Chapter 10 – Chemical Quantities

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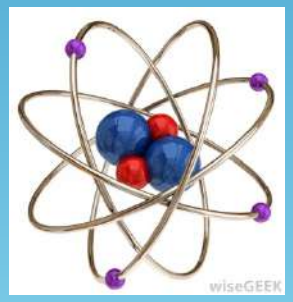
Section 10.1 – The Mole: A Measurement of Matter

- You often measure the amount of something by count, by mass, or by volume.
- A mole (mol) of a substance is 6.02×10^{23} representative particles of that substance.
- 6.02×10^{23} is called Avogadro's number.

1 mole = 6.02×10^{23} representative particles

Representative Particles

- A representative particle refers to the species present in a substance: usually atoms, molecules, or ions.
- Elements normally exist as atoms, but 7 elements exist as diatomic molecules: H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2.



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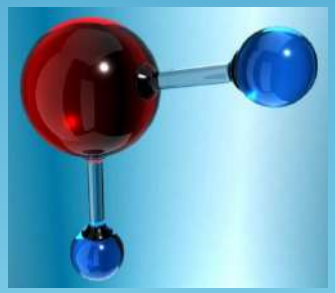
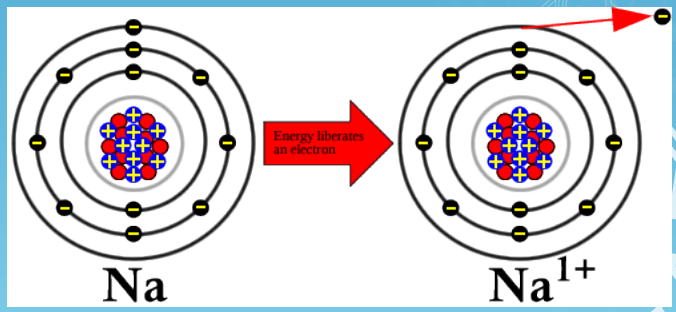


H_2O



Na^+

Sample Problem

- How many moles is 2.80×10^{24} atoms of silicon?

4.65 mol Si

Practice Problems

- How many moles is 2.17×10^{23} representative particles of bromine?

0.360 mole Br_2

- How many molecules are in 2.12 mol of propane? (m/c = molecules)

1.28×10^{24} m/c C_3H_8

Sample Problem

- How many atoms are in 1.14 mol SO_3?

2.75×10^{24} atoms

Practice Problems

- How many moles are in 4.65×10^{24} molecules of NO_2?

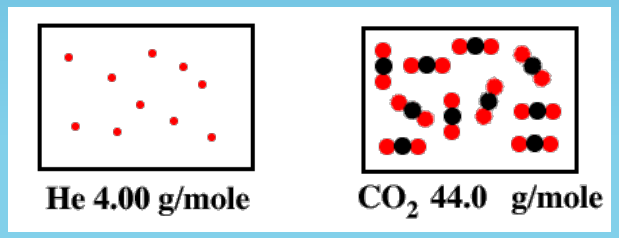
7.72 mol NO_2

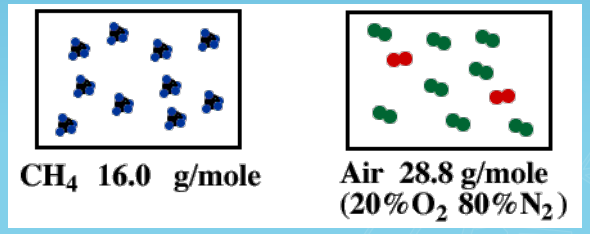
- How many atoms are in 4.33 mol magnesium sulfate?

1.564×10^{25} atoms

Molar Mass

- The atomic mass of an element expressed in grams is the mass of a mole of the element.
- The mass of a mole of an element is the molar mass.
- To calculate the molar mass of a compound, find the number of grams of each element in one mole of the compound. Then add the masses of the elements in the compound.





Sample Problem

- What is the molar mass of PCl_3?

137.5 g/mol

Practice Problems

- What is the molar mass of sodium hydrogen carbonate?

84 g/mol

- What is the mass of calcium nitrate?

164 g/mol

Section 10.1 Assessment

1. Describe the relationship between Avogadro's number and one mole of any substance.
2. How can you calculate the mass of a mole of a compound?
3. How many moles is 1.50×10^{23} molecules of NH_3?

   0.249 mol NH_3
4. How many atoms are in 1.75 mol of $CHCl_3$?

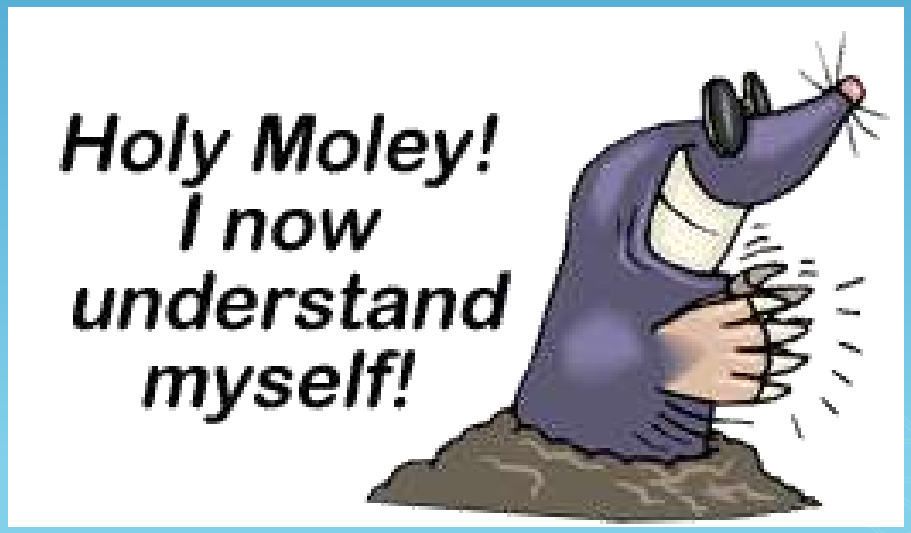
   5.27×10^{24} atoms
5. What is the molar mass of $CaSO_4$?

   136.2 g/mol

Section 10.2 – Mole-Mass and Mole-Volume Relationships

- You can use the molar mass of a substance as a conversion factor to convert between moles and mass.

1 mole = molar mass



Sample Problem

- What is the mass of 9.45 mol of alumiunum oxide?

964 g Al_2O_3

Practice Problems

- Find the mass, in grams, of 4.52×10^{-3} mol $C_{20}H_{42}$.

1.27g $C_{20}H_{42}$

- Calculate the mass of 2.50 mol of iron (II) hydroxide.

225g $Fe(OH)_2$

- Calculate the number of moles in 75.0g of dinitrogen trioxide.

0.987 mol N_2O_3

Volume

- Avogadro's hypothesis states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.
- At STP, 1 mole of any gas occupies a volume of 22.4L.
- STP = standard temperature (0°C) and pressure (1 atm)

Volume

- The volume of a gas changes with temperature and pressure, so 22.4L can only be used if the gas is at STP.

1 mol = 22.4L

Sample Problem

- Determine the volume, in liters, of 0.60 mol of SO_2 gas at STP.

13L SO_2

Practice Problems

- What is the volume of 3.70 mol N_2 at STP?

82.9L N_2

- How many moles is in 127L of CO_2 at STP?

5.67 mol CO_2

Mole Conversion Factors

- Now you have 3 conversion factors for moles:
- 1 mol = 6.02×10^{23} r.p. (for atoms, m/c, or ions)
- 1 mol = molar mass (for grams or mass)
- 1 mol = 22.4L (for liters or volume)

Section 10.2 Assessment

1. What is the volume of one mole of any gas at STP?
2. How many grams are in 5.66 mol of calcium carbonate? **567g $CaCO_3$**
3. Find the number of moles in 508g of ethanol (C_2H_5OH). **11 mol C_2H_5OH**
4. Calculate the volume, in liters, of 1.50 mol chlorine at STP. **33.6L Cl_2**

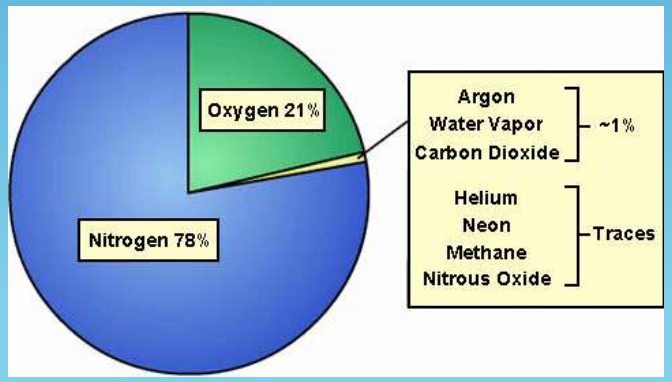
Section 10.2 Assessment

5. Three balloons filled with 3 different gaseous compounds each have a volume of 22.4L at STP. Would these balloons have the same mass or contain the same number of molecules? Explain.

Section 10.3 – Percent Composition and Chemical Formulas

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

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



Sample Problem

- When a 13.60g sample of a compound containing only magnesium and oxygen is decomposed, 5.40g of oxygen is obtained. What is the percent composition of this compound?

Mg = 60.3%
O = 39.7%

Practice Problems

- A compound formed when 9.03g Mg combines completely with 3.48g N. What is the percent composition of this compound?

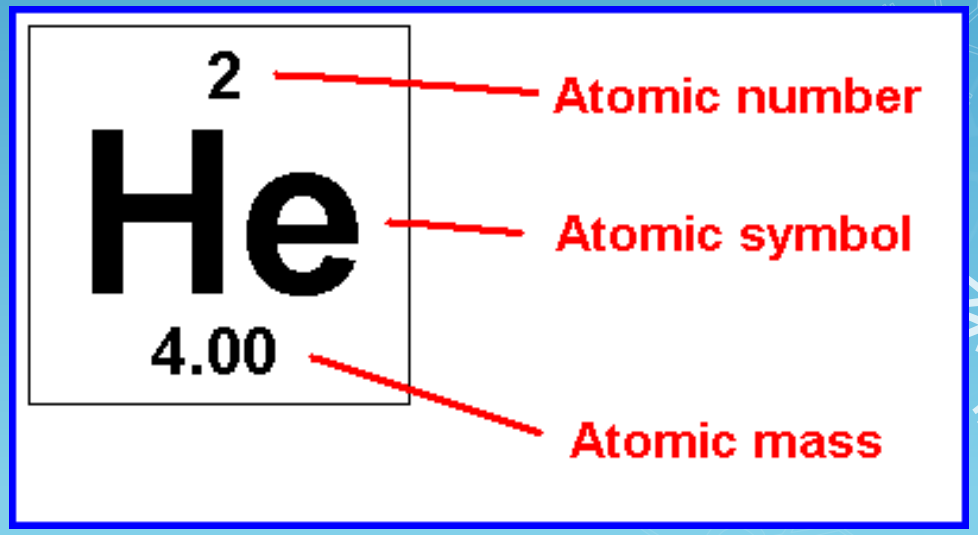
Mg = 72.2%, N = 27.8%

- When a 14.2g sample of mercury (II) oxide is decomposed into its elements by heating, 13.2g of Hg is obtained. What is the percent composition of this compound?

Hg = 93%, O = 7%

Percent Composition

- If a percent composition problem does not give you the exact masses of the elements, then you can use the molar masses instead.
- Use the same formula for percent composition.



Sample Problem

- Calculate the percent composition of propane (C_3H_8).

C = 81.8%
H = 18%

Practice Problems

- Calculate the percent composition of sodium hydrogen sulfate.

Na = 19.2%, H = 0.83%, S = 26.7%, O = 53.3%

- Calculate the percent composition of NITROGEN in ammonium nitrate.

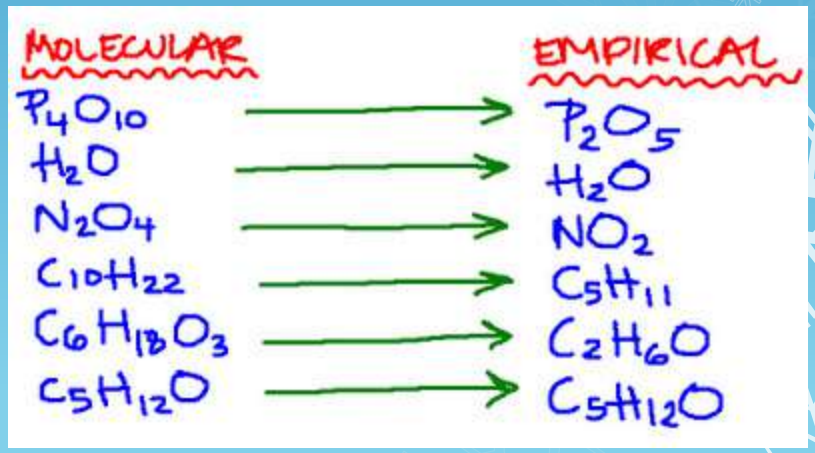
N = 35%N

Chemical Formulas

- The molecular formula is the actual formula for a molecular compound. It contains the actual number of each type of atom.
- The empirical formula is the lowest whole-number ratio of atoms in a molecular compound.

$C_6H_{12}O_6$ → CH_2O

m.f. e.f.



Empirical Formula

- Sometimes the empirical formula is the same as the molecular formula. Ex: H_2O
- To calculate the empirical formula, you follow 3 steps:

1. Change % to grams.
2. Convert grams to moles.
3. Divide each number by the smallest answer.

Sample Problem

- Calculate the empirical formula for a compound that is 67.6% Hg, 10.8% S, and 21.6% O.

$HgSO_4$

Practice Problems

- Calculate the empirical formula for the following:
- 94.1% O and 5.9% H

OH

- 62.1% C, 13.8% H, and 24.1% N

C_3H_8N

Empirical Formula

- After step 3, you should get whole numbers that can be used as the subscripts.
- Sometimes you will get a number that ends in .5 or .33. Do NOT round these numbers.
- For .5, multiply all answers by 2.
- For .33, multiply all answers by 3.

Sample Problem

- A compound is analyzed and found to contain 25.9% nitrogen and 74.1% oxygen. What is the empirical formula of the compound?

N_2O_5

Practice Problem

- Determine the empirical formula for a compound that is 50.7% C, 4.2% H, and 45.1% O.

$C_3H_3O_2$

Molecular Formula

- An empirical and molecular formula differ by a whole-number multiple, so their masses also differ by the same whole-number multiple.

MOLECULAR	EMPIRICAL
P_4O_{10}	P_2O_5
$C_{10}H_{22}$	C_5H_{11}
$C_6H_{18}O_3$	C_3H_6O
$C_5H_{12}O$	$C_5H_{12}O$
N_2O_4	NO_2

m.f. e.f.

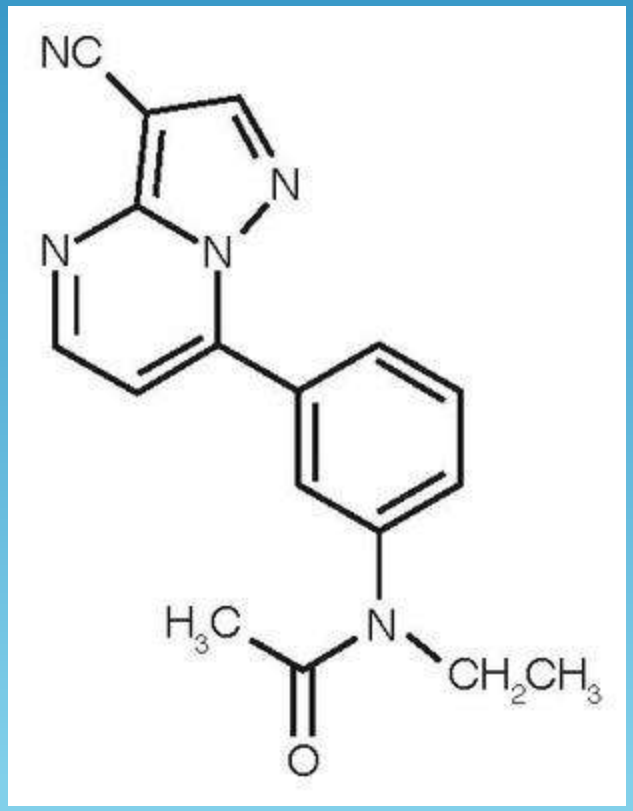
$C_6H_{12}O_6 \rightarrow CH_2O$

180 g/mol → 30 g/mol

Multiplier = 6

Molecular Formula

Whole-number multiplier = $\frac{\text{mass of m.f.}}{\text{mass of e.f.}}$



Sample Problem

- Calculate the molecular formula of a compound whose molar mass is 60g/mol and empirical formula is CH_4N.

$C_2H_8N_2$

Practice Problems

- Find the molecular formula for antifreeze with a molar mass of 62 g/mol and an empirical formula of CH_3O.

$C_2H_6O_2$

- What is the molecular formula for a compound with a molar mass of 90 g/mol and an empirical formula of CH_2O?

$C_3H_6O_3$

Section 10.3 Assessment

1. How do you calculate the percent by mass of an element in a compound?
2. What information can you obtain from an empirical formula?
3. How is the molecular formula of a compound related to its empirical formula?
4. Calculate the percent composition of calcium acetate.

Ca = 25.4%, C = 30.4%, H = 3.8%, O = 40.5%

Section 10.3 Assessment

5. The compound methyl butanoate has a percent composition of 58.8% C, 9.8% H, and 31.4% O and its molar mass is 102 g/mol. What is its empirical and molecular formula?

e.f. = $C_5H_{10}O_2$ m.f. = $C_5H_{10}O_2$

6. Which of the following molecular formulas are also empirical formulas?

a. $C_5H_{10}O_5$

b. $C_6H_{12}O_2$

c. $C_{55}H_{72}MgN_4O_5$

d. $C_{12}H_{17}ON$

THE END