## Note Packet # 17

Chemistry is my favorite subject

# Math of Chemistry and the Mole Concept

Even the smallest amounts of materials that can be measured in a labratory contain uncountable amounts of atoms, ions, electrons, or molecules. It is necessary to have a special unit to describe enormous numbers. The term mole (abbreviated "mol") is a very large number. The number is named **Avagadro's numbe**r.
The number is $6.02 \times 10^{23}$ or 602 000 000 000 000 000 000 000.

What is the abbreviation for mole? _____
**This giant number is based on the amount of carbon atoms in a 12 gram sample of carbon-12.**
Using the term **mole** is similar to using the term "dozen".
**1** dozen is 12. **2** dozen is 24. **1/2** dozen is 6.

**1** mole = $6.02 \times 10^{23}$ **2** moles = **2** X $6.02 \times 10^{23}$ **1/2** mole = **.5** X $6.02 \times 10^{23}$

**Compounds, diatomic elements, and polyatomic ions are composed of individual atoms.** You will be required to determine the # of moles of atoms in a compound, polyatomic ion, or diatomic element.

**1** mole of $H_2O$ contain **2** moles of hydrogen atoms and **1** mole of oxygen atoms, for a total of **3** moles of atoms.

**1** mole of $CaCO_3$ contains **1** mole of Calcium atoms, **1** mole of carbon atoms, and **3** moles of oxygen atoms for a total of **5** moles of atoms.

**1** mole of $CH_4$ contains **1** mole of carbon atoms and **4** moles of hydrogen atoms, for a total of **5** moles of atoms.

Determine the number of moles of atoms of each element in **1mole** of the following compounds, and the total # of moles of all atoms in each compound.

1. $C_6H_{12}O_6$ C_____ H_____ O_____Total moles of all atoms_____

2. NaOH Na_____ O_____ _H_____Total moles of all atoms_____

3. $NH_4NO_3$ N____ H____ O_____ Total moles of all atoms_____

4. $Ba(OH)_2$ Ba____ O_____ H_____ Total moles of all atoms_____

5. $Al(NO_3)_3$ Al_____ N_____ O_____ Total moles of all atoms_____

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Determine the total number of moles of atoms of each element for the following #s of moles of compounds and determine the total # of moles of all atoms for that quantity of compound.

a) **2 mol** $C_6H_{12}O_6$ C____ H_____ O_____ Total moles of all atoms_____

b) **3 mol** NaOH N_____ H_____ O_____ Total moles of all atoms_____

c) **2 mol** $NH_4NO_3$ N_____ H_____ O_____ Total moles of all atoms_____

d) **1.5 mol** $Ba(OH)_2$ Ba_____ O _____ H ____ Total moles of all atoms_____

e) **2 mol** $Al(NO_3)_3$ Al ____ N____ O _____ Total moles of all atoms_____

**Molar Mass** describes the mass of one mole of anything. In chemistry we are concerned with the mass of atoms, diatomic elements and compounds.

One carbon-12 atom has a mass of 12 amu (atomic mass unit). One mole of carbon-12 has a mass of 12 grams.

One uranium-238 atom has a mass of 238 amu. One mole of uranium 238 has a mass of 238 grams.

Remember! Atomic mass of an element on the periodic table is the **weighted average of that element's naturally ocurring isotopes.**

**Atomic mass unit "Amu"** The term Amu is used to describe the mass of individual atoms, protons,neutrons, and electrons.

An Amu is very small. The mass of an Amu is $1.7 \times 10^{-24}$ gram.

**An Amu is based on 1/12 the mass af a carbon-12 atom.**

What is the mass in grams of an amu? _____

What is an Amu based on? _____

**Gram Formula Mass** is the mass of 1 mole of all the elements that are present in a chemical formula measured in **grams**. Find the masses of the parts (elements) in the periodic table.

Ex: What is the gram formula mass of NaCl? Look at the periodic table!

The mass of 1 mole of Na is 23g/mol.

The mass of 1 mole of Cl is 35g/mol.

Therefore; the gram formula mass of 1 mole of NaCl is 23g/mol + 35g/mol = **58g/mol**

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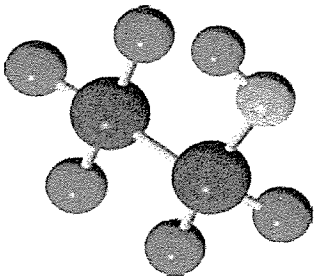
**Gram Molecular Mass** is the same as a formula mass but it specifically describes molecules (covalently bonded atoms). **No metals in molecules!**



This is a molecule of ethanol. 1 ethanol molecule has a mass of **46 amu**. 1 mole of ethanol has a mass of **46g**.

**Ex: What is the gram molecular mass of ethanol "$C_2H_6O$"?**

The mass of **two** moles of carbon is 12g X 2 = 24g.
The mass of **six** moles oh hydrogen is 1g X 6 = 6g
The mass of **one** mole of oxygen is 16g X 1 = 16g

24g + 6g + 16 = **46g/mol**

Determine the mass of the following. **Include proper Units!** (Atoms and molecules are measured in amu. Moles are measured in grams.)

1. one carbon **atom** _____
2. one **mole** of carbon atoms _____
3. one **molecule** of $CO_2$ _____
4. one **mole** of $CO_2$_____

Determine the gram formula mass of the following. Units are: g/mol

5. CaO
6. NaOH
7. $Sc_2(CO_3)_3$
8. KCl
9. $NH_4NO_3$
10. $Al_2O_3$
11. $Ba(OH)_2$
12. $ZnCl_2$

# Moles, Mass, and Gram Formula Mass

If any 2 of these three items are known, the third one can be calculated.

The formula: $\#\text{ moles} = \dfrac{given..mass}{gram..formula..mass}$

given mass can just be called **mass**
gram formula mass can be abbreviated **gfm**

**Ex: How many moles are contained in 116g of NaCl?**

To solve:

Step 1: Find the gram formula mass of NaCl.
23g + 35g = 58g

Step 2: Insert the information into the equation.

$\#\text{ moles} = \dfrac{116g}{58g/mol}$ answer: **2 moles**

**Ex: What is the mass of 3.5 moles of $CaCl_2$?**

To solve:

Step1: Find the gram formula mass of $CaCl_2$.
40g + 35g + 35g = 110g

Step 2: Insert the information into the equation.

$\#\text{ moles} = \dfrac{given..mass}{gram..formula..mass}$ $3.5\text{ mol} = \dfrac{given..mass}{110g/mol}$

Step 3: Cross multiply and divide to solve for the unknown. Remember! Any number can be changed into a fraction by dividing by 1.

$\dfrac{3.5}{1} = \dfrac{given..mass}{110g}$ 3.5 X 110 = mass answer: **385g** = mass

**Ex: What is the gram formula mass of a compound if 4 moles of it have a mass of 129g?**
To solve:

Step 1: Insert the information into the equation.

$$\#\text{ moles} = \frac{given..mass}{gram..formula..mass} \qquad 4\text{ moles} = \frac{129g}{gfm}$$

Step 2: Cross multiply and divide to solve for the unknown. Remember! Any number can be changed into a fraction by dividing by 1.

$$\frac{4}{1} = \frac{129g}{gfm} \qquad 4 \text{ X gfm} = 129\text{g} \qquad \text{gfm} = \frac{129g}{4} \qquad \textbf{gfm = 32.25g/mol}$$

**Solve the following problems. Show your work! Include proper units!**

1. What is the mass of 4.0 moles of $Na_2S$ ?

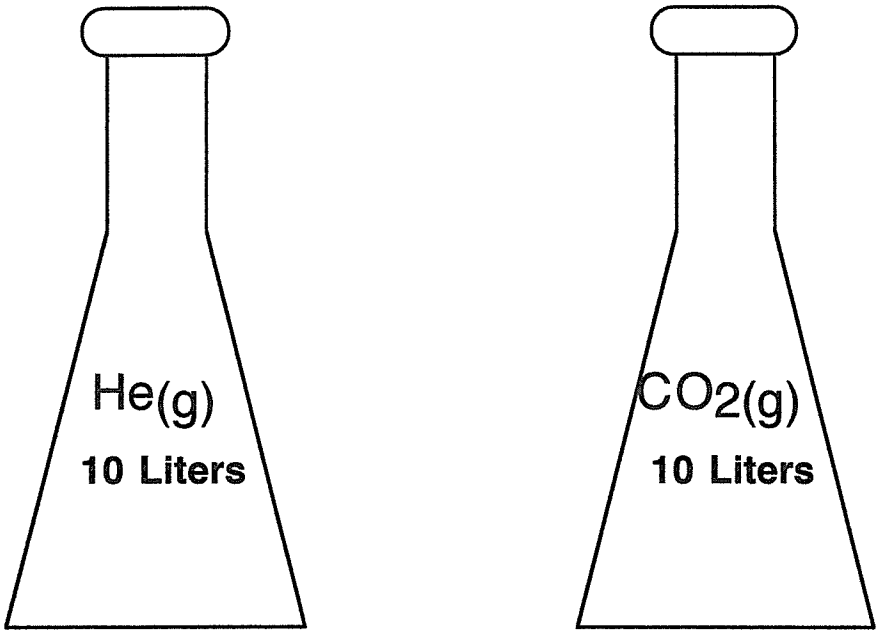
2. How many moles are represented by 25.0 g of $Ca(OH)_2$?

3. What is the gram formula mass of a compound if 2 moles of the compound have a mass of 360g?

4. How many moles are represented by 203 g of sodium chloride?

# Moles and Gas Volume

**Avagadro's Hypothesis** Equal volumes of any gas at the same conditions of temperature and pressure contain an equal number of particles, therefore, equal #s of moles of gas particles. These gases can exist with a large or small mass or can be monoatomic or a complex molecule.




**Equal numbers of moles of any gas**, under the same conditions of temperature and pressure, will occupy the same volume and contain the same # of gas particles.

Describe: Avagadro's Hypothesis _____

_____

**Ex:** 1 mole of helium gas will occupy the same volume and contain the same number of gas particles as 1 mole of carbon dioxide gas as long as they are under the same conditions of temperature and pressure.
Both of the above flasks are at equal temperature and pressure. They contain equal numbers of gas particles even though the two gases are very different. $He_{(g)}$ is a very light monoatomic gas and $CO_{2(g)}$ is a heavy gas compound.

**Ex:** 2.5 mol of $CO_{2(g)}$ will contain the same # of particles and occupy the same volume as 2.5 mol of $H_{2(g)}$ as long as they are under the same conditions of temperature and pressure.

**Sample Question:**
5.9 mol of $SF_{6(g)}$ at STP will contain the same # of particles and occupy the same volume as _____mol of $N_{2(g)}$ at STP?

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# Percent Composition

The percent composition by mass of a compound can be calculated using the following formula:

$$\textbf{\textit{Percent composition by mass}} = \frac{mass..of..part}{mass..of..whole} \textbf{ X 100 \%}$$

**Ex: What is the percent composition by mass of oxygen in $H_2O$?**

To solve: Divide the mass of the oxygen by the mass of the whole $H_2O$.
The mass of the one oxygen is **16** (found on the periodic table).

There are 2 hydrogens present. Each hydrogen has a mass of **1** (found on the periodic table).
The mass of the hydrogen part is **1** X 2 = **2**.

The mass of $H_2O$ is **16** (from O) + **2** (from H) = **18**

Percent composition of oxygen by mass = $\frac{16g}{18g}$ X 100 % = .89 X 100 % = **89 %**

**Ex: What is the percent by mass of oxygen in $CO_2$?**

There are 2 oxygen atoms, each with a mass of **16**. 16 + 16 = **32**

The mass of $CO_2$ is **12** (from C) + **32** (from O) = **44**

% Oxygen = $\frac{32}{44}$ X 100 % = .73 X 100 % = **73 %**

**Ex: What is the percent composition by mass of sulfur in $SO_3$?**

$$\textit{Percent composition by mass} = \frac{mass..of..part}{mass..of..whole} \text{ X 100 \%}$$

The mass of the sulfur is **32**.

The mass of the oxygen in $SO_3$ is **16 + 16 + 16 = 48**.

The mass of $SO_3$ is **32 + 48 = 80**.

Percent composition of sulfur by mass = $\frac{32}{80}$ X 100 % = .40 X 100 % = **40 %**

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Calculate the following % compositions by mass. **SHOW YOUR WORK!**

Round the masses from the periodic table to the nearest whole number.

1. The % of Ca in $CaCO_3$

2. The % of Fe in $Fe_2O_3$

3. The % of O in $PbO_2$

4. The % of Ag in AgCl

5. The % of Na in NaCl

6. The % of H in $H_2O_2$

7. The % of U in $UF_6$

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A **hydrate** is an ionic compound with whole water molecules incorporated (built-into) into its crystal structure. The water molecules and the ionic compound exist in a definite ratio.
Ex: $CuSO_4 \bullet 5\ H_2O$. The large dot indicates that this is a hydrate with 5 water molecules for every $CuSO_4$. We can also say that there are 5 moles of water molecules for every mole of $CuSO_4$.
The water of a hydrate can be removed by high heat.
Heating a hydrate removes the water. The term **annhydrous** refers to a hydrate with its water removed.

You must know how to calculate the % composition by mass of the water in a hydrate.
We know that the mass of $H_2O$ is 18 ( 1 + 1 + 16 = 18)
Ex: What is the % composition by mass of water in $CuSO_4 \bullet 5\ H_2O$?
To solve: Use the % composition formula.

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

- Mass of $CuSO_4$ = 64 + 32 + 16 + 16 + 16 +16 = 160
  Mass of $H_2O$ X 5 = 18 X 5 = **90**
  Mass of the whole hydrate ($CuSO_4 \bullet 5\ H_2O$) = 160 + 90 = **250**

$$\% \text{ composition of water by mass} = \frac{90}{250} \times 100\ \% = .36 \times 100\ \% = \mathbf{36\%}$$

Percent composition of water in a hydrate data is often presented as follows:

Mass of Crucible + hydrate = 7.5g (before heating)
Mass of empty crucible = 5.0g
Mass of crucible and annhydrous material = 6.6g (after heating)

Calculate the % composition of water in this hydrate.
To solve: Before inserting the information into the % composition formula you must determine the mass of the hydrate and the mass of the water by doing some simple subtractions.
Mass of the hydrate = hydrate and crucible - crucible
7.5g - 5.0g = 2.5g hydrate
Mass of the water = crucible and hydrate - crucible and annhydrous material
7.5g - 6.6g = .9g

Insert this information into the % composition formula.

$$\% \text{ composition of water by mass} = \frac{.9g}{2.5g} \times 100\ \% = .36 \times 100\ \% = \mathbf{36\ \%}$$

Describe: Hydrate _____

_____

Describe: annhydrous_____

_____

How can water molecules be removed from a hydrate?

_____

After all the water has been removed from a hydrate, will additional heating cause an additional loss of mass?

_____

**Why?**

_____

What is the ratio of moles of water to moles of $MgSO_4$ in $MgSO_4 \cdot 7H_2O$

_____

**Determine the percent composition by mass of water in this hydrate using the following data.**

| | |
|---|---|
| Mass of Crucible | 25.0 g |
| Mass of Crucible and Hydrate | 30.0 g |
| Mass of Crucible and Annhydrous Material (after heating) | 28.5 g |

To solve:

1) Determine the mass of the hydrate.

Subtract the mass of the crucible from the mass of the crucible and hydrate.

30.0 g Mass of Crucible and Hydrate
-25.0 g Mass of Crucible
5.0g Mass of Hydrate

2) Determine the mass of the annhydrous material.

Subtract the mass of the crucible from the mass of the crucible and annhydrous material.

28.5 g Mass of Crucible and Annhydrous Material
-25.0 g Mass of Crucible
3.5 g Mass of Annhydrous Material

3) Determine the mass of the water.

Subtract the mass of the annhydrous material from the mass of the hydrate.

5.0g Mass of Hydrate
-3.5 g Mass of Annhydrous Material
1.5 g Mass of Water

4) Determine the Percent of the water by mass.

Use the formula % composition by mass = $\frac{mass..of..part}{mass..of..whole}$ X 100 %

$\frac{1.5g(water)}{5.0g(hydrate)}$ = .3 X 100% = **30%**

List the steps you would perform to determine the % composition by mass of water in a hydrate. (use complete sentances.)