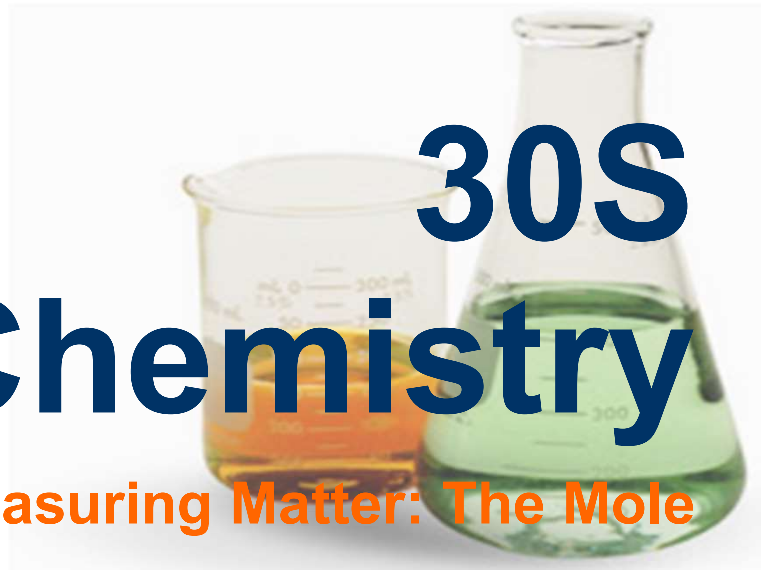
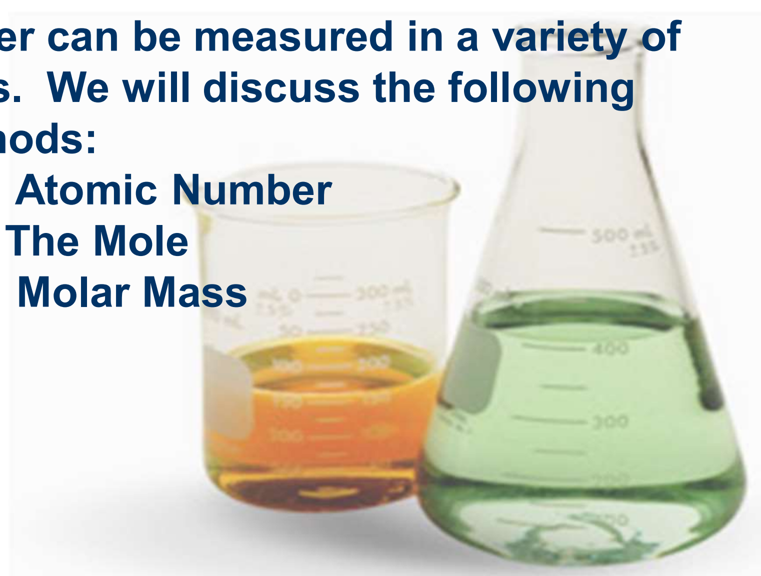


# 30S Chemistry

## Measuring Matter: The Mole



## Measuring Matter: The Mole

Matter can be measured in a variety of ways. We will discuss the following methods:

1) Atomic Number
2) The Mole
3) Molar Mass

## Atomic Number:

- The number used to arrange elements in order in the periodic table.
- It equals the number of protons in the nucleus of an atom of that element.
- There are no units included with atomic numbers.
- No two elements can have the same atomic number.

## Practice:

Using your periodic table, find and record the atomic numbers of the following elements:

Li, Pb, Cs, Fe, O, Hg, Cl

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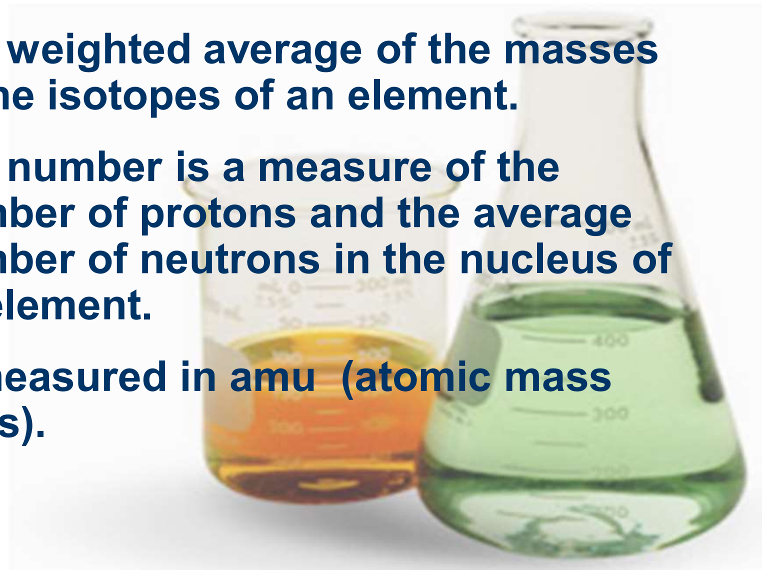
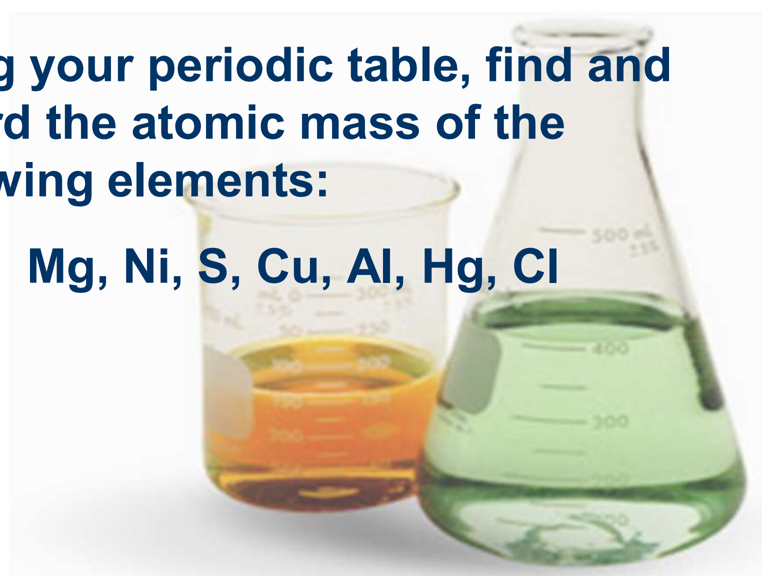
Li, Pb, Cs, Fe, O, Hg, Cl

## Atomic Mass:



- The weighted average of the masses of the isotopes of an element.
- The number is a measure of the number of protons and the average number of neutrons in the nucleus of an element.
- Is measured in amu (atomic mass units).

## Practice:



Using your periodic table, find and record the atomic mass of the following elements:

Mg, Ni, S, Cu, Al, Hg, Cl

- The molar mass of any 2 elements contain the same number of atoms.

Ex: Carbon and Oxygen

12.01 grams of C contains the same number of atoms as 16.00 grams of O.

## Molar Mass:

- The molar mass is the mass of 1 mole of atoms of a monoatomic element.

Ex: Magnesium (Mg) MM = 24.3 g

24.31 g Mg = 1 mol Mg = 24.31 g/mol

= $6.02 \times 10^{23}$ atoms Mg

24.31 amu = atomic mass

## Practice:

- Find the molar mass for each of the following:

a) Na b) As c) U

**Solution:**

a) 22.99 g/mol b) 74.92 g/mol c) 238.03 g/mol

## The Molar Mass:

- The mass of one mole of a molecular compound expressed in grams.

Ex: 1 mol $SO_3$ = 1 S + 3 O

= 32.06 g/mol + 3(16.00 g/mol)

= 80.06 g/mol

- **Two methods can be used to calculate the Molar Mass:**

**1) Use the atomic mass:**

$H_2O_2$ = 2(1.01 g/mol) + 2(16.00g/mol) = 34.02 g/mol

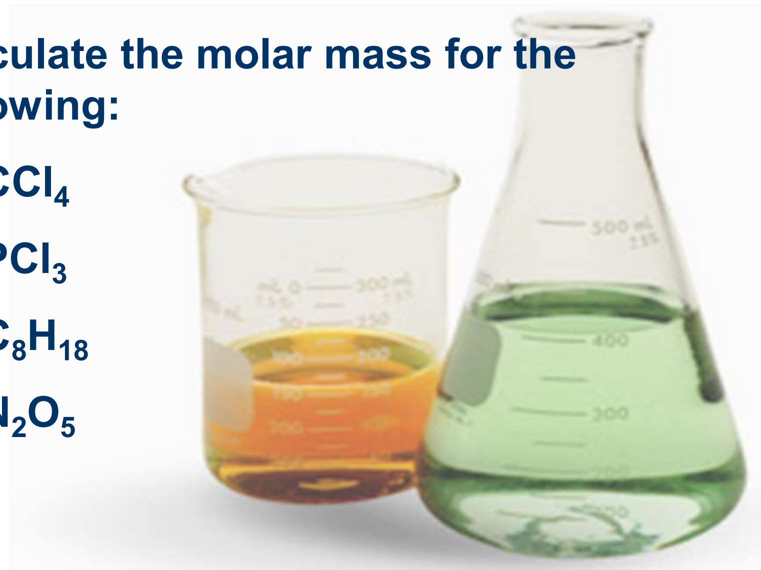
**2) Use conversion factors and atomic mass:**

$$2\text{ mol H} \times \frac{1.01\text{ g H}}{1\text{ mol H}} = 2.02\text{ g H}$$

$$2\text{ mol O} \times \frac{16.00\text{ g O}}{1\text{ mol O}} = 32.00\text{ g O}$$

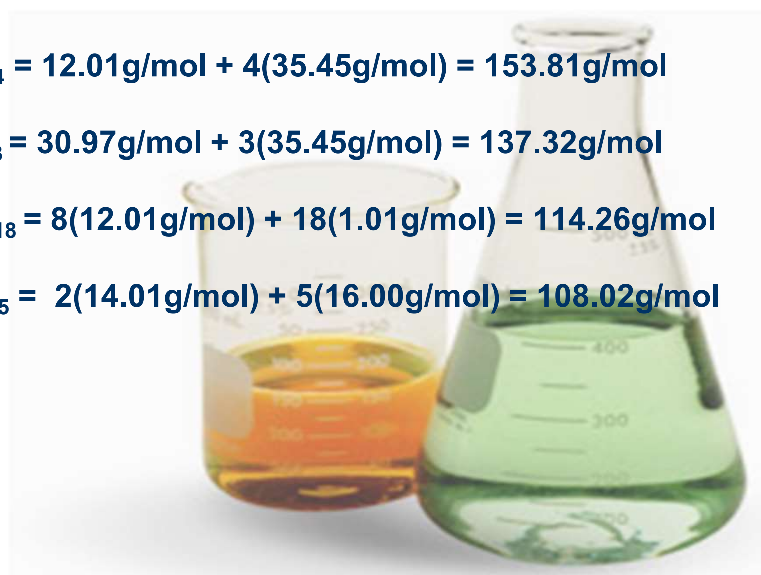
2.02 g + 32.00 g = 34.02 g $H_2O_2$

# Practice:



- Calculate the molar mass for the following:
  1) $CCl_4$
  2) $PCl_3$
  3) $C_8H_{18}$
  4) $N_2O_5$

# Key:



1) $CCl_4$ = 12.01g/mol + 4(35.45g/mol) = 153.81g/mol
2) $PCl_3$ = 30.97g/mol + 3(35.45g/mol) = 137.32g/mol
3) $C_8H_{18}$ = 8(12.01g/mol) + 18(1.01g/mol) = 114.26g/mol
4) $N_2O_5$ = 2(14.01g/mol) + 5(16.00g/mol) = 108.02g/mol

## Molar Mass:

- The mass of one mole of an ionic compound expressed in grams.
- It is calculated using the same process as gram molecular mass.

**Example:**

$SrCl_2$ = 87.62g/mol + 2(35.45g/mol ) = 158.52g/mol

## Practice:

- Calculate the molar mass for the following compounds:

1) $Na_2CO_3$
2) $Al_2(SO_4)_3$
3) $Ca(CN)_2$

## Key:

1) $Na_2CO_3$ = 2(22.99g/mol ) + 12.01g/mol + 3(16.00g/mol ) = 105.99g/mol
2) $Al_2(SO_4)_3$ = 2(26.98g/mol ) + 3(32.06 g/mol ) + 12(16.00g/mol ) = 342.14g/mol
3) $Ca(CN)_2$ = 40.08g/mol + 2(12.01g/mol) + 2(14.01g/mol) = 92.12g/mol

## The Mole:

- The standard method in Chemistry for communicating “how much” of a substance is present.
- One mole contains 6.02 x $10^{23}$ entities (objects)

## IUPAC Definition:

- The mole is the amount of a substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, etc.

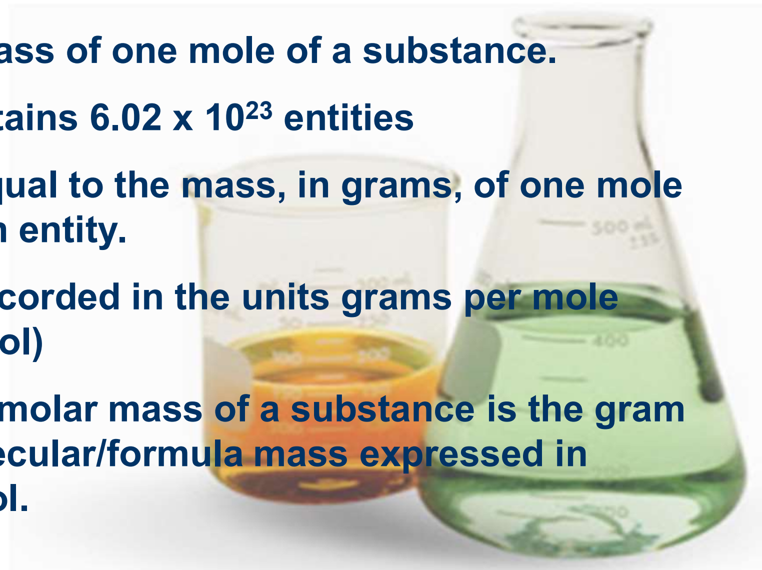
## Avagadro’s Number:

- The number of representative particles contained in one mole of a substance; equal to $6.02 \times 10^{23}$ representative particles.
- Named in honour of Amedeo Avagadro di Quarenga (1776-1856), an Italian scientist. His work made the calculation of this number possible.

## Molar Mass:

The mass of one mole of a substance.

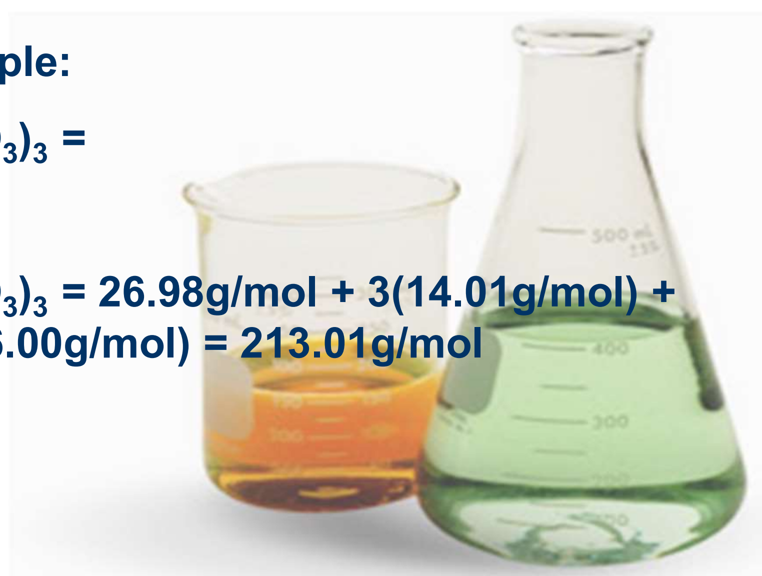
- Contains $6.02 \times 10^{23}$ entities
- Is equal to the mass, in grams, of one mole of an entity.
- Is recorded in the units grams per mole (g/mol)
- The molar mass of a substance is the gram molecular/formula mass expressed in g/mol.

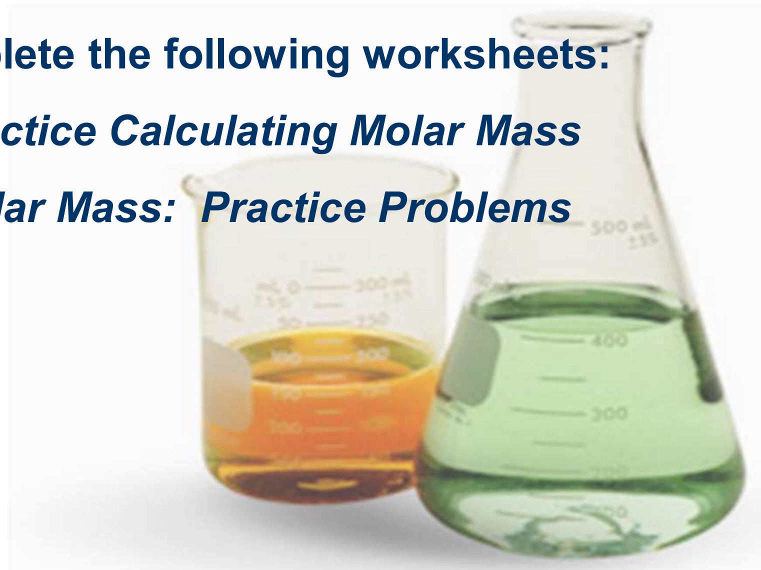


**Example:**

$Al(NO_3)_3$ =

$Al(NO_3)_3$ = 26.98g/mol + 3(14.01g/mol) + 9(16.00g/mol) = 213.01g/mol

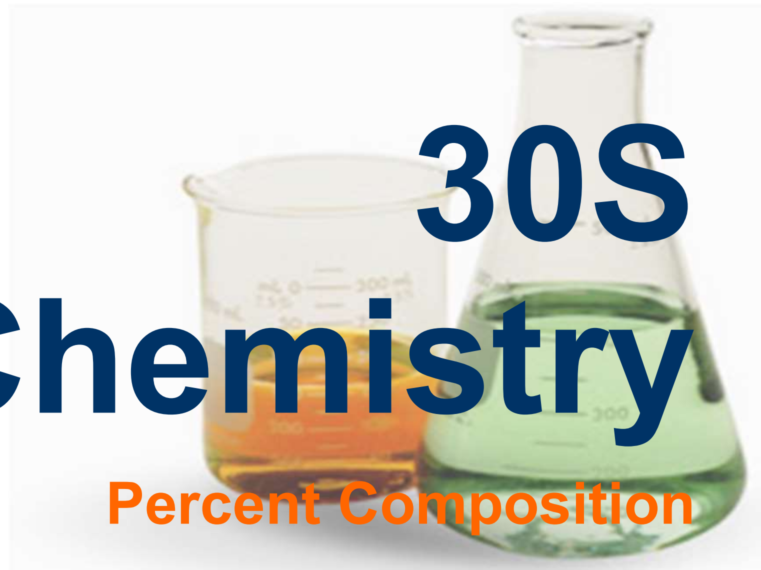




## Assignment:

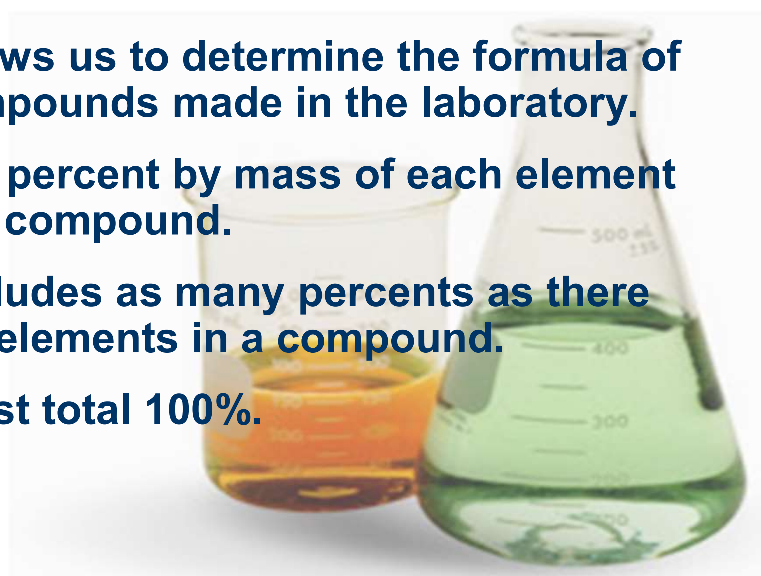
**Complete the following worksheets:**

- ✓ ***Practice Calculating Molar Mass***
- ✓ ***Molar Mass: Practice Problems***



# 30S Chemistry

## Percent Composition



## Percent Composition:

- Allows us to determine the formula of compounds made in the laboratory.
- The percent by mass of each element in a compound.
- Includes as many percents as there are elements in a compound.
- Must total 100%.

**Example:**

$K_2CrO_4$ is 40.3% K, 26.8% Cr, and 32.9% O

- The percent by mass of an element in a compound is the number of grams of the element divided by the grams of the compound, multiplied by 100%.

$$\% \text{ mass} = \frac{\text{grams of element}}{\text{grams of compound}} \times 100$$

- The mass of each element in the compound must be known to calculate percent composition.

## Example:

- An 8.20g piece of magnesium combines with 5.40g of oxygen to form a compound. What is the percent composition of this compound?

8.20g + 5.40g = 13.60g

$$\% \text{ Mg} = \frac{\text{mass of Mg}}{\text{mass of compound}} \times 100\% = \frac{8.20\text{g}}{13.60\text{g}} \times 100 = 60.3\%$$

$$\% \text{ O} = \frac{\text{mass of O}}{\text{mass of compound}} \times 100\% = \frac{5.40\text{g}}{13.60\text{g}} \times 100 = 39.7\%$$

Check: 60.3% + 39.7% = 100%

- To calculate the percent composition of a known compound, use the chemical formula to calculate the molar mass. This gives us the mass of 1 mole of the compound.
- For each element, calculate the percent by mass in one mole of the compound.

- **To calculate the percent by mass, divide the mass of the element in one mole by the Molar Mass and multiply by 100%.**

**% mass = $\frac{\text{g of element in 1 mol of compound}}{\text{Molar Mass of compound}}$ x 100**

**OR**

**% mass = $\frac{\text{Molar Mass of element}}{\text{Molar Mass of compound}}$ x 100**

## Example:

**Calculate the percent composition of ethane, $C_2H_6$.**

**Solution:**

**$C_2H_6$ = 2(12.01g/mol) + 6(1.01g/mol) = 30.08 g/mol**

**% C = $\frac{\text{grams of C}}{\text{MM of } C_2H_6}$ x 100% = $\frac{24.02\text{g}}{30.08\text{g}}$ x 100 = 79.82 %**

**% H = $\frac{\text{grams of H}}{\text{MM of } C_2H_6}$ x 100% = $\frac{6(1.01\text{g})}{30.08\text{g}}$ x 100 = 20.2 %**

**Check: 79.8% + 20.2% = 100%**

- Percent composition can be used to calculate  the number of grams of an element in a specific amount of a compound.
- The mass of the compound is multiplied by a conversion factor that is based on the percent composition

## Example:

Calculate the amount of carbon in 82g of ethane, $C_2H_6$.

% composition of C in $C_2H_6$ = 79.8%

Assume 100g of substance: 79.8% = 79.8g

$$82.0\text{g } C_2H_6 \times \frac{79.8\text{g C}}{100.\text{g } C_2H_6} = 65.436 = 65.4\text{g C}$$

## Practice:

1. Calculate the percent composition of the compounds that are formed from these reactions.

a) 29.0g Ag combines completely with 4.30g S.

b) 9.03g Mg combines completely with 3.48g N.

c) 222.6g Na combines completely with 77.4g O.

## Key:

1. a) 87.1% Ag, 12.9% S

   b) 72.2% Mg, 27.8% N

   c) 74.2% Na, 25.8% O

## Practice:

2. Calculate the % composition of each of these compounds.
   a) Propane, $C_3H_8$
   b) sodium bisulfate, $NaHSO_4$
   c) calcium acetate, $Ca(C_2H_3O_2)_2$
   d) hydrogen cyanide, HCN

## Key:

2. a) 81.8% C, 18.2% H,
   b) 19.2% Na, 0.83% H, 26.7% S, 53.3% O
   c) 25.4% Ca, 30.4% C, 3.8% H, 40.5% O
   d) 3.7% H, 44.4% C, 51.9% N

## Practice:

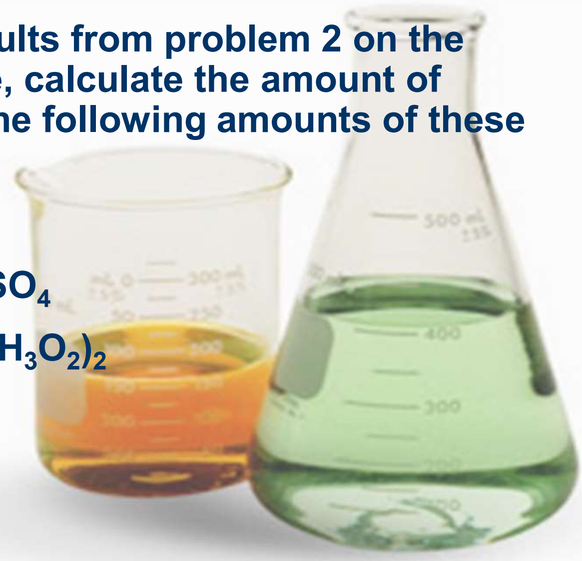
3. Using the results from problem 2 on the previous slide, calculate the amount of hydrogen in the following amounts of these compounds.

   a) 350.g $C_3H_8$

   b) 20.2g $NaHSO_4$

   c) 124g $Ca(C_2H_3O_2)_2$

   d) 378g HCN



## Key:

3. a) 63.7g H

   b) 0.17g H

   c) 4.71g H

   d) 14.0g H

## Empirical Formulas:

- The empirical formula gives the lowest whole-number ratio of the elements in a compound.  It is the lowest whole number ratio of moles of atoms in a compound.
- The  empirical formula of a compound can be calculated from the percent composition data. It may or may not be the same as the molecular formula.

## Examples:

- Carbon dioxide:

  Empirical and molecular formula are $CO_2$.
- Dinitrogen tetrahydride:

  Empirical formula $NH_2$
  Molecular formula $N_2H_4$

## Example:

- A formula can be interpreted on a microscopic level (atoms) or on a macroscopic level (moles of atoms).

Example:

- What is the empirical formula of a compound that is 25.9% N and 74.1% O?

## Solution:

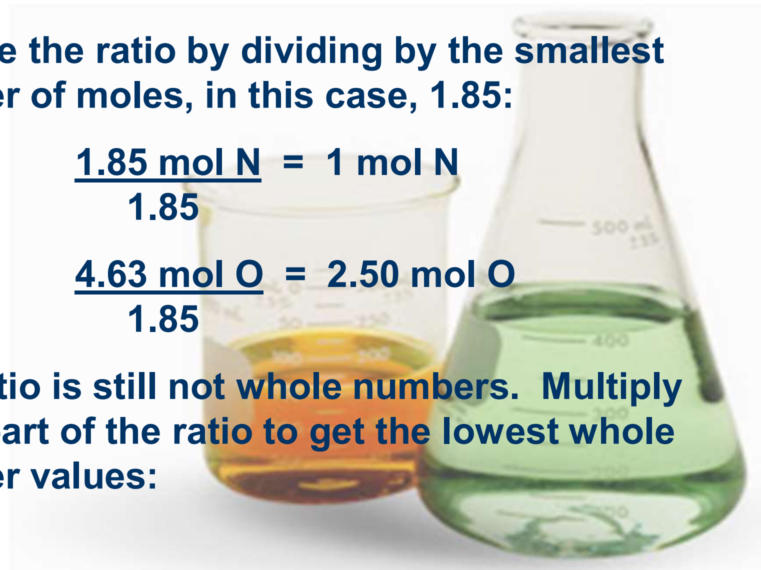
Assume 100g of compound:

Find % composition of 1 mol of each element:

$$25.9\cancel{g}\,N \times \frac{1.00\text{ mol N}}{14.01\cancel{g}\,N} = 1.85\text{ mol N}$$

$$74.1\cancel{g}\,O \times \frac{1.00\text{ mol O}}{16.00\cancel{g}\,O} = 4.63\text{ mol O}$$

The ratio $N_{1.85}O_{4.63}$ is not a simple whole number ratio.

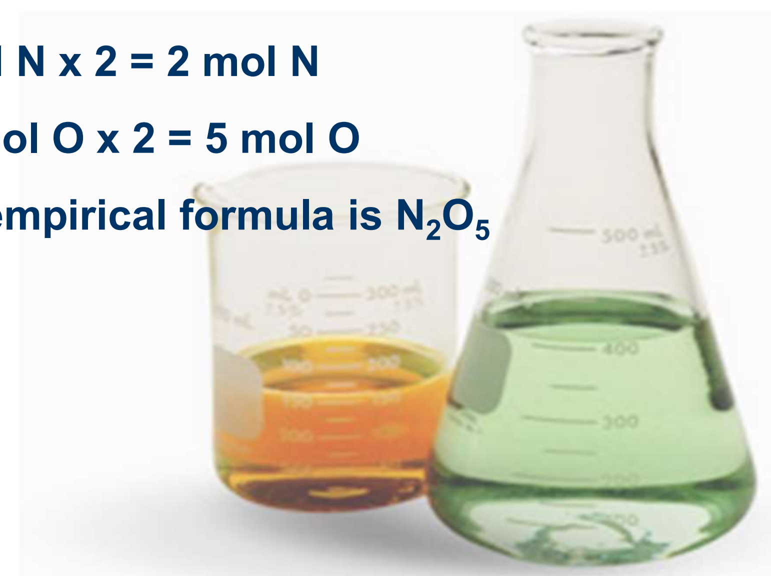


Reduce the ratio by dividing by the smallest number of moles, in this case, 1.85:

$$\frac{1.85 \text{ mol N}}{1.85} = 1 \text{ mol N}$$

$$\frac{4.63 \text{ mol O}}{1.85} = 2.50 \text{ mol O}$$

The ratio is still not whole numbers. Multiply each part of the ratio to get the lowest whole number values:



1 mol N x 2 = 2 mol N

2.5 mol O x 2 = 5 mol O

The empirical formula is $N_2O_5$

## Practice:

- Calculate the empirical formula of each compound with the following percent compositions:

1. 79.8% C, 20.2% H
2. 67.6% Hg, 10.8% S, 21.6% O
3. 94.1% O, 5.9% H
4. 17.6% Na, 39.7% Cr, 42.7% O
5. 27.59% C, 1.15% H, 16.09% N, 55.17% O

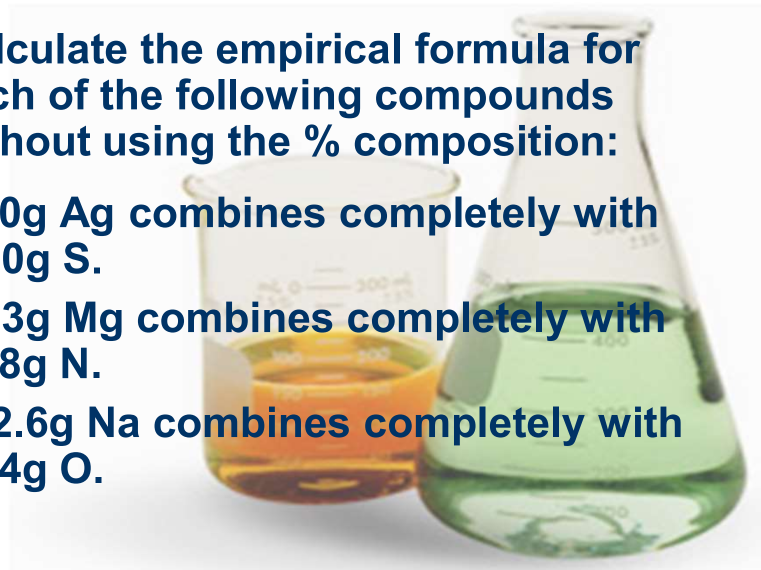
## Key:

1. $CH_3$
2. $HgSO_4$
3. $OH$
4. $Na_2Cr_2O_7$
5. $C_2HNO_3$

## Practice:

- Calculate the empirical formula for each of the following compounds without using the % composition:

6. 29.0g Ag combines completely with 4.30g S.
7. 9.03g Mg combines completely with 3.48g N.
8. 222.6g Na combines completely with 77.4g O.



## Key:

1. $Ag_2S$
2. $Mg_3N_2$
3. $Na_2O$

## Calculating Molecular Formula:

The molecular formula of a compound will either be the same as its experimentally determined empirical formula or it will be a simple whole number multiple of it.

Consider the following table:

| Formula (Name) | Classification | Molar Mass |
|---|---|---|
| CH | Empirical | 13g/mol |
| $C_2H_2$ (acetylene) | Molecular | 26g/mol (2x13) |
| $C_6H_6$ (benzene) | Molecular | 78g/mol (6x13) |

- The molecular formula of a compound can be found if we know the molar mass and its empirical formula.

The following steps are followed:

1. The empirical formula can be used to calculate the empirical formula mass (efm). (This is simply the molar mass of the empirical formula.)

   CH (empirical formula) 12.01g/mol + 1.01g/mol = 13.02g/mol

2. Divide the molar mass by the efm. This gives the number of empirical formula units in a molecule of the compounds

CH (empirical formula) 26.04g/mol

$$\text{efu} = \frac{\text{MM}}{\text{efm}} = \frac{26.04}{13.02} = 2$$

3. Multiply each element by the empirical formula unit: C x 2, H x 2

The molecular formula is $C_2H_2$

Practice:

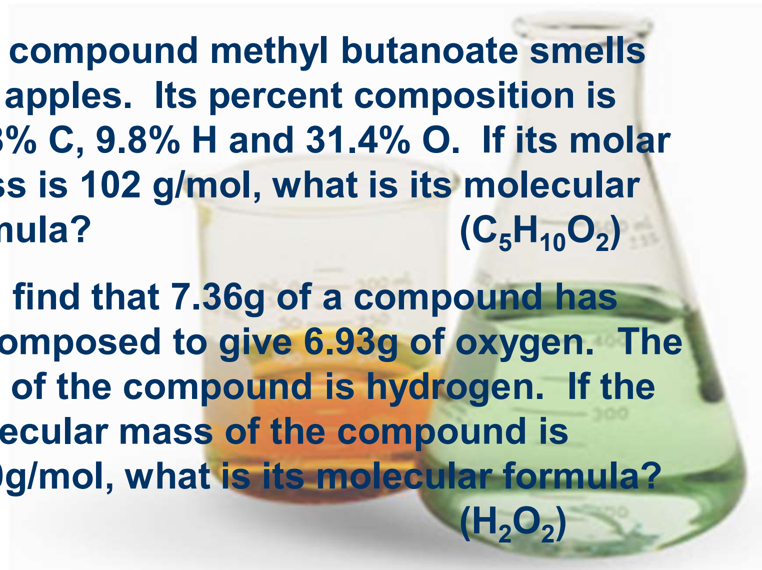
Calculate the molecular formulas of the following compounds:

| Molar Mass | Empirical Formula |
|---|---|
| 60.0g | $CH_4N$ |
| 88.04g | $N_2O$ |
| 181.5g | $C_2HCl$ |

**Key:**

1. $C_2H_8N_2$
2. $N_4O_2$
3. $C_6H_3Cl_3$

# Problems:



1. The compound methyl butanoate smells like apples. Its percent composition is 58.8% C, 9.8% H and 31.4% O. If its molar mass is 102 g/mol, what is its molecular formula? ($C_5H_{10}O_2$)
2. You find that 7.36g of a compound has decomposed to give 6.93g of oxygen. The rest of the compound is hydrogen. If the molecular mass of the compound is 34.0g/mol, what is its molecular formula? ($H_2O_2$)