THE MOLE "n"

- The mole term is similar to the "dozen" term.
- Just as a dozen represents "12"; the mole represents 6.022 x 10^{23}. A very large amount.
- This is due to atoms & molecules being very small.

Counting Atoms by Moles

- If we can find the mass of a particular number of atoms, we can use this information to convert the mass of an element sample into the number of atoms in the sample.
- The number of atoms we will use is 6.022×10^{23} and we call this a **mole**
  - ✓ 1 mole = 6.022×10^{23} things
    - ➢ Like 1 dozen = 12 things

Twenty-two copper pennies contain approximately 1 mol of copper atoms.

Chemical Packages - Moles

- mole = number of particles equal to the number of atoms in 12 g of C-12
  - ✓ 1 atom of C-12 weighs exactly 12 amu
  - ✓ 1 mole of C-12 weighs exactly 12 g
- The number of particles in 1 mole is called **Avogadro's Number = 6.0221421 x 10^{23}**
  - ✓ 1 mole of C atoms weighs 12.01 g and has 6.022 x 10^{23} atoms
    - ➢ the average mass of a C atom is 12.01 amu

Relationship Between Moles and Mass

- The mass of one mole of atoms is called the **molar mass**
- The molar mass of an element, in grams, is numerically equal to the element's atomic mass, in amu
- The lighter the atom, the less a mole weighs
- The lighter the atom, the more atoms there are in 1 g

Mole and Mass Relationships

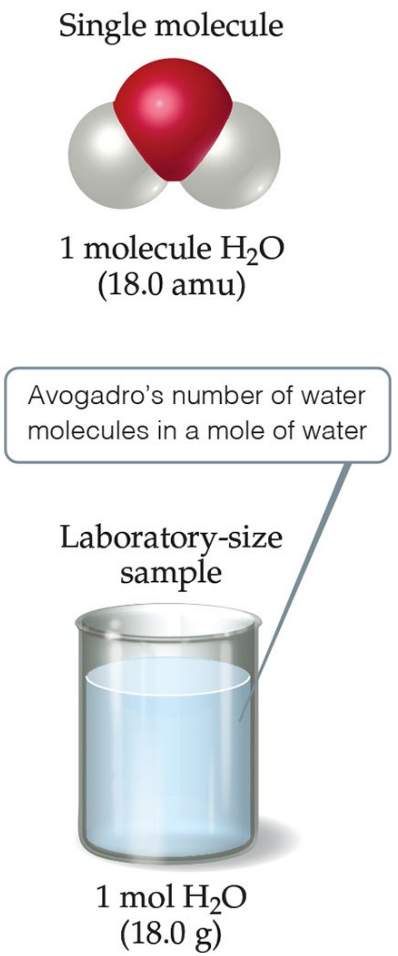
Substance	*Weight of 1 atom*	*Pieces in 1 mole*	*Weight of 1 mole*
hydrogen	1.008 amu	6.022×10^{23} atoms	1.008 g
carbon	12.01 amu	6.022×10^{23} atoms	12.01 g
oxygen	16.00 amu	6.022×10^{23} atoms	16.00 g
sulfur	32.06 amu	6.022×10^{23} atoms	32.06 g
calcium	40.08 amu	6.022×10^{23} atoms	40.08 g
chlorine	35.45 amu	6.022×10^{23} atoms	35.45 g
copper	63.55 amu	6.022×10^{23} atoms	63.55 g

1 mole
sulfur
32.06 g

1 mole
carbon
12.01 g

Avogadro's Number

- In a lab, we cannot work with individual molecules. They are too small.
- One **mole** (abbreviated: mol) is the amount of particles found in **exactly** 12 g of C-12.
- 6.022×10^{23} atoms or molecules is the number of particles in one mole.



THE MOLE & MOLAR MASS

- **The atomic or formula mass (weight) is measured in reference to the mole.**
- **The atomic/formula mass is also known as the MOLAR MASS.**
- **Molar mass = MM = m/n or mass/mole.**
- **Units for molar mass is grams per mole or g/mol.**

For example:

H = 1.008 amu

= 1.008 g/mol

= 6.022 x 10^{23} atoms

= 1 molar mass

K_2CO_3 = ?

2K + C + 3O = ?

2(39.10 g/mol) + 12.011g/mol + 3(16.00g/mol) =

138.11g/mol

Lecture quick quiz #7A on the mole

1. The molar mass of sodium is__________, of phosphorous is ___________, of oxygen is __________. What is the molar mass of sodium phosphate?

Simple MOLE Calculations $MM = {}^{m}/_{n}$

1) What mass of NH_4NO_3 contains 3.15 moles of NH_4NO_3?

MM = 2N + 4H + 3O = 80 g/mol

m = MM*n = (80g/mol)(3.15 mol)

252 g

or using dimensional analysis

3.15 mol (80 g/mol) = m

MM = 3N + 12H + P + 4O = 149 /mol

2) How many total & H - atoms are in 6.34 g of $(NH_4)_3PO_4$

$$6.34\text{ g } ({}^{1\text{ mole}}/_{149\text{ g}})\ ({}^{6.022 \times 10^{23}\text{ units}}/_{1\text{ mole}})\ ({}^{20\text{ atoms}}/_{1\text{ unit}}) =$$

5.12×10^{23} total atoms

$$6.34\text{ g } ({}^{1\text{ mole}}/_{149\text{ g}})\ ({}^{6.022 \times 10^{23}\text{ units}}/_{1\text{ mole}})\ ({}^{12\text{ atoms}}/_{1\text{ unit}}) =$$

3.07×10^{23} H - atoms

Simple MOLE Calculations

CHAT

1) How many moles of Mg are contained in 15.0 grams of Mg?

$$MM = {}^{m}/_{n}$$

$${}^{m}/_{MM} = n = 15g/24.3\ g/mol \quad \text{or}$$

$$15.0g\ ({}^{1\ mole}/_{24.3g}) = n = \ 0.617\ moles$$

2) How many atoms of Mg are contained in 15.0 grams of Mg?

$$15.0g\ ({}^{1\ mole}/_{24.3g})({}^{6.022x10^{23}\ atoms}/_{1\ mole}) = \#\ atoms$$

$$\#\ atoms = 3.72\ x\ 10^{23}\ Mg\ atoms.$$

Chapter 3

The MOLE SUMMARY

(1) Grams (mass) ↔ moles (n) use Molar mass

(2) moles (n) ↔ units (atoms, molecules, ions, etc.) use 6.022×10^{23}

(3) Percent by general definition: % = (portion / total)100

(4) Ratios can be used IF it involves LDP (compounds) – no mixtures

(5) Balancing equations and moles (coefficients)

For example: how many moles of hydrogen are available if you start with 5 moles of water?

$$2H_2O \rightarrow 2H_2 + O_2$$

Calculations involving the mole

$$\boxed{\text{Mass(g)}} \xrightarrow{\text{Molecular Mass}} \boxed{\text{MOLE}} \xrightarrow[6.022 \times 10^{23}]{\text{Avogadro's \#}} \boxed{\text{Atoms, Ions, or Molecules}}$$

What mass of sodium will contain the same number of atoms as 100.0 g of potassium?

$$100.0\text{g K} \left(\frac{1 \text{ mole K}}{39.1 \text{ g K}}\right)\left(\frac{6.022\text{x}10^{23} \text{ K-atoms}}{1 \text{ mole K}}\right) = 1.540 \text{ x } 10^{24} \text{ K-atoms.}$$

Now since atoms of K = atoms of Na

$$1.540\text{x}10^{24} \text{ atoms Na} \left(\frac{1 \text{ mol}}{6.02 \text{ x}10^{23} \text{ atoms}}\right)\left(\frac{22.98 \text{ g}}{1 \text{ mol}}\right) = \mathbf{58.77 \text{ g of Na}}$$

Calculations involving the mole

$$\text{Mass(g)} \xrightarrow{\text{Molecular Mass}} \text{MOLE} \xrightarrow[6.022 \times 10^{23}]{\text{Avogadro's \#}} \text{Atoms, Ions, or Molecules}$$

A solution of sulfuric acid contained 65% H_2SO_4 by mass and had a density of 1.56 g/mL. How many moles of acid are present in 1.00 L of the solution?

dV = m   1000 mL (1.56 g/mL) =1560 g of solution

but only 65% of the solution is H_2SO_4 therefore:
65 % = (x / 1560 g) 100 so x= mass of H_2SO_4 = 1014 g

1014 g H_2SO_4 (1 mole / 98.04 g) = 10.3 moles

GROUP QUIZ #7B on the mole conversion

2. Which has the LEAST mass:
    a) 0.19 moles of $CaCO_3$
    b) 6.12×10^{22} formula units of Fe_2O_3
    c) 1 mole of oxygen molecules
    d) 15.9 moles of hydrogen molecules
    e) 5.0 moles of helium gas

WRITING CHEMICAL EQUATIONS

Reactants (starting materials) → Products (ending materials)

(g) = gas | **(l) = liquid** | **(s) = solid**

(aq) = aqueous
(dissolved in water)

Δ = heat

→ = yields

$\xrightarrow{X}$ **= catalyst**

+ = combines

The number of molecules (moles) involved in the reaction are written in the front of the chemical formula.

CHEMICAL EQUATIONS

CHEMICAL EQUATIONS represent chemical reactions which, in turn, are driven by changes like:

Change	Observation
• formation of a precipitate	solid is formed
• formation of water	heat is formed
• formation of a gas	bubbles formed

other changes are:

Electrochemistry	electrons are transferred
Thermochemistry	heat is transferred

BALANCING CHEMICAL EQUATIONS

$$Mg + O_2 \rightarrow MgO$$

First list all atoms in order of metals, nonmetals, then "H" & "O" last. Leave the species that is split between more than one compound for last.

Mg - 1	Mg - 1
O - 2	O - 1

Next, start with the top atom; one Mg on the reactant side and one Mg atom on the product side. The Mg atom is balanced. Now do oxygen, two "O" atoms on the reactant side and one on the product side. The product side needs to change so place a "2" in front of MgO. Remember you can not change the formula.

$$Mg + O_2 \rightarrow 2\ MgO$$

This now makes the list:

Mg - 1	Mg - 2
O - 2	O - 2

If a two is placed in front of the Mg on the reactant side;

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

Mg - 2	Mg - 2
O - 2	O - 2

Now the equation is balanced.

BALANCING CHEMICAL EQUATIONS

$$2\ NaBr(aq) + Cl_2(g) \rightarrow 2\ NaCl(aq) + Br_2(l)$$

First list all atoms in order of metals, nonmetals, then "H" & "O" last. Leave the species that is split between more than one compound for last.

Na - 2	**Na – 1**
Br – 2	**Br – 2**
Cl - 2	**Cl - 1**

$$\underline{2}\ SbCl_3(aq) + \underline{3}\ Na_2S(aq) \rightarrow \underline{\quad}\ Sb_2S_3(s) + \underline{6}\ NaCl(aq)$$

Na – 6	**Na – 6**
Sb – 2	**Sb – 2**
S – 3	**S – 3**
Cl – 6	**Cl – 6**

Balance the following molecular equations

$$\_\_Mg(OH)_{2(aq)} + \_\_H_2SO_{4(aq)} \rightarrow \_\_H_2O_{(l)} + \_\_MgSO_{4(aq)}$$

$$\_\_C_2H_4(g) + \_\_O_2(g) \rightarrow \_\_CO_2(g) + \_\_H_2O(g)$$

CHEMICAL EQUATIONS

There are three basic types of chemical equations:

Molecular, Ionic, & Net ionic.

- **MOLECULAR EQUATIONS are written as if all substances were molecular, even though some substances may exist as ions.**

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$$

- **IONIC EQUATIONS have the substances which exist as ions written in ionic form.**

$$H^+_{(aq)} + \cancel{Cl^-}_{(aq)} + \cancel{Na^+}_{(aq)} + OH^-_{(aq)} \rightarrow \cancel{Na^+}_{(aq)} + \cancel{Cl^-}_{(aq)} + H_2O_{(l)}$$

- **Precipitation, Acid/base, and Redox reactions can all be written depicting the appropriate substances as ions**

- **NET IONIC EQUATIONS are ionic equations with the Spectator ions removed.**

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

- **SPECTATOR IONS do not participate in a reaction (that is they do not react to form a new substance). Common Spectator ions are Group I, many Group II, and NO_3^- (nitrate) and $C_2H_3O_2^-$ (acetate) ions.**

Write the molecular, ionic, & net ionic equations.

1. **Aqueous Ammonium hydroxide decomposes into ammonia gas and liquid water.**

$$NH_4OH_{(aq)} \rightarrow NH_{3\,(g)} + H_2O_{(l)}$$

$$NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow NH_{3\,(g)} + H_2O_{(l)}$$

Write the molecular, ionic, & net ionic equations.

2. Solid calcium carbonate reacts with hydrochloric acid to produce a gas, water, and aqueous salt.

$$CaCO_{3(aq)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$H^+_{(aq)} + \cancel{Cl^-}_{(aq)} + \cancel{Ca^{2+}}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow \cancel{Ca^{2+}}_{(aq)} + \cancel{Cl^-}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$$

Write the molecular, ionic, & net ionic equations.

3. The following two solutions are mixed; cobalt iodide & lithium sulfate, what happens?

$$CoI_{2\,(aq)} + Li_2SO_{4\,(aq)} \rightarrow ?$$

$$CoI_{2\,(aq)} + Li_2SO_{4\,(aq)} \rightarrow CoSO_{4\,(aq)} + 2\ LiI_{(aq)}$$

$$Co^{2+}{}_{(aq)} + I^{-}{}_{(aq)} + Li^{+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow Co^{2+} + SO_4{}^{2-}{}_{(aq)} + Li^{+}{}_{(aq)} + I^{-}{}_{(aq)}$$

No Reaction!

SELF-STUDY QUIZ

Predict the product, balance, & then write the net ionic equation:

A. $KClO_3(s) \rightarrow$

B. $NH_3(g) + O_2(g) \rightarrow$

C. $Fe(s) + H_2O(g) \rightarrow$

D. $H_2S(g) + SO_2(g) \rightarrow$

E. $H_2SO_{4\,(aq)} + Pb(NO_3)_{2(aq)} \rightarrow$