_2 \rightarrow 4\ CO_2 + 2H_2O$

   How many moles of oxygen are required to react completely with 1.0 moles of C_2H_2?

4. Given the reaction: $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

   How many moles of carbon dioxide are produced when 0.5 moles of Fe_2O_3 are completely reacted?

   Convert your answer to grams of CO_2

5. Given the reaction: $3MgCl_2 + 2Al \rightarrow 3Mg + 2AlCl_3$
   How many moles of aluminum chloride are produced when 8 moles of magnesium chloride are completely reacted with aluminum?

6. Consider the combustion of methane. How many moles of carbon dioxide are obtained when 20 moles of methane are completely burned.

7. Given the reaction: $2H_2 + O_2 \rightarrow 2H_2O$
   How many moles of H_2O can be produced if 20 moles of hydrogen completely react with oxygen?

Law of Conservation of Mass Worksheet

Since there is a conservation of mass in all balanced chemical reactions, these problems are also quite easy. Consider the following balanced chemical reaction **$CaCO_3 \rightarrow CaO + CO_2$**. In this reaction the mass of $CaCO_3$ **must** equal the combined mass of CaO and CO_2. If you know the mass of the reactants you automatically know the mass of the products and vice-versa.

Using the reaction above, determine the mass of CaO produced if 200 grams of $CaCO_3$ decomposed and produced 88 grams of CO_2.

$CaCO_3 \rightarrow CaO + CO_2$

200g = Xg + 88g → 200g – 88g = 112g CaO produced

Complete the following problems

1) Hydrogen and oxygen react chemically to form water. How much water would form if 14.8 grams of hydrogen reacted with 34.8 grams of oxygen? ($H_2 + O_2 \rightarrow H_2O$)

2) When ammonium nitrate (NH_4NO_3) explodes, the products are nitrogen, oxygen, and water. When 40 grams of ammonium nitrate explode, 14 grams of nitrogen and 8 grams of oxygen form. How many grams of water form? ($NH_4NO_3 \rightarrow N_2 + O_2 + H_2O$)

3) 40 g of calcium reacts with 71 g of chlorine to produce ____ g of calcium chloride.

4) ____ g of potassium reacts with 16 g of oxygen to produce 94 g of potassium oxide.

5) 14 g of lithium reaction with ____ g sulfur to produce 46 g of lithium sulfide.

6) 24 g of magnesium reacts with 38 g of fluorine to produce ____ g magnesium fluoride.

7) 65.5 g copper reacts with ____ g oxygen to produce 81 g copper (I) oxide.

8) 88 g of strontium reacts with 160 g bromine to produce ____ g strontium bromide.

9) 46 g of sodium reacts with ____ g chlorine to produce 117 g sodium chloride.

10) ___ g iron reacts with 71 g chlorine to produce 129 g of iron (II) chloride.

11) 137 g of barium reacts with _____ g iodine to produce 391 g barium iodide.

12)____ g hydrogen reacts with 32 g of oxygen to produce 34 g of hydrogen peroxide.

13)Why do we balance chemical reactions?

Practice:

1. Given the balanced equation representing a reaction:

$$CaO_{(s)} + CO_{2(g)} \rightarrow CaCO_{3\,(s)} + \text{heat}$$

What is the total mass of CaO that reacts with 75 grams of $CO_{2\,(g)}$ to produce 200. Grams of $CaCO_{3(s)}$?

2. Given the balanced equation representing a reaction:

$$2H_2 + O_2 \rightarrow 2H_2O$$

What is the total mass of water formed when 4 grams of hydrogen reacts completely with 32 grams of oxygen?

<u>Video 10.5</u>: Empirical and Molecular Formulas

<u>Determining an empirical formula from a molecular formula</u>

To convert a molecular formula into an empirical formula, we need to find the largest common multiple of all the subscripts in a formula. Then simply divide each subscript by that common multiple to create an empirical formula.

Molecular Formula	Largest Common Multiple	Empirical Formula
$C_6H_9O_3$	3	C_2H_3O
C_6H_{14}		
$C_2H_4O_2$		
H_2O_2		
$C_{12}H_{22}$		
$C_{12}H_{24}$		
N_2O_3		
C_3H_6		

Determining a molecular formula from an empirical formula

1. Determine the molecular mass of the empirical formula.
2. Divide the molecular mass of the molecular formula by the molecular mass of the empirical formula. This represents the common multiple.
3. Multiply each subscript in the empirical formula by this common multiple to obtain the molecular formula.

Practice

1. A substance w/ a molecular mass of 172.0 g/mole is determined to have an empirical formula of C_3H_7. Determine the molecular formula of this substance.

2. Determine the molecular formula of a substance w/ an empirical formula of $C_2H_3S_2$ and a molecular mass of 456.0 g/mole.

3. Determine the molecular formula of a substance w/ an empirical formula of C_2H_4N and a molecular mass of 294.0 g/mole.

4. Determine the molecular formula of a compound with an empirical formula of NH_2 and a molecular mass of 32.0 g/mole.

5. An organic gas has the empirical formula CH_3 and a molecular mass of 165.0 g/mole. Determine the molecular formula.

6. Vitamin C has an empirical formula of $C_3H_4O_3$ and a molecular mass of 264.0 g/mole. Determine the molecular formula.

7. Ibuprofen, a common headache remedy, has an empirical formula of C_7H_9O and a molar mass of 545.0 g/mole. Determine the molecular formula.

8. Oxalic acid has the empirical formula HCO_2 and a molar mass of 90.0 g/mole. Determine the molecular formula.

Name:

Chemical Calculations Review

1. Which type of formula represents the simplest whole-number ratio of atoms of the elements in a compound?

   1) molecular formula
   2) condensed formula
   3) empirical formula
   4) structural formula

2. Given two formulas representing the same compound:

   Formula A CH_3
   Formula B C_2H_6
   Which statement describes these formulas?

   1) Formulas *A* and *B are both empirical.*
   2) Formulas *A* and *B are both molecular.*
   3) Formula *A is empirical, and formula B is molecular.*
   4) Formula *A is molecular, and formula B is empirical.*

3. What is the empirical formula of a compound that has a carbon-to-hydrogen ratio of 2 to 6?

   1) CH_3 2) C_2H_6 3) C_3H 4) C_6H_2

4. Which pair consists of a molecular formula and its corresponding empirical formula?

   1) C_2H_2 and CH_3CH_3
   2) C_6H_6 and C_2H_2
   3) P_4O_{10} and P_2O_5
   4) SO_2 and SO_3

5. Which formula is both a molecular and an empirical formula?

   1) $C_6H_{12}O_6$ 3) C_3H_8O
   2) $C_2H_4O_2$ 4) C_4H_8

6. What is the gram-formula mass of $(NH_4)_3PO_4$?

   1) 112 g/mol 3) 149 g/mol
   2) 121 g/mol 4) 242 g/mol

7. A 1.0-mole sample of krypton gas has a mass of

   1) 19 g 2) 36 g 3) 39 g 4) 84 g

8. The gram-formula mass of H_2O is defined as the mass of

   1) one mole of H_2O
   2) one molecule of H_2O
   3) two moles of H_2O
   4) two molecules of H_2O

9. What is the gram formula mass of Li_2SO_4?

   1) 54 g 2) 55 g 3) 110 g 4) 206 g

10. What is the total number of oxygen atoms in the formula $MgSO_4 \cdot 7\ H_2O$? [The • represents seven units of H_2O attached to one unit of $MgSO_4$.]

    1) 11 2) 7 3) 5 4) 4

11. The gram-formula mass of a compound is 48 grams. The mass of 1.0 mole of this compound is

    1) 1.0 g 2) 4.8 g 3) 48 g 4) 480 g

12. Which sample contains a mole of atoms?

    1) 23 g Na 3) 42 g Kr
    2) 24 g C 4) 78 g K

13. A compound has a molar mass of 90. grams per mole and the empirical formula CH_2O. What is the molecular formula of this compound?

    1) CH_2O 3) $C_3H_6O_3$
    2) $C_2H_4O_2$ 4) $C_4H_8O_4$

14. A substance has an empirical formula of CH_2 and a molar mass of 56 grams per mole. The molecular formula for this compound is

    1) CH_2 2) C_4H_6 3) C_4H_8 4) C_8H_4

15. Which quantity can be calculated for a solid compound, given only the formula of the compound and the Periodic Table of the Elements?

    1) the density of the compound
    2) the heat of fusion of the compound
    3) the melting point of each element in the compound
    4) the percent composition by mass of each element in the compound

16. Which compound has the highest precent composition by mass of strontium?

    1) $SrCl_2$ 2) SrI_2 3) SrO 4) SrS

17. What is the percent composition by mass of sulfur in the compound $MgSO_4$ (gram-formula mass = 120. grams per mole)?

    1) 20% 2) 27% 3) 46% 4) 53%

18. What is the percent composition by mass of nitrogen in NH_4NO_3 (gram-formula mass = 80.0 grams/mole)?

    1) 17.5% 3) 52.5%
    2) 35.0% 4) 60.0%

19. During all chemical reactions, mass, energy, and charge are

    1) absorbed 3) formed
    2) conserved 4) released

20. The coefficients in a balanced chemical equation represent

1) the mass ratios of the substances in the reaction
2) the mole ratios of the substances in the reaction
3) the total number of electrons in the reaction
4) the total number of elements in the reaction

21. Given the balanced equation representing a reaction:

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
What is the *minimum* number of moles of O_2 that are needed to completely react with 16 moles of NH_3?

1) 16 mol
2) 20. mol
3) 64 mol
4) 80. mol

22. Given the balanced equation representing a reaction:

$$Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$$

The mole ratio of $NaOH$ to $Al(OH)_3$ is

1) 1:1 2) 1:3 3) 3:1 4) 3:7

23. Given the balanced equation representing a reaction:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

What is the total number of moles of $O_2(g)$ required for the complete combustion of 1.5 moles of $C_3H_8(g)$?

1) .30 mol
2) 1.5 mol
3) 4.5 mol
4) 7.5 mol

24. Given the balanced equation representing a reaction:

$CaO(s) + CO_2(g) \rightarrow CaCO_3(s) + heat$
What is the total mass of CaO(s) that reacts completely with 88 grams of $CO_2(g)$ to produce 200. grams of $CaCO_3(s)$?

1) 56 g 2) 88 g 3) 112 g 4) 288 g

25. Given the balanced equation representing a reaction:
$2H_2 + O_2 \rightarrow 2H_2O$

What is the total mass of water formed when 8 grams of hydrogen reacts completely with 64 grams of oxygen?

1) 18 g 2) 36 g 3) 56 g 4) 72 g

26. Given the reaction:

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

The total number of grams of O_2 needed to produce 54 grams of water is

1) 36 2) 48 3) 61 4) 75

____ 27. Base your answer to the following question on the information below and on your knowledge of chemistry.

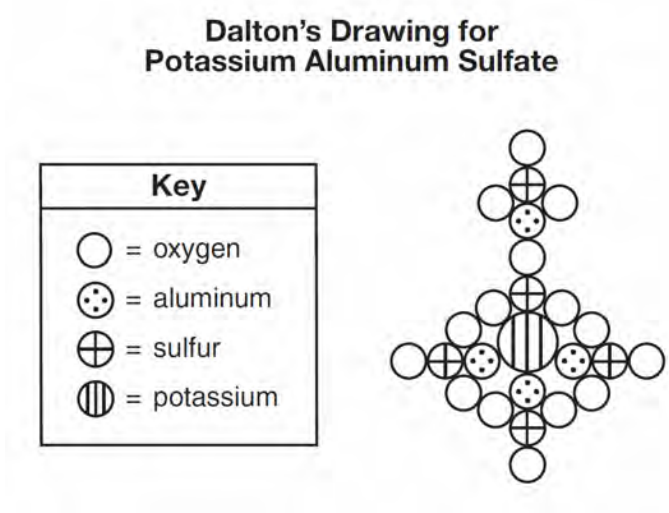
Many breads are made by adding yeast to dough, causing the dough to rise. Yeast is a type of microorganism that produces the catalyst zymase, which converts glucose, $C_6H_{12}O_6$, to ethanol and carbon dioxide gas. The balanced equation for this reaction is shown below.

$$C_6H_{12}O_6(aq) \xrightarrow{zymase} 2C_2H_5OH(aq) + 2CO_2(g)$$

Determine the total mass of ethanol produced when 270. grams of glucose reacts completely to form ethanol and 132 grams of carbon dioxide.

____ 28. Base your answer to the following question on the information below.

John Dalton, an early scientist, sketched the structure of compounds using his own symbols for the elements known at the time. Dalton's symbols for four elements and his drawing of potassium aluminum sulfate are represented by the diagram below.



Today, it is known that the chemical formula for potassium aluminum sulfate is $KAl(SO_4)_2 \bullet 12H_2O$. It is a hydrated compound because water molecules are included within its crystal structure. There are 12 moles of H_2O for every 1 mole of $KAl(SO_4)_2$. The compound contains two different positive ions. The gram-formula mass of $KAl(SO_4)_2 \bullet 12H_2O$ is 474 grams per mole.

Show a numerical setup for calculating the percent composition by mass of water in $KAl(SO_4)_2 \bullet 12H_2O$.

____ 29. Base your answer to the following question on the information below.

Vitamin C, also known as ascorbic acid, is water soluble and cannot be produced by the human body. Each day, a person's diet should include a source of vitamin C, such as orange juice. Ascorbic acid has a molecular formula of $C_6H_8O_6$ and a gram-formula mass of 176 grams per mole.

Show a numerical setup for calculating the percent composition by mass of oxygen in ascorbic acid.

Base your answers to questions **30** and **31** on the information below.

Hydrogen peroxide, H_2O_2, is a water-soluble compound. The concentration of an aqueous hydrogen peroxide solution that is 3% by mass H_2O_2 is used as an antiseptic. When the solution is poured on a small cut in the skin, H_2O_2 reacts according to the balanced equation below.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

____ 30. Determine the gram-formula mass of H_2O_2.

____ 31. Calculate the total mass of H_2O_2 in 20.0 grams of an aqueous H_2O_2 solution that is used as an antiseptic. Your response must include *both* a numerical setup and the calculated result.

_____

____ 32. Base your answer to the following question on the information below.

The Solvay process is a multistep industrial process used to produce washing soda, $Na_2CO_3(s)$. In the last step of the Solvay process, $NaHCO_3(s)$ is heated to 300°C, producing washing soda, water, and carbon dioxide. This reaction is represented by the balanced equation below.

$$2NaHCO_3(s) + \text{heat} \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

Determine the total mass of washing soda produced if 3360. kilograms of $NaHCO_3$ reacts completely to produce 360. kilograms of H_2O and 880. kilograms of CO_2.

_____

Free Response Review

1. Consider the reaction below that represents the combustion of benzene, C_2H_6

$$2\ C_2H_6 + 15\ O_2 \rightarrow 12\ CO_2 + 6H_2O$$

   a. How many moles of benzene are in 22.3 gram sample of benzene?

   b. What is the mass of a 1.79 mole sample of O_2?

   c. A 4.4 mole sample of O_2 will react to produce how many moles of CO_2?

   d. How many moles of benzene are needed to react completely with 3.47 moles of O_2?

2. Putrescine, is a compound produced in decaying animals and creates the characteristic odor associated with rotten meat. The empirical formula for putrescine is C_2H_6N.
   a. If putrescine has a molecular mass of 88.0 g/mol, determine the molecular formula of putrescine.

   b. How many moles of putrescine are in a 37.5 gram sample of putrescine?

   c. What is the percent of nitrogen in putrescine?

3. Answer the following questions about the following hydrated salt:

   a. Calculate the gram formula mass of $CaSO_3 \bullet 4H_2O$

   b. Determine the moles of $CaSO_3 \bullet 4H_2O$ in a 15.6 gram sample.

   c. Calculate the percent of water in $CaSO_3 \bullet 4H_2O$

4. In an experiment, 4.56 grams of sodium completely reacts with sulfur, producing 7.89 grams of sodium sulfide. Determine the total mass of sulfur consumed.