The Mole   **Make sure you get your daily work signed off on. That way, when
                            we test you'll have the grade you earned instead of
Videos   freaking out about 50's in the book.
#1 -- The Mole
#2 -- Particles Per Mole Video   NAME: _____
#3 -- Molar Mass Conversion Video   PERIOD: _____
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Practice Problems: Practice Sheets:
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Labs:
            Chalk Lab
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Quizzes:
            Particles per mole
            Gram mole conversions
            Molar mass as conversion factor.
            Percent composition
            Empirical and Molecular Formulas

0THE MOLE

How many molecules would be in 3 moles of water?

The **mole** (mol) is one of the seven base units in the SI system.
It measures the **_____**.

The form in which a substance exists is its "**_____**".
- Representative particles can be atoms, ions, molecules, formula units, or anything else.

Just as a dozen is 12 representative particles, a mole is _____ representative particles.

Ex. 1 mole Fe atoms = 6.02 x 10^{23} atoms of Fe
1 mole H_2O molecules = 6.02 x 10^{23} molecules of water
1 mole NaCl formula units = 6.02 x 10^{23} NaCl formula units
1 mole eggs = 6.02 x 10^{23} eggs

Write the memory tricks for remembering diatomic elements.

Diatomic Elements
Certain elements are only stable in pairs or with other elements in a compound. These elements are called the **_____**.
There are 7 diatomic elements:

_____,_____,_____,_____,_____,_____,_____

(Memory trick: _____ or _____)

Avogadro's Number

6.02 x 10^{23} is called Avogadro's number. It is named after Amadeo Avogadro who did work in the 1800's that allowed 6.02 x 10^{23} to be calculated.
The mole is the "chemist's dozen". It is a convenient way to count extremely large numbers of atoms, molecules or ions.

New Conversion Factor! **1 mole = 6.02 x 10^{23} representative particles**

We work these problems using dimensional analysis.

_____

Examples:
How many moles are 1.20 x 10^{25} atoms of phosphorous?

Your friend gives you a gold ring that contains 2.3 mol of atoms. How many atoms is this?

How many atoms are in 0.750 mol of Zn?

How many molecules are in 0.400 mol N_2O_5?

How many moles are contained in 1.20 x 10^{24} molecules CO_2?

<u>**Gram atomic mass**</u> (gam) – atomic mass of an _____ in grams
  -mass of one mole of atoms of a monatomic element
  -use the periodic table and take masses to 0.1 g

  Ex. C =   12.0 g = mass of _____ atoms
                12.0 g/mol is the gram atomic mass of _____

There are two terms to describe the mass of a chemical compound; gram molecular mass or gram formula mass. We will most often use the term gram formula mass. Molar mass or _____ are terms also used to mean the same thing.

What is the gram molecular mass of P_2O_5?

- **<u>Gram molecular mass</u>** (gmm) – mass of one mole of a _____
  -sum of the atomic masses of each atom in the molecule

  Ex. 1 mol H_2O: 2 mol H   =2 x 1.0 g H/mol   =   2.0 g
                        1 mol O   =1 x 16.0 g O/mol   =   16.0 g
                                                               18.0 g H_2O

  Example   What is the gram molecular mass of CH_3OH?

- **<u>Gram formula mass</u> (gfm)**
  -mass of one mole of an _____ compound
  -sum of the atomic masses of each atom in a formula unit

  Example   What is the gfm of magnesium phosphate ($Mg_3(PO_4)_2$)?

           What is the molar mass of ammonium sulfate (($NH_4)_2SO_4$)?

Write the two conversion factors we have discussed below. Show how they are related.

<u>**Mole – Mass Conversions**</u>   **New Conversion factor!   1 mol = gfm**

Find the mass in grams of 3.32 mol of K.
        3.32 mol K = ? g K
        Conversion factor: 1 mol K = 39.1 g (from periodic table)

_____

Use dimensional analysis:
                $$\frac{3.32 \text{ mol K} \mid 39.1 \text{ g K}}{\mid 1 \text{ mol K}} = 1.30 \times 10^2 \text{ g K}$$

Find the mass in grams of 15.0 mol of sulfuric acid (H_2SO_4).
Find the number of moles in 11.0 g of methane (CH_4).

MULTI-STEP MOLE PROBLEMS:

Calculate the number of molecules present in 4.29 g of nitrogen dioxide (NO_2).

Calculate the number of moles of sulfur atoms present in 2.01g of sodium sulfide (Na_2S).

Calculate the mass in grams of 2.49 x 10^{20} carbon dioxide (CO_2) molecules.

Calculate the grams of carbon in 12.2 mol of sucrose, $C_{12}H_{22}O_{11}$.

Molar Volume of a Gas

Relate the three conversion factors we have learned below.

The volume of a gas is usually measured at _____ and _____ atmosphere of pressure. This is called standard temperature and pressure (STP).

At STP, one mole of any gas has a volume of 22.4 L.
- 22.4 L is called the <u>molar volume</u> of a gas.
- 22.4 L of a gas at STP contains 6.02 x 10^{23} particles of the gas.
  - 22.4 L of a gas has a mass equal to the gfm of the gas.

New conversion factor!   **1 mol of any gas at STP = 22.4 L**
                                          (for gases only)

_____

What is the volume (liters) at STP of 0.960 mol of methane, CH_4?
           0.960 mol = ? L

At STP, how many moles are in 0.542 mL of neon gas?

<u>Percent Composition</u>

(remember: percent = _____)

-percent by mass of _____ in a compound

Two types of problems:

- Find the % composition for a compound that is formed from 28.0 g Fe and 8.0g O.

- What is the percent composition of calcium acetate $(Ca(C_2H_3O_2)_2)$?

$$\% \ mass = \left(\frac{grams \ of \ element}{gfm \ of \ compound} \right) x \quad 100$$

CALCULATING EMPIRICAL FORMULAS

Empirical formula – formula that represents the lowest _____ of the various types of atoms in a compound

> *Empirical Formula Poem*
> Percent to mass,
> Mass to mole,
> Divide by smallest,
> Round (or multiply) 'till whole

Steps to calculate empirical formula:
1. Find the mass of each element in a sample of the compound
2. Convert the mass to moles of each element
3. Simplify mole ratio (divide each mass by the smallest mass to get ratios of each element).
4. If your answers are not in whole numbers, you must multiply by 2,3,4,or 5 to get whole numbers.
5. Use mole ratio as subscripts in the formula

If given % composition, assume 100 g of compound.

A compound is 79.8% C and 20.2% H. Find its empirical formula.

Find the empirical formula for a compound made up of 26.7% P, 12.1% N and 61.2%Cl.

Finding Molecular Formulas

- Molecular formulas are the _____ formulas. They may be the same as the empirical formula or a multiple of it.
- To find the multiple (n), take the gram formulas mass (gfm) and divide by the

  _____

$$n = \frac{gfm}{efm}$$

Multiply each subscript in the empirical formula by n to get the molecular formula.

A white powder is analyzed and found to have the empirical formula P_2O_5. The compound has a molar mass of 283.9 g. What is the compound's molecular formula?

A compound used as an additive for gasoline to help prevent engine knock shows the following percentage composition:

        71.65% Cl   24.27% C   4.07% H

The molar mass is known to be 98.96 g. Determine the empirical formula and the molecular formula for this compound.

Grams/Moles Calculations

Given the following, find the number of moles:

1)   30 grams of H_3PO_4

2)   25 grams of HF

3)   110 grams of $NaHCO_3$

4)   1.1 grams of $FeCl_3$

5)   987 grams of $Ra(OH)_2$

6)   564 grams of copper

7)   12.3 grams of CO_2

8)   89 grams of $Pb(CH_3COO)_4$

Given the following, find the number of grams:

9)   4 moles of $Cu(CN)_2$

10)   5.6 moles of C_6H_6

11)   21.3 moles of $BaCO_3$

12)   1.2 moles of $(NH_4)_3PO_3$

13) 9.3×10^{-3} moles of SmO

14)   6.6 moles of ZnO

15)   5.4 moles of K_2SO_4

16)   88.4 moles of NI_3

Grams/Moles Calculations – Answer Key

Given the following, find the number of moles:

1)   30 grams of H_3PO_4 **0.31 moles**

2)   25 grams of HF **1.25 moles**

3)   110 grams of $NaHCO_3$ **1.31 moles**

4)   1.1 grams of $FeCl_3$ **0.0068 moles**

5)   987 grams of $Ra(OH)_2$ **3.80 moles**

6)   564 grams of copper **0.11 moles**

7)   12.3 grams of CO_2 **0.28 moles**

8)   89 grams of $Pb(CH_3COO)_4$ **0.20 moles**

Given the following, find the number of grams:

9)   4 moles of $Cu(CN)_2$ **462 grams**

10)   5.6 moles of C_6H_6 **436.8 grams**

11)   21.3 moles of $BaCO_3$ **4202.5 grams**

12)   1.2 moles of $(NH_4)_3PO_3$ **159.6 grams**

13) 9.3×10^{-3} moles of SmO **1.5 grams**

14)   6.6 moles of ZnO **537.2 grams**

15)   5.4 moles of K_2SO_4 **941.2 grams**

16)   88.4 moles of NI_3 **34679.3 grams**

Molar Mass Worksheet

Calculate the molar mass of the following chemicals:

1) Cl_2

2)   KOH

3) $BeCl_2$

4) $FeCl_3$

5) BF_3

6) CCl_2F_2

7) $Mg(OH)_2$

8) UF_6

9) SO_2

10) H_3PO_4

11) $(NH_4)_2SO_4$

12) CH_3COOH

13) $Pb(NO_3)_2$

14) $Ga_2(SO_3)_3$

Molar Mass Worksheet – Answer Key

Calculate the molar mass of the following chemicals:

1) Cl_2 **71 g/mol**

2) KOH **56.1 g/mol**

3) $BeCl_2$ **80 g/mol**

4) $FeCl_3$ **162.3 g/mol**

5) BF_3 **67.8 g/mol**

6) CCl_2F_2 **121 g/mol**

7) $Mg(OH)_2$ **58.3 g/mol**

8) UF_6 **352 g/mol**

9) SO_2 **64.1 g/mol**

10) H_3PO_4 **98 g/mol**

11) $(NH_4)_2SO_4$ **132.1 g/mol**

12) CH_3COOH **60 g/mol**

13) $Pb(NO_3)_2$ **331.2 g/mol**

14) $Ga_2(SO_3)_3$ **379.7 g/mol**

Mole Calculation Worksheet

1) How many moles are in 15 grams of lithium?

2) How many grams are in 2.4 moles of sulfur?

3) How many moles are in 22 grams of argon?

4) How many grams are in 88.1 moles of magnesium?

5) How many moles are in 2.3 grams of phosphorus?

6) How many grams are in 11.9 moles of chromium?

7) How many moles are in 9.8 grams of calcium?

8) How many grams are in 238 moles of arsenic?

What are the molecular weights of the following compounds?

9) NaOH

12) H_3PO_4

10) H_2O

13) Mn_2Se_7

11) $MgCl_2$

14) $(NH_4)_2SO_4$

15) How many grams are in 4.5 moles of sodium fluoride, NaF?

16) How many moles are in 98.3 grams of aluminum hydroxide, $Al(OH)_3$?

17) How many grams are in 0.02 moles of beryllium iodide, BeI_2?

18) How many moles are in 68 grams of copper (II) hydroxide, $Cu(OH)_2$?

19) How many grams are in 3.3 moles of potassium sulfide, K_2S?

20) How many moles are in 1.2×10^3 grams of ammonia, NH_3?

21) How many grams are in 2.3×10^{-4} moles of calcium phosphate, $Ca_3(PO_3)_2$?

22) How many moles are in 3.4×10^{-7} grams of silicon dioxide, SiO_2?

23) How many grams are in 1.11 moles of manganese sulfate, $Mn_3(SO_4)_7$?

Mole Calculation Worksheet – Answer Key

1) How many moles are in 15 grams of lithium? **0.46 moles**

2) How many grams are in 2.4 moles of sulfur? **77.0 grams**

3) How many moles are in 22 grams of argon? **0.55 moles**

4) How many grams are in 88.1 moles of magnesium? **2141 grams**

5) How many moles are in 2.3 grams of phosphorus? **0.074 moles**

6) How many grams are in 11.9 moles of chromium? **618.8 grams**

7) How many moles are in 9.8 grams of calcium? **0.24 moles**

8) How many grams are in 238 moles of arsenic? **17,826 grams**

What are the molecular weights of the following compounds?

9) NaOH **40.1 grams**   12) H_3PO_4 **98.0 grams**

10) H_2O **18.0 grams**   13) Mn_2Se_7 **663.0 grams**

11) $MgCl_2$ **95.3 grams**   14) $(NH_4)_2SO_4$ **132.1 grams**

15) How many grams are in 4.5 moles of sodium fluoride, NaF? **189 grams**

16) How many moles are in 98.3 grams of aluminum hydroxide, $Al(OH)_3$?
1.26 moles

17) How many grams are in 0.02 moles of beryllium iodide, BeI_2? **5.2 grams**

18) How many moles are in 68 grams of copper (II) hydroxide, $Cu(OH)_2$?
0.70 moles

19) How many grams are in 3.3 moles of potassium sulfide, K_2S? **364.0 grams**

20) How many moles are in 1.2×10^3 grams of ammonia, NH_3? **70.6 moles**

21) How many grams are in 2.3×10^{-4} moles of calcium phosphate, $Ca_3(PO_3)_2$?
0.064 grams

22) How many moles are in 3.4×10^{-7} grams of silicon dioxide, SiO_2?
5.66×10^{-9} moles

23) How many grams are in 1.11 moles of manganese sulfate, $Mn_3(SO_4)_7$?
929.5 grams

Moles, Molecules, and Grams Worksheet

1) How many molecules are there in 24 grams of FeF_3?

2) How many molecules are there in 450 grams of Na_2SO_4?

3) How many grams are there in 2.3×10^{24} atoms of silver?

4) How many grams are there in 7.4×10^{23} molecules of $AgNO_3$?

5) How many grams are there in 7.5×10^{23} molecules of H_2SO_4?

6) How many molecules are there in 122 grams of $Cu(NO_3)_2$?

7) How many grams are there in 9.4×10^{25} molecules of H_2?

8) How many molecules are there in 230 grams of $CoCl_2$?

9)   How many molecules are there in 2.3 grams of NH_4SO_2?

10)   How many grams are there in 3.3×10^{23} molecules of N_2I_6?

11)   How many molecules are there in 200 grams of CCl_4?

12)   How many grams are there in 1×10^{24} molecules of BCl_3?

13)   How many grams are there in 4.5×10^{22} molecules of $Ba(NO_2)_2$?

14)   How many molecules are there in 9.34 grams of $LiCl$?

15)   How many grams do 4.3×10^{21} molecules of UF_6 weigh?

16)   How many molecules are there in 230 grams of NH_4OH?

Moles, Molecules, and Grams Worksheet – Answer Key

1) How many molecules are there in 24 grams of FeF_3? **1.28 x 10^{23} molecules**

2) How many molecules are there in 450 grams of Na_2SO_4? **1.91 x 10^{24} molecules**

3) How many grams are there in 2.3 x 10^{24} atoms of silver? **421 grams**

4) How many grams are there in 7.4 x 10^{23} molecules of $AgNO_3$? **209 grams**

5) How many grams are there in 7.5 x 10^{23} molecules of H_2SO_4? **122 grams**

6) How many molecules are there in 122 grams of $Cu(NO_3)_2$? **3.92 x 10^{23} molecules**

7) How many grams are there in 9.4 x 10^{25} molecules of H_2? **312 grams**

8) How many molecules are there in 230 grams of $CoCl_2$? **1.07 x 10^{24} molecules**

9) How many molecules are there in 2.3 grams of NH_4SO_2? **1.69 x 10^{22} molecules**

10) How many grams are there in 3.3 x 10^{23} molecules of N_2I_6? **430 grams**

11) How many molecules are there in 200 grams of CCl_4? **7.82 x 10^{23} molecules**

12) How many grams are there in 1 x 10^{24} molecules of BCl_3? **195 grams**

13) How many grams are there in 4.5 x 10^{22} molecules of $Ba(NO_2)_2$? **17.1 grams**

14) How many molecules are there in 9.34 grams of LiCl? **1.33 x 10^{23} molecules**

15) How many grams do 4.3 x 10^{21} molecules of UF_6 weigh? **2.51 grams**

16) How many molecules are there in 230 grams of NH_4OH? **3.96 x 10^{24} molecules**

Mole Problem

Using your knowledge of mole calculations and unit conversions, determine how many atoms there are in 1 gallon of gasoline. Assume that the molecular formula for gasoline is C_6H_{14} and that the density of gasoline is approximately 0.85 grams/mL.

There are _____ atoms in 1 gallon of gasoline.

　　　　　　　　For chemistry help, visit http://www.chemfiesta.com

Mole Problem – Solution

Using your knowledge of mole calculations and unit conversions, determine how many atoms there are in 1 gallon of gasoline. Assume that the molecular formula for gasoline is C_6H_{14} and that the density of gasoline is approximately 0.8500 grams/mL.

Using a conversion factor of 3785 mL per gallon, we can determine that the mass of gasoline in one gallon is 3785 mL x 0.8500 g/mL = 3217 grams.

Because the molar mass of C_6H_{14} is 86 g/mole, there are 3217 / 86 moles of gasoline molecules, or 37.4 moles of molecules present.

Multiplying 37.4 x 20 (the number of atoms per mole of gasoline), there are 748 moles of atoms.

Finally, multiplying 748 moles of atoms by 6.02 x 10^{23} atoms/mole, we can find that there are 4.50 x 10^{25} atoms present in the sample.

There are **4.50 x 10^{25}** atoms in 1 gallon of gasoline.

Moles Worksheet

1)   Define "mole".

2)   How many moles are present in 34 grams of $Cu(OH)_2$?

3)   How many moles are present in 2.45 x 10^{23} molecules of CH_4?

4)   How many grams are there in 3.4 x 10^{24} molecules of NH_3?

5)   How much does 4.2 moles of $Ca(NO_3)_2$ weigh?

6)   What is the molar mass of MgO?

7)   How are the terms "molar mass" and "atomic mass" different from one another?

8)   Which is a better unit for expressing molar mass, "amu" or "grams/mole"?

Moles Worksheet (Solutions)

1) Define "mole".
   6.02 x 10^{23} of anything, usually atoms or molecules.

2) How many moles are present in 34 grams of $Cu(OH)_2$?
   0.35 moles

3) How many moles are present in 2.45 x 10^{23} molecules of CH_4?
   0.41 moles

4) How many grams are there in 3.4 x 10^{24} molecules of NH_3?
   96 grams

5) How much does 4.2 moles of $Ca(NO_3)_2$ weigh?
   689 grams

6) What is the molar mass of MgO?
   40.3 grams/mole

7) How are the terms "molar mass" and "atomic mass" different from one another?
   "Molar mass" is used to describe the mass of one mole of a chemical compound, while "atomic mass" is used to describe the mass of one mole of an element or the mass of one atom of an element.

8) Which is a better unit for expressing molar mass, "amu" or "grams/mole"?
   "Grams/mole" is better, because any macroscopic amount of a substance is better expressed in grams than amu.

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Name _____   Period _____

THA MOLE! Worksheets

7.1

1. Find the molar mass of each compound. (Show your work!)
    a. Li_2S _____

    b. $FeCl_3$ _____

    c. $Ca(OH)_2$ _____

2. Define the following using your own words.
    a. atom: _____

    b. molecule: _____

    c. formula unit: _____

3. Label each of the following as atom, molecule, or formula unit.
    a. oxygen   _____   c. sulfur dioxide _____
    b. sodium sulfide _____   d. potassium   _____

4. How many moles is each of the following?
    a. 1.50×10^{23} molecules NH_3

    b. 1 billion (1×10^9) molecules O_2

    c. 6.02×10^{22} molecules Br_2

5. Which contains more atoms? Justify your answer *(hint remember definitions from your notes)*
    1.00 mol H_2O_2, 1.00 mol C_2H_6, or 1.00 mol CO?

▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬ ▪ ▬

7.2

1. Find the mass of each substance:
    a. 1.50 mol C_5H_{12}

    b. 14.4 mol F_2

    c. 7.00 mol H_2O_2

    d. 0.780 mol $NaOH$

2. Calculate the volume of each of the following gases at STP:
   a. 7.9 mol Ar

   b. 0.45 mol O_2

   c. 1.23 mol C_2H_6

7.3

Write the 3 mole conversion factors:

1 mol = _____ L @ STP   1 mol = _____ g   1 mol = _____ particles

1. Calculate the percent composition of each compound:
   a. H_2S

   b. $(NH_4)_2C_2O_4$

   c. $Mg(OH)_2$

2. Using your answers from #2, calculate the number of grams of these elements:
   a. sulfur in 7.23 g H_2S

   b. nitrogen in 24.0 g $(NH_4)_2C_2O_4$

   c. magnesium in 94.2 g $Mg(OH)_2$

Empirical and Molecular Formulas Worksheet

1. The molecular formulas of some substances are as follows. Write their empirical formulas.

   a. Acetylene, C_2H_2 (used in oxyacetylene torches) _____

   b. Glucose, $C_6H_{12}O_6$ (the chief sugar in blood) _____

   c. Octane, C_8H_{18} (a component of gasoline) _____

   d. Ethylene glycol is $C_2H_6O_2$ (antifreeze) _____

2. Determine the empirical formula of a compound that contains 36.5% sodium, 25.4% sulfur, and 38.1% oxygen.

┌─────────┐
│   │
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3. Nitrogen and oxygen form an extensive series of oxides with the general formula N_xO_y. One of them is a blue solid that comes apart, reversibly, in the gas phase. It contains 36.84% N. What is the empirical formula of this oxide?

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│   │
└─────────┘

4. An organic compound has an empirical formula of CH and a molecular mass of 78 g/mol. What is the **molecular** formula?

┌─────────┐
│   │
└─────────┘

5. A well-known reagent in analytical chemistry, dimethylglyoxime, has the empirical formula C_2H_4NO. If its molar mass is 116.1 g/mol, what is the **molecular** formula of the compound?

┌─────────┐
│   │
└─────────┘

6. Determine the molecular formula for each compound: *(remember that you need to find empirical formula first!)*

   a. 94.1% O and 5.9% H; molar mass = 34 g

┌─────────┐
│   │
└─────────┘

   b. 40.0% C, 6.6% H, and 53.4% O; molar mass = 120 g

┌─────────┐
│   │
└─────────┘