

## Chem. Ch. 12 Notes, part 1 ~ CHEMICAL QUANTITIES

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics*.

- I. Counting Particles of Matter: Moles  
A. SI unit of chemical quantity = the **mole** (abbreviated *mol*)  
B. The **mole** is a counting unit

**1 MOLE =  $6.02 \times 10^{23}$  representative particles**  
(representative particles (r.p.) = ATOMS, IONS, MOLECULES, & FORMULA UNITS)

<b><math>6.02 \times 10^{23}</math> atoms = 1 mol atoms</b>	<b><math>6.02 \times 10^{23}</math> molecules = 1 mol molecules</b>
<b><math>6.02 \times 10^{23}</math> ions = 1 mol ions</b>	<b><math>6.02 \times 10^{23}</math> formula units = 1 mol f.units</b>

- **atom** = one symbol, no charge: *Br, U, Cs*
- **ion** = one symbol with charge (monatomic) or more than one symbol with charge (polyatomic): *Na<sup>+</sup>, N<sup>3-</sup>, (C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sup>-</sup>*
- **molecule** = compound with all nonmetals (BM, TM): *CO, BF<sub>3</sub>, Cl<sub>2</sub>*
- **formula unit** = compound with metal and nonmetal (BI, TI): *KI, Na<sub>2</sub>SO<sub>4</sub>*

- C.  **$6.02 \times 10^{23}$  = Avogadro's number** (named after Amedeo Avogadro, 1776–1856)  
D. **stoichiometry**—using balanced chemical equations to obtain info.  
E. mole-to-r.p. and r.p.-to-mole example problems:

E1) How many moles of Ca are in  $9.00 \times 10^{16}$  atoms of Ca?

$$9.00 \times 10^{16} \text{ atoms Ca} \times \frac{1 \text{ mol Ca}}{6.02 \times 10^{23} \text{ atoms Ca}} = \boxed{1.50 \times 10^{-7} \text{ mol Ca}}$$

E2) How many moles of sulfide ions are in  $4.14 \times 10^{30}$  ions of S<sup>2-</sup>?

$$4.14 \times 10^{30} \text{ ions S}^{2-} \times \frac{1 \text{ mol S}}{6.02 \times 10^{23} \text{ ions S}^{2-}} = \boxed{6.88 \times 10^6 \text{ mol S}^{2-}}$$

E3) How many molecules are in 0.0221 mol O<sub>2</sub>?

$$0.0221 \text{ mol O}_2 \times \frac{6.02 \times 10^{23} \text{ molecules O}_2}{1 \text{ mol O}_2} = \boxed{1.33 \times 10^{22} \text{ molecules O}_2}$$

- F. Finding the number of atoms in a compound—look at the subscripts  
example problems:

E4) How many hydrogen atoms are in 0.89 mol water?

$$0.89 \text{ mol H}_2\text{O} \times \frac{6.02 \times 10^{23} \text{ molecules H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \times \frac{2 \text{ H atoms}}{1 \text{ molecule H}_2\text{O}} = \boxed{1.1 \times 10^{24} \text{ H atoms}}$$

E5) How many Na<sup>+</sup> ions are found in 0.129 mol of Na<sub>3</sub>PO<sub>4</sub>?

$$0.129 \text{ mol Na}_3\text{PO}_4 \times \frac{6.02 \times 10^{23} \text{ f.units}}{1 \text{ mol Na}_3\text{PO}_4} \times \frac{3 \text{ Na}^+ \text{ ions}}{1 \text{ f. unit Na}_3\text{PO}_4} = \boxed{2.33 \times 10^{23} \text{ Na}^+ \text{ ions}}$$

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## II. Molar Masses of Elements and Compounds

Remember, the atomic masses on the periodic table (decimal numbers) have a unit of **atomic mass unit** (amu, or u).

- A. **GAM = gram atomic mass**

1) *the atomic mass (listed on the periodic table) written in grams*

$$1 \text{ atom Xe} = 131.30 \text{ u} \quad \& \quad 1 \text{ mol Xe} = 131.30 \text{ g} \quad \& \quad \text{GAM of Xe} = 131.301 \text{ g}$$

2) *these numbers are usually rounded to 0.1 (tenths)*

B. **GMM = gram molecular mass**

1) *the sum of all masses of atoms in a molecular compound*

$$1 \text{ molecule Cl}_2 = 70.9 \text{ u} \quad \& \quad 1 \text{ mol Cl}_2 = 70.9 \text{ g} \quad \& \quad \text{GMM Cl}_2 = 70.9 \text{ g}$$

2) example:

E6) Find the GMM of methane, CH<sub>4</sub>.

$$\text{CH}_4 = 1(12.0) + 4(1.0) = 12.0 + 4.0 = \boxed{16.0 \text{ g}}$$

C. **GFM = gram formula mass**

1) *the mass of one mole of ionic compound*

$$1 \text{ f.unit NaCl} = 58.4 \text{ amu} \quad \& \quad 1 \text{ mol NaCl} = 58.4 \text{ g} \quad \& \quad \text{GFM NaCl} = 58.4 \text{ g}$$

2) example:

E7) Find the GFM of calcium hydroxide, Ca(OH)<sub>2</sub>.

$$\text{Ca(OH)}_2 = 1(40.1) + 2(16.0) + 2(1.0) = \boxed{74.1 \text{ g}}$$

D. **molar mass**—*the mass, in g, of 1 mole of a substance*

- molar mass is a general term for doing GAM, GMM, or GFM

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III. Mole-to-Mass and Mass-to-Mole Conversions (dimensional analysis)

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$$\text{grams A} \times \frac{1 \text{ mol A}}{\text{MOLAR MASS (g) A}} = \boxed{\text{mol A}} \quad \text{mol B} \times \frac{\text{MOLAR MASS (g) B}}{1 \text{ mol B}} = \boxed{\text{grams B}}$$

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examples:

E8) How many grams are in 3.50 mol CO<sub>2</sub>?

$$3.50 \text{ mol CO}_2 \times \frac{[1(12.0) + 2(16.0)] \text{ g CO}_2}{1 \text{ mol CO}_2} = 3.50 \text{ mol CO}_2 \times \frac{44.0 \text{ g CO}_2}{1 \text{ mol CO}_2} = \boxed{154 \text{ g CO}_2}$$

E9) How many moles are in 150 g of NaBr?

$$150 \text{ g NaBr} \times \frac{1 \text{ mol NaBr}}{(23.0 + 79.9) \text{ g NaBr}} = \boxed{1.5 \text{ mol NaBr}}$$

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IV. Molar Volume: volume-to-mole and mole-to-volume conversions

A. **STP = standard temperature and pressure**

1) *standard temperature = 0 °C, 273 K*

2) *standard pressure = 101.3 kPa, 1 atm, 760 mm Hg, 14.7 psi*

B. At STP, all gases occupy the same amount of space:

<b>MOLAR VOLUME of any gas at STP: 22.4 L = 1 mol</b>
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C. examples

E10) What is the volume, in L, of 0.495 mol of NO<sub>2</sub> gas at STP?

$$0.495 \text{ mol NO}_2 \times \frac{22.4 \text{ L NO}_2}{1 \text{ mol NO}_2} = \boxed{11.1 \text{ L NO}_2}$$

E11) How many moles are found in 84 L of neon gas at STP?

$$84 \text{ L Ne} \times \frac{1 \text{ mol Ne}}{22.4 \text{ L Ne}} = \boxed{3.8 \text{ mol Ne}}$$

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**CONVERSION FACTOR SUMMARY:**

<u><math>6.02 \times 10^{23}</math> representative particles</u>	<u>1 MOLE</u>
1 MOLE	$6.02 \times 10^{23}$ representative particles
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<u>MOLAR MASS (g)</u>	<u>1 MOLE</u>
1 MOLE	MOLAR MASS (g)
<hr style="border: none; border-top: 1px wavy orange;"/>	
<u>22.4 L (for a gas at STP)</u>	<u>1 MOLE</u>
1 MOLE	22.4 L (for a gas at STP)

V. Mass-to-r.p. and r.p.-to-mass conversions

E12) How many grams of barium sulfide are in  $3.39 \times 10^{25}$  f.units of barium sulfide?

$$3.39 \times 10^{25} \text{ f.units BaS} \times \frac{1 \text{ mol BaS}}{6.02 \times 10^{23} \text{ f.units BaS}} \times \frac{169.4 \text{ g BaS}}{(137.3 + 32.1) \text{ g BaS}} = \boxed{9540 \text{ g BaS}}$$

E13) How many r.p. of rubidium nitrate are in 45.00 g of rubidium nitrate?

$$45.00 \text{ g RbNO}_3 \times \frac{1 \text{ mol RbNO}_3}{[85.5 + 14.0 + 3(16.0)] \text{ g RbNO}_3} \times \frac{6.02 \times 10^{23} \text{ f.units RbNO}_3}{1 \text{ mol RbNO}_3} = \boxed{1.84 \times 10^{23} \text{ f.units RbNO}_3}$$

There are many types of mole problems:

1 step:	r.p. → mol	&	mol → r.p.
	mass → mol	&	mol → mass
2 step:	mass → r.p.	&	r.p. → mass
	mass → volume	&	volume → mass (of gas at STP)
	r.p. → volume	&	volume → r.p. (of gas at STP)

VI. Gas Density and Molar Mass

- A. Density  $D = M / V$
- B. gas density usually measured in g/L
- C. use  $22.4 \text{ L} = 1 \text{ mol}$  to calculate molar masses (g/mol, the mass of 1 mole)
- D. examples

E14) The density of a gas is 3.64 g/L in STP conditions. What is its molar mass?

$$\frac{3.64 \text{ g}}{\text{L}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = \boxed{81.5 \text{ g/mol}}$$

E15) At STP, 6.00 L of a gas has a mass of 25.10 g.

Calculate the density of the gas and its molar mass.

$$D = \frac{M}{V} = \frac{25.10 \text{ g}}{6.00 \text{ L}} = \boxed{4.18 \text{ g/L}} \quad \text{MOLAR MASS} = \frac{25.10 \text{ g}}{6.00 \text{ L}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = \boxed{93.7 \text{ g/mol}}$$

VII. **Percent Composition**

- A. % by mass of each individual element in a compound
- B. remember to list all percentages
- C. double-check that the % total is 100% (or very close if rounding)
- D. formulas

$\% = \frac{\# \text{ g element}}{\# \text{ g cmpd.}} \times 100$	$\% = \frac{\text{MOLAR MASS of element}}{\text{MOLAR MASS of cmpd.}} \times 100$
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E. examples

E16) Find the % by mass of hydrogen and oxygen in water.

$$\begin{aligned} \text{MOLAR MASS H}_2\text{O} &= 2(1.0) + 1(16.0) = 18.0 \text{ g} \\ 2 \text{ H's} + 1 \text{ O} &= \text{total mass H}_2\text{O} \end{aligned}$$

$$\% \text{ H} = \frac{2.0 \text{ g}}{18.0 \text{ g}} \times 100 = \boxed{11\% \text{ H}} \quad \% \text{ O} = \frac{16.0 \text{ g}}{18.0 \text{ g}} \times 100 = \boxed{88.9\% \text{ O}}$$

E17) Calculate the % composition of sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

$$\begin{aligned} \text{MOLAR MASS H}_2\text{SO}_4 &= 2(1.0) + 32.1 + 4(16.0) = 98.1 \text{ g} \\ 2 \text{ H's} + 1 \text{ S} + 4 \text{ O's} &= \text{total mass H}_2\text{SO}_4 \end{aligned}$$

$$\% \text{ H} = \frac{2.0 \text{ g}}{98.1 \text{ g}} \times 100 = \boxed{2.0\% \text{ H}} \quad (2.04) \quad \% \text{ S} = \frac{32.1 \text{ g}}{98.1 \text{ g}} \times 100 = \boxed{32.7\% \text{ S}} \quad (32.72)$$

$$\% \text{ O} = \frac{4(16.0) \text{ g}}{98.1 \text{ g}} \times 100 = \boxed{65.2\% \text{ O}} \quad (65.24)$$