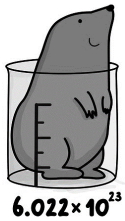
The Mole



Objective #1: Counting Significant Figures

When a measurement or calculation is recorded on paper, the precision of the measurement is based on what placeholder the number is recorded to. For example, a measurement of 54.0 grams is not as precise as a measurement of 54.000 grams. To any scientist reading those two values, there is more _____ and _____ with a measurement rounded to the thousandths place than one rounded to the tenths place.

When recording a measurement, _____ are used to determine the numbers in a measurement that are for confidence and precision versus those that are for placeholders only. Use the following rules for determining if a number in a measurement is significant or not.

1) All non-zero digits are considered significant (1 2 3 4 5 6 7 8 9)

2) Trailing zeros (zeroes at the end of a number) are significant in a measurement with a decimal point; they are NOT significant in a measurement without a decimal point

3) Leading zeros (zeros at the beginning of a number) are NOT significant in a measurement with a decimal point → they are used only as placeholders

4) Zeroes in-between two non-zero numbers are always significant.

Significant Figures

1. Which mass measurement contains four significant figures?
   1) 0.086 g 2) 0.431 g 3) 1003 g 4) 3870 g

2. The measurement 0.41006 grams, rounded to three significant figures, is expressed as
   1) 0.41 g 2) 0.410 g 3) 0.4100 g 4) 0.4101 g

3. Which measurement contains a total of three significant figures?
   1) 0.12 2) 012 3) 120 4) 120.

4. Which measurement contains 1 significant figure?

1) 0.08 cm 2) 0.080 cm 3) 800. cm 4) 8.08 cm

5. Which measurement contains a total of three significant figures?

1) 0.012 g 2) 0.125 g 3) 1,205 g 4) 12,050 g

6. Which volume measurement is expressed to four significant figures?

1) 5.50 mL 2) 550. mL 3) 5,500 mL 4) 5,500. mL

7. Which mass measurement contains a total of two significant figures?

1) 22.0 g 2) 22.00 g 3) 220. g 4) 2200 g

8. Which measurement has the greatest number of significant figures?

1) 6.060 mg 2) 60.6 mg 3) 606 mg 4) 60600 mg

9. Which measurement contains three significant figures?

1) 0.05 g 2) 0.050 g 3) 0.056 g 4) 0.0563 g

10. How many significant figures are in the measurement 0.070200

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

Objective #2: Calculations and Rounding to Significant Figures

A) Multiplying and Dividing

When multiplying or dividing measurements, the final answer must have the same number of significant figures as the measurement with the _____ significant figures.

Ex) 4.610 ÷ 5.50 =

Ex) 297.05 ÷ 3.1

Ex) 0.72 x 8.00 =

Ex) 1.72 x 5.080 x 15 =

B) Adding and Subtracting

When adding and subtracting measurements, the final answer must have the same precision to the right of the decimal point as the measurement with the _____ after the decimal point.

Ex) 4.271 + 2.0 + 10.57 =

Ex) 212.59 - 7 =

Ex) 0.00560 + 2.1 =

Math and Significant Figures

1) During a laboratory experiment, a sample of aluminum is found to have a mass of 12.50 grams and a volume of 4.6 milliliters. What is the density of this sample, expressed to the correct number of significant figures?

1) 2.717 g/mL 2) 2.72 g/mL 3) 3 g/mL 4) 2.7 g/mL

2) A student calculates the density of an unknown solid. The mass is 10.04 grams and the volume is 8.21 cubic centimeters. How many significant figures should appear in the final answer?

1) 1 2) 2 3) 3 4) 4

3) Expressed to the correct number of significant figures, the sum of two masses is 445.2 grams. Which two masses produce this answer?

1) 210.10 g + 235.100 g
2) 210.100 g + 235.10 g
3) 210.1 g + 235.1 g
4) 210.10 g + 235.10 g

4) What is the product of 2.324 cm x 1.11 cm expressed to the correct number of significant figures?

1) 2.58 cm^2 2) 2.5780 cm^2 3) 2.5796 cm^2 4) 2.57964 cm^2

5) What is the quotient of 8.01 grams divided by 3.127 grams, expressed to the correct number of significant figures?

1) 2.6 2) 2.56 3) 2.562 4) 2.5616

6) Which quantity expresses the sum of the given masses (22.1 g + 375.66 g + 5400.132 g) to the correct number of significant figures?

1) 5800 g 2) 5798 g 3) 5797.9 g 4) 5797.892 g

7) The volume of a gas sample is 22.40 liters. The density of the gas is 1.34 grams per liter. What is the mass of the gas sample, expressed to the correct number of significant figures?

1) 16.7 g 2) 17.00 g 3) 30.00 g 4) 30.0 g

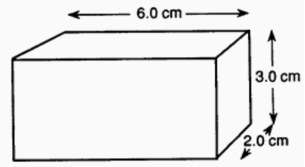
8) Given (52.6 cm x 1.214 cm) What is the product expressed to the correct number of significant figures?

1) 64 cm^2 2) 63.9 cm^2 3) 63.86 cm^2 4) 63.8564 cm^2

9) When 1.255 grams of X completely reacts with 3.2 grams of Y, Z is the only product of the reaction. What is the total mass of Z, expressed to the proper number of significant figures?

1) 4.455 g 2) 4.46 g 3) 4.5 g 4) 5g

10) A solid object shown below has a mass of 162.2 grams.



What is the density of the object rounded to the correct number of significant figures?

1) 0.22 g/cm^3 2) 0.2219 g/cm^3 3) 4.5 g/cm^3 4) 4.505 g/cm^3

Objective #3: Mathematics of Formulas

Chemical formulas can tell us many things. There is qualitative analysis and quantitative analysis that can come from a formula.

- qualitative data from a formula tells us _____ are in the formula
- quantitative data from a formula tells us _____ are in the formula

example: $C_6H_{12}O_6$ qualitative analysis = _____

quantitative analysis = _____

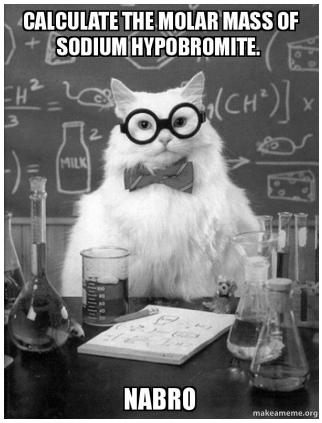
When writing a formula, we can also determine the number of moles of each element. A mole is a quantitative way of describing atoms in chemistry. With a formula, we use _____ (small numbers) after an element's symbol to indicate if we have more than one of an atom in an substance.

Practice:

Compound	First Element	Second Element	Third Element	Fourth Element	Total
KCl					
$LiNO_3$					
$Sr(NO_3)_2$					
$Fe_3(PO_4)_2$					
$(NH_4)_2SO_4$					

Objective #4: Determining Gram Formula Mass (G.F.M.)

Describing chemical substances in terms of atoms is very difficult, since you need a large amount of atoms to have any kind of measurable data. So instead, scientists use _____ (also sometimes called *molar mass*) to calculate and express the quantity of a given substance in grams.



- Thanks to the work of Amedeo Avogadro, it was then determined that the gram formula mass for any substance is then equal to the mass of _____ _____ of that substance, which then equals _____ atoms.

To calculate gram formula mass for any substance, you need to look at the _____ for the elements written on the periodic table.

- Step 1: Determine the number of atoms of each element from the formula
- Step 2: Consult the periodic table for the atomic mass for each element (round to the TENTHS place), and then multiply it by the number of atoms to determine the total mass for each element
- Step 3: Add the total mass for each element to determine the "Gram Formula Mass"

*** The gram formula mass should be express in units of _____. ***

Ag	O_2	MgO
Fe_2O_3	H_2SO_4	$Al_2(CO_3)_3$

Formulas and Gram Formula Mass Questions

1. What are the total number of sulfur atoms in $(NH_4)_2SO_4$?
   1) 1 2) 2 3) 3 4) 4

2. What is the total number of moles of hydrogen atoms contained in 1 mole of $(NH_4)_2C_2O_4$?
   1) 6 2) 2 3) 8 4) 4

3. What is the total number of atoms present in 1 mole of $Pb(C_2H_3O_2)_2$?
   1) 9 2) 14 3) 3 4) 15

4. Which sample contains a mole of atoms?
   1) 23.0 g Na 2) 24.0 g C 3) 42.0 g Kr 4) 78.0 g K

5. What is the gram formula mass of Li_2SO_4?
   1) 54 g 2) 55 g 3) 110 g 4) 206 g

6. What is the gram formula mass of CH_3COOH?
   1) 22.4 g 2) 44.0 g 3) 48.0 g 4) 60.0 g

7. What is the gram-formula mass of $Ca_3(PO_4)_2$?
   1) 248.4 g/mole 2) 263.0 g/mole 3) 279.9 g/mole 4) 310.3 g/mole

8. What is the gram formula mass of $Ca(OH)_2$?
   1) 29.6 g 2) 34.8 g 3) 57.1 g 4) 74.1 g

Objective #5: Mole Unit Conversions

A) Introduction to Dimensional Analysis

Dimensional analysis is a process that can be used to cancel out units when converting between different units. When using dimensional analysis, a relationship is set up between two factors in a "fraction-type" setup. Each contributing part in a dimensional analysis problem will work together in conjunction to contribute to the final answer with a new unit.

Example 1: 3.5 days = ? hours

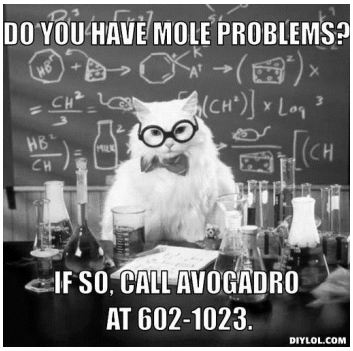
Example 2: 10,360 seconds = ? hours

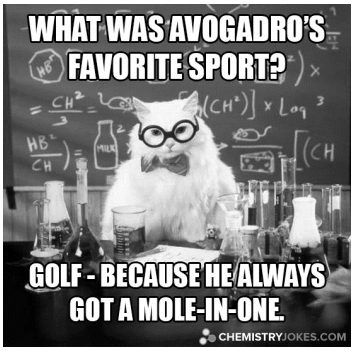
Example 3: 240,950 minutes = ? weeks

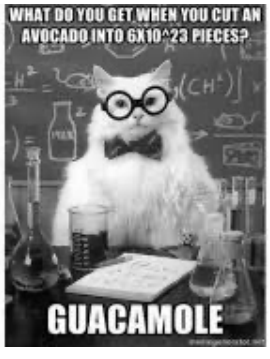
B) One Step Mole Unit Conversions

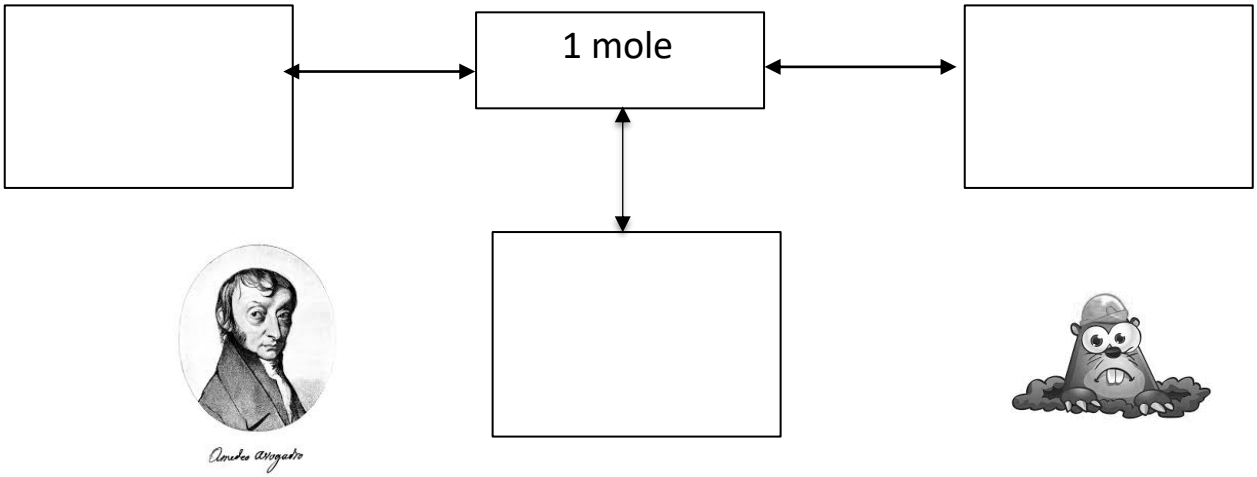
A mole is defined as 6.02×10^{23} of some chemical unit, be it atoms, molecules, ions, or others. The mole is a convenient unit to use because of the great number of atoms, molecules, or others in any substance. The mole was originally defined as the number of atoms in 12 grams of carbon-12, but in 2018 it was announced that the mole would be just 6.02×10^{23} of some chemical unit.

When converting between units of grams, liters, atoms or molecules, dimensional analysis will use the relationship of each versus 1 mole. The "mole map**"** on the next page shows the relationship of each to 1 mole.









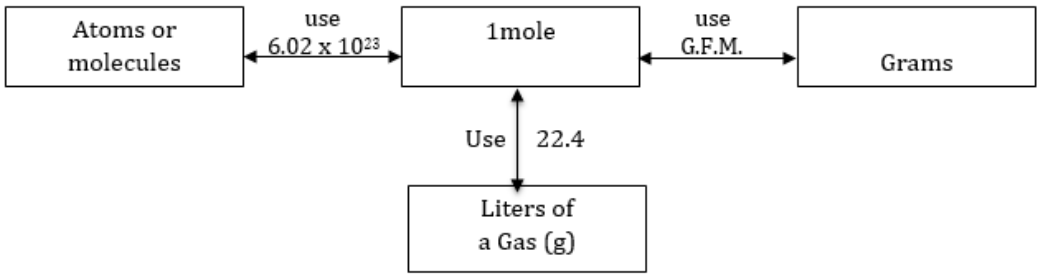
Ex 1: How many liters are in 2.5 moles of $CO_2(g)$?

Ex 2: How many moles are in 2.59×10^{24} atoms of Ne(g)?

Ex 3: How many grams are in 4.200 moles of $H_2CO_3(s)$?

C) Mole Unit Conversions: Two Step Conversions

- first step will be to convert given unit to moles
- second step will be to convert moles to desired unit



Ex 1: How many liters are in 2.5×10^{23} molecules of CCl_4?

Ex 2: How many grams are in 16.0 L of Ne?

Ex 3: How many grams are in 5.03×10^{26} molecules of H_2?

Ex 4: How many atoms are in 79.6 grams of Argon?

Mole Conversions

1. How many molecules are contained in 126.9 grams of iodine, I_2?
   1) 1.50×10^{23} 2) 3.01×10^{23} 3) 9.03×10^{23} 4) 1.24×10^{24}

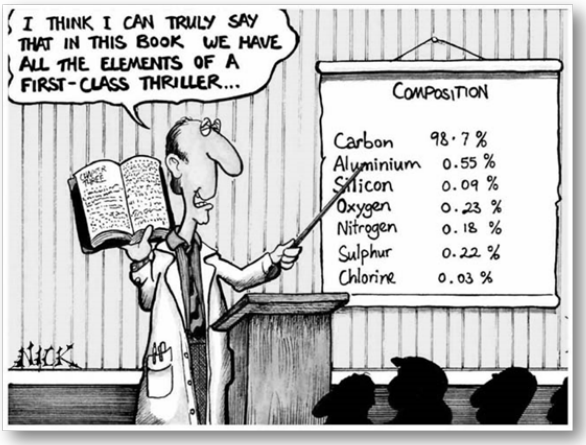
2. What is the total number of atoms contained in 2.00 moles of nickel?
   1) 6.02×10^{23} 2) 1.20×10^{24} 3) 58.9 4) 118.0

3. What is the mass of 1.22×10^{23} molecules of nitrogen gas?
   1) 2.84 g 2) 5.67 g 3) 69.1 g 4) 140.5 g

4. What is the volume, in liters, of 576. grams of SO_2 gas?
   1) 101 L 2) 201 L 3) 216 L 4) 788 L

5. What is the number of moles of CO_2 in a 220 gram sample?
   1) 0.20 moles 2) 5.0 moles 3) 15.0 moles 4) 44.0 moles

Objective #6: Calculating Percent Composition



Formula on Reference Table T:

1) What is the percentage composition by mass of oxygen in $KClO_3$?

2) What is the percent composition by mass for each element in the compound NO_2?

3) What is the percent composition by mass for each element in rubbing alcohol, C_3H_7OH?

Percent Composition

1. What is the percent by mass of oxygen in Fe_2O_3?
   1) 16% 2) 30.% 3) 56% 4) 70.%

2. What is the percent by mass of carbon in CO_2?
   1) 12% 2) 27% 3) 44% 4) 73%

3. The percent by mass of nitrogen in NH_4NO_3 is closest to
   1) 15% 2) 20% 3) 35% 4) 60%

4. What is the percent composition by mass of oxygen in $Ca(NO_3)_2$?
   1) 75% 2) 59% 3) 48% 4) 29%

5. Which compound has the greatest percent composition by mass of sulfur?
   1) BaS 2) MgS 3) CaS 4) SrS

Objective #7: Identifying and Calculations for Hydrates

Hydrates are _____ (_____ + _____) compounds that have _____ molecules trapped within the crystalline structure

* The water is _____ to the structure

Since the water is NOT bonded to the structure, the hydrate can be gently heated and the water will then _____ from the crystal

- What is left behind is called _____

(an ionic compound without the water trapped anymore)

Hydrate (ionic compound + water) ---heat---> anhydrous ionic compound + water

Identify hydrates: (for hydrates, the "●" means "and")

HYDRATE	Ionic Compound and…	Water Molecules
$CuSO_4$ ● 5 H_2O	$CuSO_4$	5 H_2O
$LiNO_3$ ● 2 H_2O	$LiNO_3$	2 H_2O
$MgSO_4$ ● 8 H_2O	$MgSO_4$	8 H_2O
$MnCl_2$ ● 4 H_2O	$MnCl_2$	4 H_2O

- The number in front of H_2O is known as a _____. This is a whole-number _____ that is distributed to everything that follows it for total gram formula mass

A) Finding the Gram Formula Mass of a hydrate

$LiNO_3$ ● 2 H_2O $MgSO_4$ ● 8 H_2O

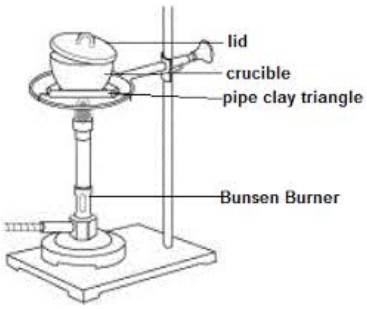
B) Determining the percentage of water in a hydrate

1) Theoretically using the formula
    a. Use the gram formula mass of the hydrate versus of just the water in the hydrate to determine the percent composition of water in a hydrate

Example: $MgSO_4 \bullet 8\ H_2O$

2) Experimentally
    a. Use data given from experiment to determine amount of water in a hydrate

Hydrate (H_2O included) $\xrightarrow{\text{heat}}$ Anhydrous (no H_2O)



Example 1: Mass of Hydrate = 5.00 grams
Mass of anhydrous after heating = 4.26 grams

Example 2: Mass of Hydrate + crucible = 23.00 grams
Mass of anhydrous + crucible after heating = 16.80 grams
Mass of just crucible = 5.00 grams

Hydrates

1. What is the gram formula mass of $CuSO_4 \cdot 5\ H_2O$?

1) 160. g 2) 178 g 3) 186 g 4) 250. g

2. The percent by mass of water in the hydrate $Na_2SO_4 \cdot 10\ H_2O$ is closest to

1) 18% 2) 44% 3) 56% 4) 76%

3. A 10.0 gram sample of a hydrate was heated until all the water of hydration was driven off. The mass of anhydrous product remaining was 8.00 grams. What is the percent of water in the hydrate?

1) 12.5% 2) 20.0% 3) 25.0% 4) 80.0%

4. A hydrate is a compound with water molecules incorporated into its crystal structure. In an experiment to find the percent by mass of water in a hydrated compound, the following data were recorded:

Mass of crucible + hydrated crystals before heating	7.50 grams
Mass of crucible	6.90 grams
Mass of crucible + anhydrous crystals after heating	7.20 grams

What is the percent by mass of water in the hydrate?

1) 8.0 % 2) 50. % 3) 72. % 4) 96. %

Objective #8: Calculating Empirical and Molecular Formulas

There are two types of chemical formulas – empirical and molecular formulas.

- An **empirical formula** is a formula in which the subscripts are _____, or in lowest terms

  Ex)

- A **molecular formula** is a formula in which the subscripts have _____ _____. They show the actual number of atoms in a formula

  Ex)

Examples:

Formula	Empirical or Molecular?	Reduce if Molecular Divide by….	 Empirical
H_2O_2			
N_2O_3			
$C_6H_{12}O_6$			

Formula	Empirical or Molecular?	Reduce if Molecular Divide by….	Empirical
LiCl			
$Mg(NO_3)_2$			
$Mg_3(PO_4)_2$			

A) Determining an Empirical formula

Step 1: Convert given all given masses (grams) to moles

Step 2: Divide all molar answers from step 1 by the smallest of the mole answers

- You should get a whole numbers when dividing

Step 3: Use these whole numbers as subscripts in formula

Ex) A compound has 6.13 grams of Cu and 1.55 grams of S. What is the empirical formula?

Ex) A compound is made up of 30.5% N and 69.5% O. What is the empirical formula?

*HINT: Change out % symbol for grams

B) Determining a Molecular formula

Step 1: Find the GFM of the empirical formula given

Step 2: Divide the molecular formula mass (given in the problem) by the empirical formula mass

- This will give you a whole number known as a "multiplier"

Step 3: Multiply the subscripts in the formula by the multiplier found in step 2.

Ex) A compound has the empirical formula of CH_2O. The molecular formula mass is 60.0 g/mole. What is the molecular formula?

Ex) Caffeine has the empirical formula of $C_4H_5N_2O$. The molecular formula mass is 291.0 g/mole. What is the molecular formula?

Empirical and Molecular Formulas

1. What is the empirical formula of a compound consisting of 29.6% oxygen and 70.4% fluorine by mass?

1) OF 2) OF_2 3) O_2F 4) O_2F_4

2. What is the empirical formula of a compound if a sample contains 8.52 grams of carbon and 1.42 grams of hydrogen?

1) C_2H 2) CH_2 3) CH 4) C_2H_2

3. 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

4. A compound has an empirical formula of HCO_2 and a molecular mass of 90. grams per mole. What is the molecular formula of this compound?

1) HCO 2) $H_2C_2O_4$ 3) $H_4C_4O_8$ 4) $H_6C_6O_{12}$

DID YOU KNOW….

What is the longest chemical compound?

"($C_{18}H_{24}N_2O_6$), a miticide and contact fungicide used to control powdery mildew in crops. The IUPAC name for **Titin**. This is the largest known protein and so has the longest chemical name. Written in full, it contains 189,819 letters."