The Mole Concept

Avogadro's Number = 6.022×10^{23}

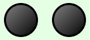
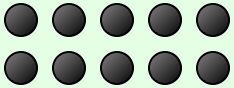
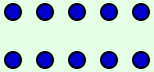
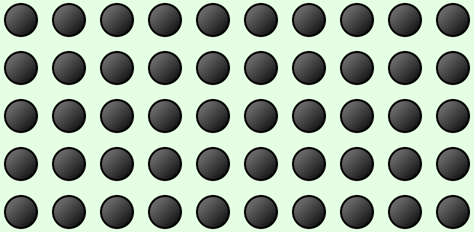
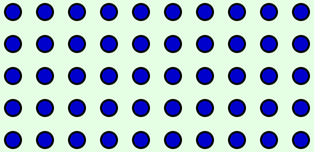
Counting Atoms

- Chemistry is a *quantitative* science - we need a "counting unit."
- The **MOLE**

- 1 mole is the amount of substance that contains as many particles (atoms or molecules) as there are in 12.0 g of C-12.

The Mole is Developed

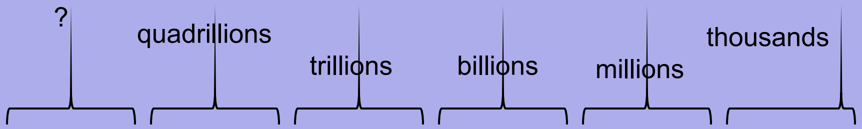
AvogadroPaper

Carbon Atoms		Hydrogen Atoms		Mass Ratio
Number	**Mass (amu)**	**Number**	**Mass (amu)**	**Mass carbon / Mass hydrogen**
	12		1	$\frac{12\text{ amu}}{1\text{ amu}} = \frac{12}{1}$
	24 [2 x 12]		2 [2 x 1]	$\frac{24\text{ amu}}{2\text{ amu}} = \frac{12}{1}$
	120 [10 x 12]		10 [10 x 1]	$\frac{120\text{ amu}}{10\text{ amu}} = \frac{12}{1}$
	600 [50 x 12]		50 [50 x 1]	$\frac{600\text{ amu}}{50\text{ amu}} = \frac{12}{1}$
Avogadro's number	$(6.02 \times 10^{23}) \times (12)$	**Avogadro's number**	$(6.02 \times 10^{23}) \times (1)$	$\frac{(6.02 \times 10^{23}) \times (12)}{(6.02 \times 10^{23}) \times (1)} = \frac{12}{1}$

Particles in a Mole

Amadeo Avogadro

Amedeo Avogadro (1766-1856)
never knew his own number;
it was named in his honor by a
French scientist in 1909.
its value was first estimated
by Josef Loschmidt, an Austrian
chemistry teacher, in 1895.



?

quadrillions

trillions

billions

millions

thousands

1 mole = 602213673600000000000000

or 6.022×10^{23}

There is Avogadro's number of particles in a mole of any substance.

Careers in Chemistry - Philosopher

Q: *How much is a mole?*

A: *A mole is a quantity used by chemists to count atoms and molecules. A mole of something is equal to 6.02 x 10*^{23} *"somethings."*

1 mole = 602 200 000 000 000 000 000 000

Q: *Can you give me an example to put that number in perspective?*

A: *A computer that can count 10,000,000 atoms per second would take 2,000,000,000 years to count 1 mole of a substance.*

How Big is a Mole?

One mole of marbles would cover the entire Earth (oceans included) for a depth of three miles.

One mole of $100 bills stacked one on top of another would reach from the Sun to Pluto and back 7.5 million times.

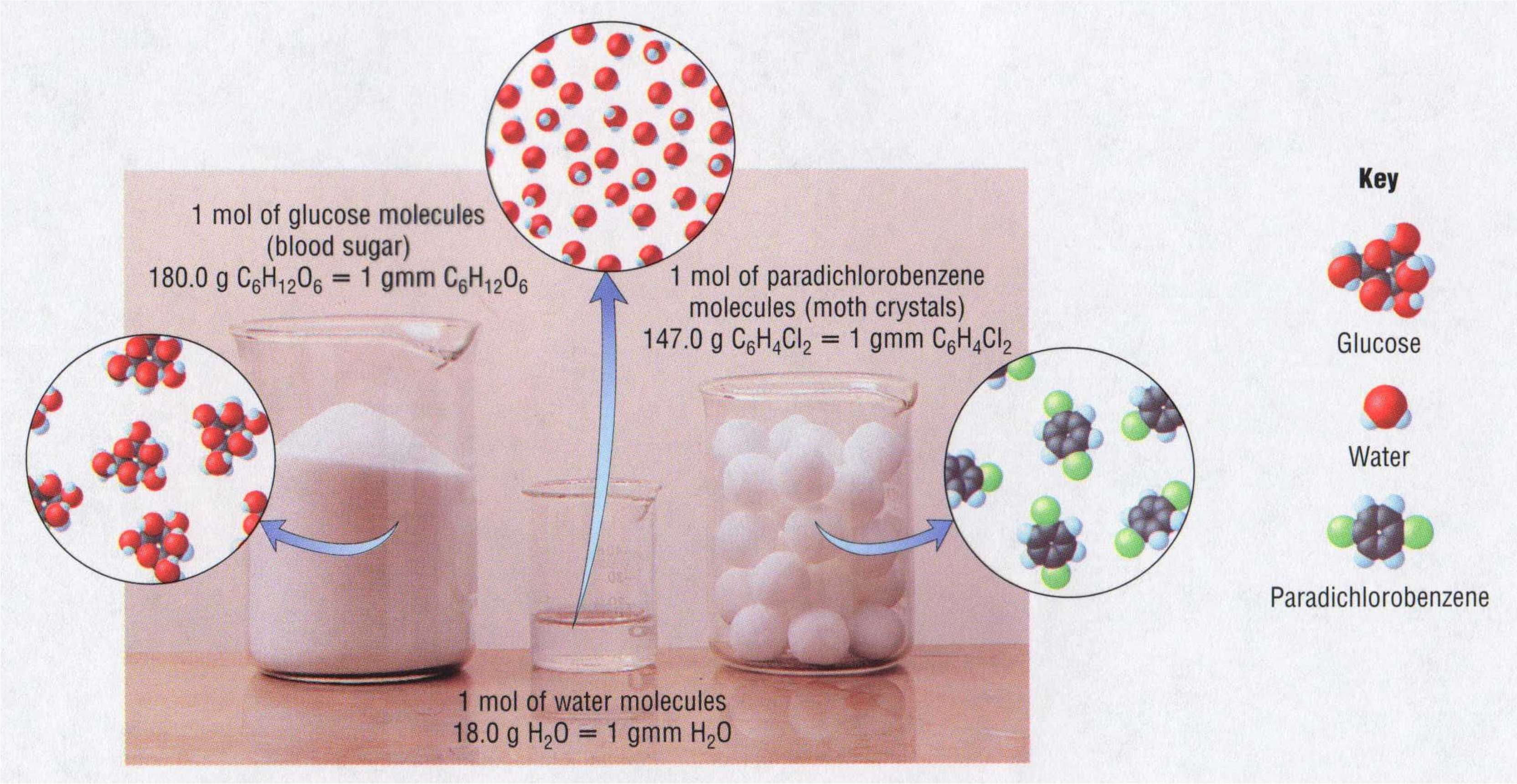
It would take light 9500 years to travel from the bottom to the top of a stack of 1 mole of $1 bills.

Avogadro's Number

- A MOLE of any substance contains as many elementary units (atoms and molecules) as the number of atoms in 12 g of the isotope of carbon-12.
- This number is called AVOGADRO's number $N_A = 6.02 \times 10^{23}$ particles/mol
- The mass of one mole of a substance is called MOLAR MASS symbolized by MM
- Units of MM are g/mol
- Examples

H_2	hydrogen	2.02	g/mol
He	helium	4.0	g/mol
N_2	nitrogen	28.0	g/mol
O_2	oxygen	32.0	g/mol
CO_2	carbon dioxide	44.0	g/mol

1 Mole of Particles



Molecular Weight and Molar Mass

- **Molecular weight** is the sum of atomic weights of all atoms in the molecule.

example: NaCl has a molecular weight of 58.5 a.m.u.

this is composed of a single molecule of NaCl

- **Molar mass** = molecular weight in grams.

example: NaCl has a molar mass of 58.5 grams

this is composed of a 6.02×10^{23} molecules of NaCl

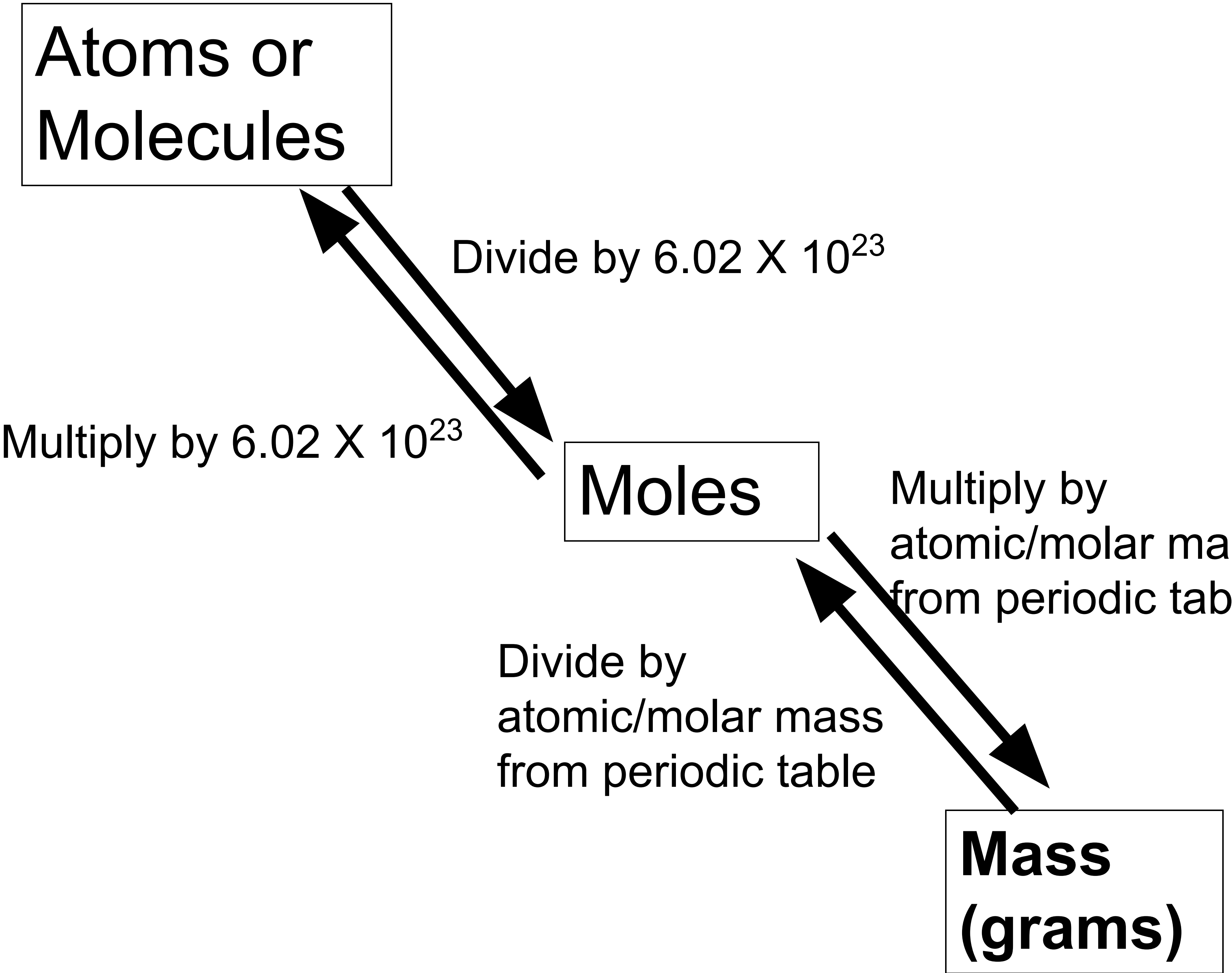
The Molar Mass and Number of Particles in One-Mole Quantities

Substance	Molar Mass	Number of Particles in One Mole
Carbon (C)	12.0 g	6.02×10^{23} C atoms
Sodium (Na)	23.0 g	6.02×10^{23} Na atoms
Iron (Fe)	55.9 g	6.02×10^{23} Fe atoms
NaF (preventative for dental cavities)	42.0 g	6.02×10^{23} NaF formula units
$CaCO_3$ (antacid)	100.1 g	6.02×10^{23} $CaCO_3$ formula units
$C_6H_{12}O_6$ (glucose)	180.0 g	6.02×10^{23} glucose molecules
$C_8H_{10}N_4O_2$ (caffeine)	194.0 g	6.02×10^{23} caffeine molecules

1 mole = 22.4 L
@ STP

1 mol = molar mass

1 mol =
6.02 x 10^{23} particles



Atoms or Molecules

Divide by 6.02 X 10^{23}

Multiply by 6.02 X 10^{23}

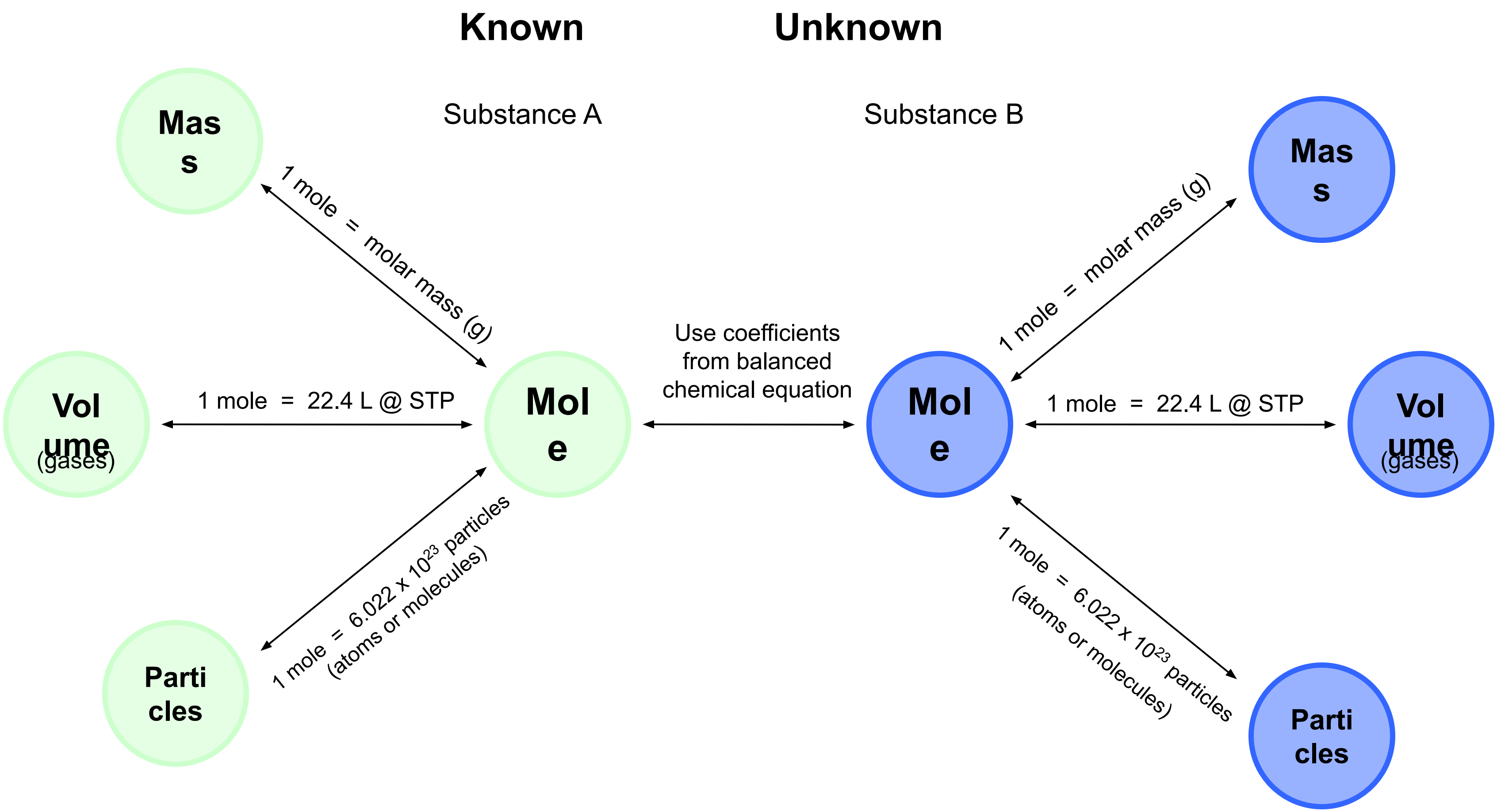
Moles

Multiply by atomic/molar mass from periodic table

Divide by atomic/molar mass from periodic table

Mass (grams)

Stoichiometry Island Diagram



Known

Substance A

Unknown

Substance B

Mass

1 mole = molar mass (g)

Volume
(gases)

1 mole = 22.4 L @ STP

Mole

Particles

1 mole = 6.022 x 10^{23} particles
(atoms or molecules)

Use coefficients
from balanced
chemical equation

Mole

Mass

1 mole = molar mass (g)

Volume
(gases)

1 mole = 22.4 L @ STP

Particles

1 mole = 6.022 x 10^{23} particles
(atoms or molecules)

Stoichiometry Island Diagram

Mole-Mole Calculations

- These mole ratios can be used to calculate the moles of one chemical from the given amount of a different chemical
- Example: How many moles of chlorine is needed to react with 5 moles of sodium (without any sodium leftover)?

$$2\ Na + Cl_2 \rightarrow 2\ NaCl$$

$$5\ \text{moles Na}\ \ \frac{1\ \text{mol}\ Cl_2}{2\ \text{mol Na}} = 2.5\ \text{moles}\ Cl_2$$

Mass-Mole Calculations

- Sometimes you are going to start with mass and will have to convert to moles of product or another reactant
- We use molar mass and the mole ratio to get to moles of the compound of interest
    - Calculate the number of moles of ethane (C_2H_6) needed to produce 10.0 g of water
    - $2\ C_2H_6 + 7\ O_2 \text{ -> } 4\ CO_2 + 6\ H_20$

10.0 g H_2O 1 mol H_2O 2 mol C_2H_6 = 0.185 mol C_2H_6

18.0 g H_2O 6 mol H_20

Mole-Mass Calculations

- Most of the time in chemistry, the amounts are given in grams instead of moles
- We still go through moles and use the mole ratio, but now we also use molar mass to get to grams
    - Example: How many grams of chlorine are required to react completely with 5.00 moles of sodium to produce sodium chloride?

$$2\text{ Na} + Cl_2 \text{ -> } 2\text{ NaCl}$$

$$5.00\text{ moles Na}\ \frac{1\text{ mol }Cl_2}{2\text{ mol Na}}\ \frac{70.90\text{g }Cl_2}{1\text{ mol }Cl_2} = 177\text{g }Cl_2$$

Mass-Mass Calculations

- Most often we are given a starting mass and want to find out the mass of a product we will get (called theoretical yield) or how much of another reactant we need to completely react with it (no leftover ingredients!)
- Now we must go from grams to moles, mole ratio, and back to grams of compound we are interested in

- Ex. Calculate how many grams of ammonia are produced when you react 2.00g of nitrogen with excess hydrogen.
- $N_2 + 3\ H_2 \text{ -> } 2\ NH_3$

$$\begin{array}{ccccc} 2.00\text{g } N_2 & 1 \text{ mol } N_2 & 2 \text{ mol } NH_3 & 17.06\text{g } NH_3 & = 2.4 \text{ g } NH_3 \\ & 28.02\text{g } N_2 & 1 \text{ mol } N_2 & 1 \text{ mol } NH_3 & \end{array}$$

Molar Volume at STP

a
g
a
s
=
2
.
4
L

Standard **T**emperature & **P**ressure
0°C and 1 atm

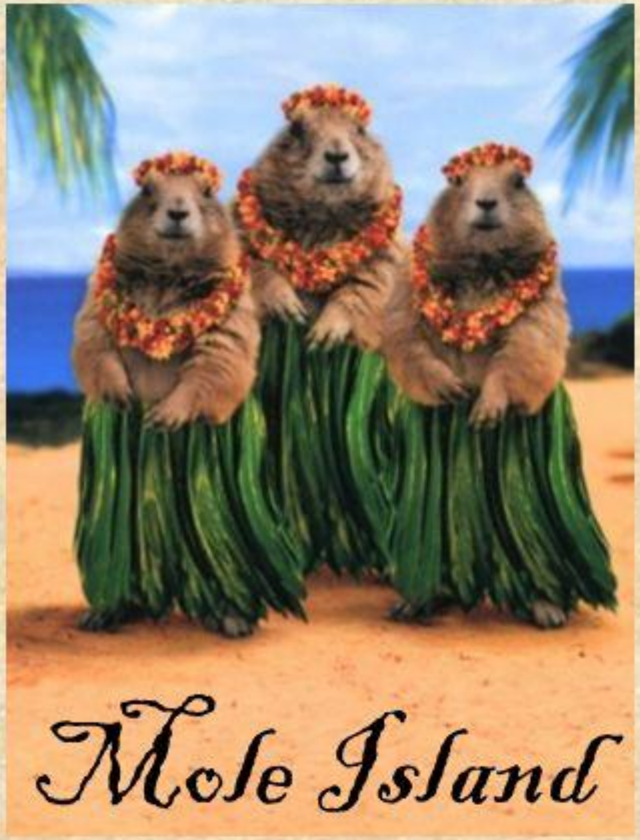
Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

Mole Map

Mass Mountain

Liter Lake

Particle
Peninsula



Proportional Relationships

- **Stoichiometry**
  - mass relationships between substances in a chemical reaction
  - based on the mole ratio

- **Mole Ratio**
  - indicated by coefficients in a balanced equation

$$2\ \mathrm{Mg} + \mathrm{O_2} \rightarrow 2\ \mathrm{MgO}$$

Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

Stoichiometry Problems

How many moles of $KClO_3$ must decompose in order to produce 9 moles of oxygen gas?

$$\underset{?\ \text{mol}}{2KClO_3} \rightarrow 2KCl + \underset{9\ \text{mol}}{3O_2}$$

$$\begin{array}{c|c} 9\ \cancel{\text{mol } O_2} & 2\ \text{mol } KClO_3 \\ \hline & 3\ \cancel{\text{mol } O_2} \end{array} = 6\ \text{mol } KClO_3$$

Courtesy Christy Johannesson www.nisd.net/communicationsarts/pages/chem

How many grams of silver will be formed from 12.0 g copper?

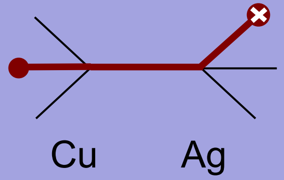
$$Cu + 2\,AgNO_3 \rightarrow 2\,Ag + Cu(NO_3)_2$$

12.0 g

? g

12.0 ~~g Cu~~	1 ~~mol Cu~~	2 ~~mol Ag~~	107.87 g Ag
	63.55 ~~g Cu~~	1 ~~mol Cu~~	1 ~~mol Ag~~

= 40.7 g Ag



$$x\ g\ Ag = 12.0\ \cancel{g\ Cu}\left(\frac{1\ \cancel{mol\ Cu}}{63.55\ \cancel{g\ Cu}}\right)\left(\frac{2\ \cancel{mol\ Ag}}{1\ \cancel{mol\ Cu}}\right)\left(\frac{107.87\ g\ Ag}{1\ \cancel{mol\ Ag}}\right) = 40.7\ g\ Ag$$

40.7 g

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