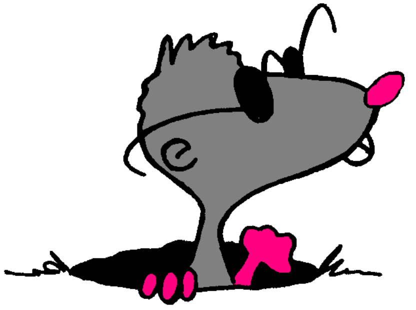
NOTES: 10.1-10.2 – Chemical Quantities (The Mole / Molar Mass)

All Roads Lead to the Mole!!

What is a mole?

- A unit of measure used to count **atoms, molecules, or ions**

- A number: **6.02 x 10^{23}**
  (Avogadro's number)



- **1 mol = 6.02 x 10^{23}** (conversion factor)

Chemical Quantities – consider another word that means a #:

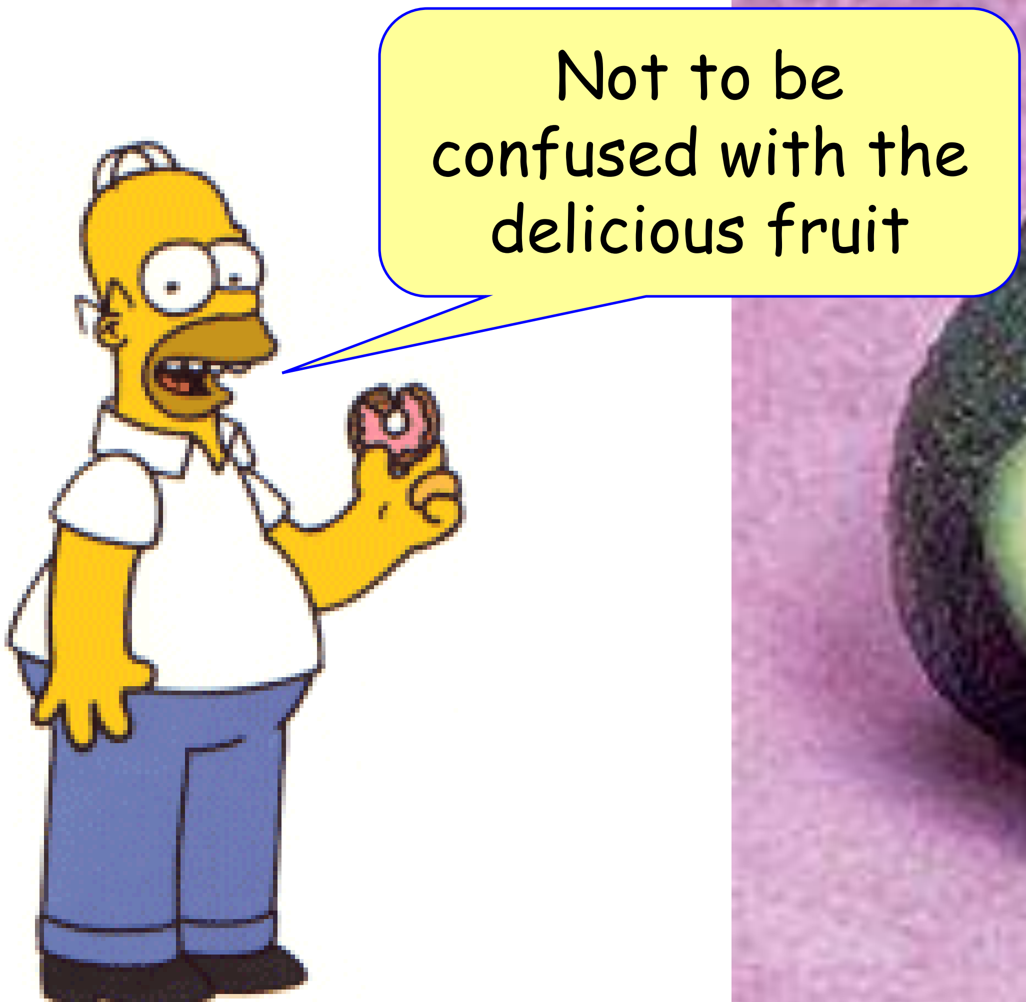
- Measuring doughnuts: a DOZEN!
  - ➔ 1 dozen = 12 doughnuts (count)
  - ➔ 1 dozen = 500 g doughnuts (mass)
  - ➔ 1 dozen = 1 box doughnuts (volume)

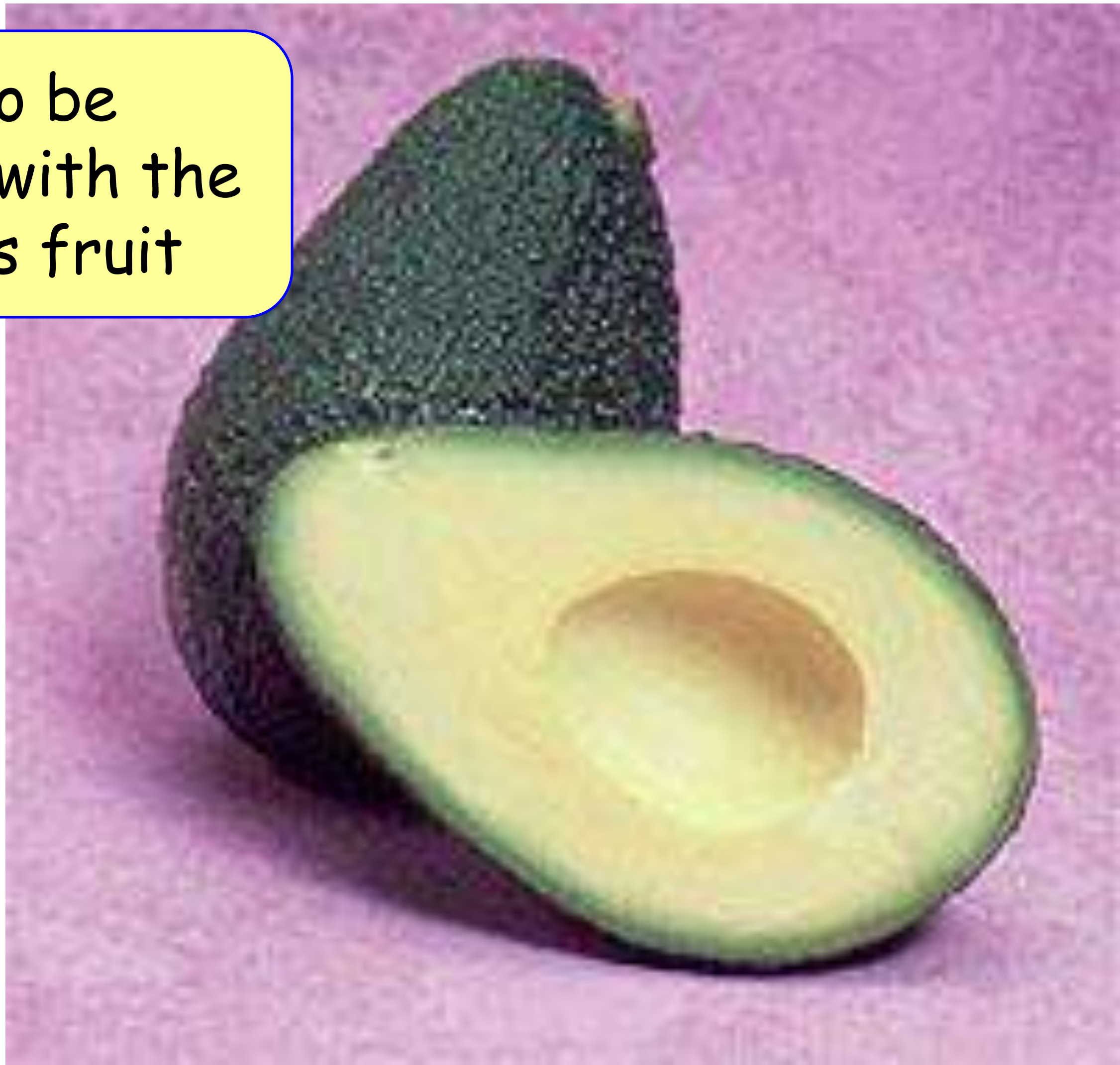
- Measuring hydrogen (H_2 gas): a MOLE!
  - ➔ 1 mole = 6.02×10^{23} H_2 molecules (count)
  - ➔ 1 mole = 2.0 g H_2 (mass)
  - ➔ 1 mole = 22.4 L H_2 (volume) at STP

Count Amedeo Avogadro

- 1776 - 1856
- Lawyer who became interested in math and physics
- Discovered that equal volumes of different gases contained an equal number of particles.
- 9 years after his death, Joseph Loschmidt determined a constant and named it after Avogadro.

AVOGADRO'S CONSTANT $= 6.02 \times 10^{23}$

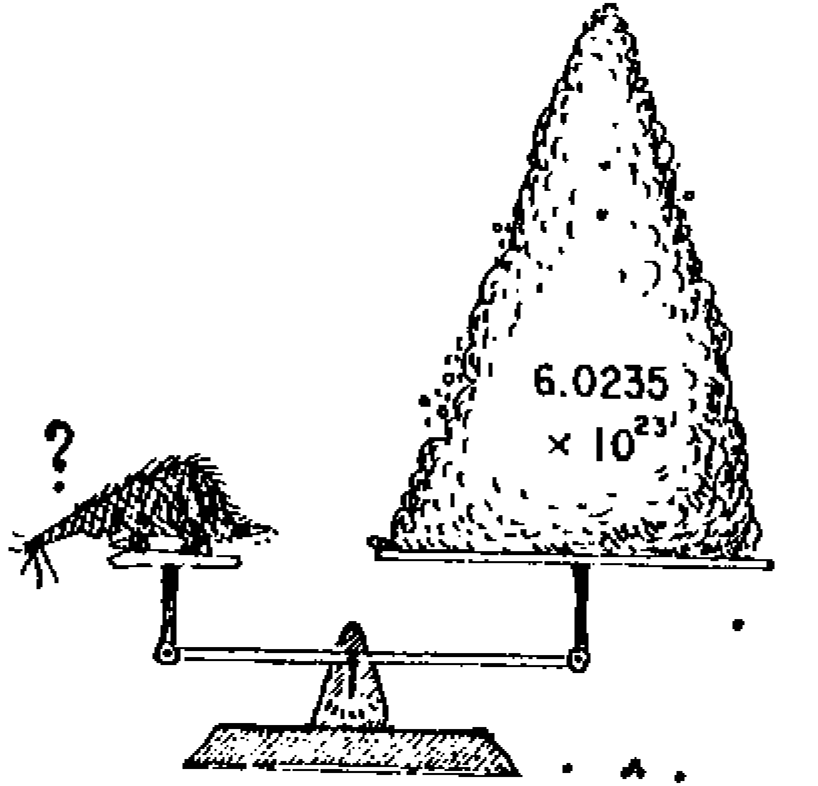




AVOGADRO'S CONSTANT $= 6.02 \times 10^{23}$

- 1 mole = **6.02×10^{23} particles**
- 1 mole = **molar mass (grams)**
- 1 mole (of a gas at STP) = **22.4 L**

The MOLE is to chemists as the DOZEN is to bakers.



A Mole Balance

A Mole Balance

How BIG is a MOLE?

- 6.02×10^{23} Grains of Sand: Would be more than all of the sand on Miami Beach.
- 6.02×10^{23} Blood Cells: Would be more than the total combined number of blood cells found in every human on earth.
- 6.02×10^{23} Watermelon Seeds: Would be found inside a melon slightly larger than the moon.
- 6.02×10^{23} Pennies: Would make at least 7 stacks that would reach the moon.
- 6.02×10^{23} Donut Holes: Would cover the earth and be 5 miles (8 km) deep.

How big is Avogadro's number?

- An Avogadro's number of soft drink cans would cover the surface of the earth to a depth of over 200 miles.
- If you spread Avogadro's number of unpopped popcorn kernels across the USA, the entire country would be covered in popcorn to a depth of over 9 miles.
- If we were able to count atoms at the rate of 10 million per second, it would take about 2 billion years to count the atoms in one mole.
- If you count out loud starting with the number "one" at the rate of one count every second, it may take you about 1,909,577,942,668,696 years to finish. This is roughly 960,000 times the estimated lifetime of our universe (assuming 20 Billion years).
- Using a Pentium 450 MHz CPU, it will still take about 4,243,506 years to finish this task. This is a period of time about a thousand times longer than the total span of our civilization.

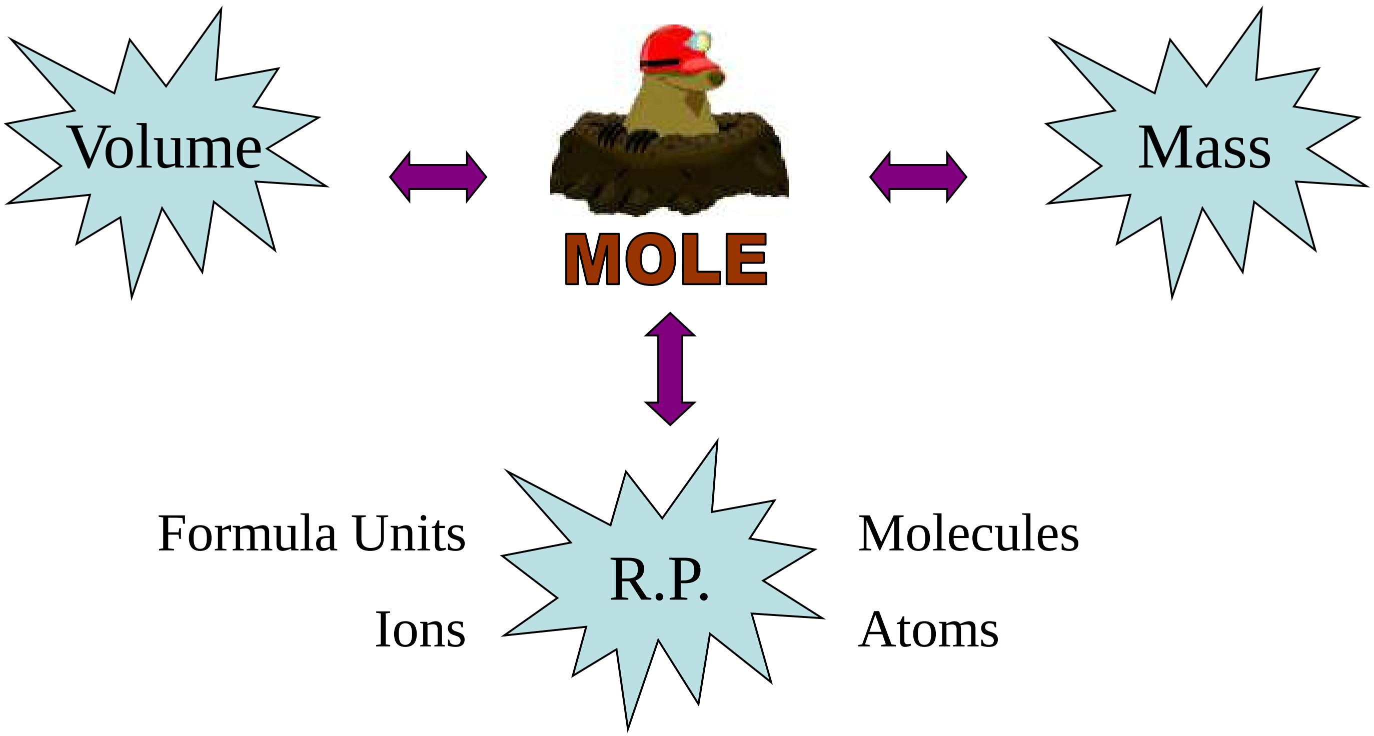
Why such a BIG number?

- because atoms, ions, molecules…are SO small!
- 5 Pound Bag of Sugar contains

6.6 moles of $C_{12}H_{22}O_{11}$ molecules

- 1 Liter bottle of Water contains **55.5 moles H_20 of water molecules**

CARRY YOUR UNITS…

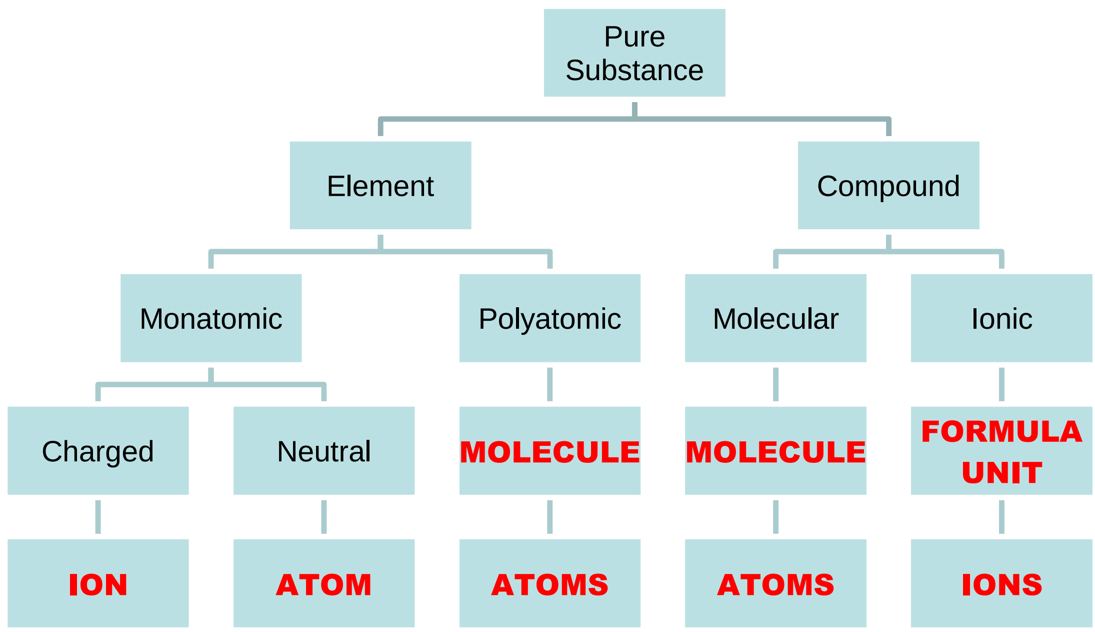


…AND YOUR UNITS WILL CARRY YOU!

Types of Representative Particles:

- Molecules (breaks down into atoms)
- Atoms
- Formula Units (breaks down into ions)
- Ions

Naming Representative Particles (R.P.s):



Mole ⟺ R.P. Calculations (particle #)

1 mole = Avogadro's Number = 6.02 x 10^{23} R.P.'s

MOLE

$$\frac{6.02 \times 10^{23}\ \text{R.P.}}{1\ \text{mol}}$$

$$\frac{1\ \text{mol}}{6.02 \times 10^{23}\ \text{R.P.}}$$

R.P.

R.P. Example #1:

How many moles are represented by 1.4×10^{22} molecules of H_2O?

$$\frac{1.4\times10^{22}\text{molecules } H_2O}{} \times \frac{1\text{mol}}{6.02\times10^{23}\text{molecules } H_2O}$$

$$= 0.023\,\text{mol}\,H_2O$$

R.P. Example #2:

How many molecules of CO_2 are present in 2.6 mol CO_2?

$$\frac{2.6\ \text{mol CO}_2}{} \times \frac{6.02\times10^{23}\ \text{molecules CO}_2}{1\ \text{mol CO}_2}$$

$$=1.6\times10^{24}\ \text{molecules CO}_2$$

R.P. Example #3:

How many **individual atoms** are in 5.2 mol CO_2?

$$\frac{5.2\ \text{mol}\ CO_2}{} \times \frac{6.02\times10^{23}\ \text{molecules}\ CO_2}{1\ \text{mol}\ CO_2} \times \frac{3\ \text{atoms}}{1\ \text{molecule}\ CO_2}$$

$$= 9.4\times10^{24}\ \text{atoms}$$

Avogadro's Number Practice Problems:

1) How many moles of magnesium are represented by 1.25×10^{23} atoms of magnesium?

ANSWER:

2) How many C_3H_8 molecules are in 2.12 mol of propane (C_3H_8)?

ANSWER:

Avogadro's Number Practice Problems:

1) How many moles of magnesium are represented by 1.25×10^{23} atoms of magnesium?

   ANSWER: **0.208 mol Mg**

2) How many C_3H_8 molecules are in 2.12 mol of propane (C_3H_8)?

   ANSWER:

Avogadro's Number Practice Problems:

1) How many moles of magnesium are represented by 1.25×10^{23} atoms of magnesium?

ANSWER: **0.208 mol Mg**

2) How many C_3H_8 molecules are in 2.12 mol of propane (C_3H_8)?

ANSWER: **1.28×10^{24} C_3H_8 molecules**

How about MOLES and MASS?

- when we measure out substances in the lab, it is not practical to count individual molecules…
- instead, we can use a balance to weigh out a certain amount…
- it is therefore useful to have a way to convert from moles to mass (and vice versa!)

MOLAR MASS
… a.k.a. Molecular Weight (MW)

- molar mass = **<u>mass of 1 mole of a substance</u>**

- Molar mass can be determined by adding up the atomic masses from the periodic table.

Molar Mass Example #1:

- Find the molar mass of CH_4.

= 1C + 4H

= 12.0 + 4(1.0)

= **16.0 g/mol**

Molar Mass Example #2:

- Find the molar mass of $Mg(OH)_2$.

= Mg + 2O + 2H

= 24.3 + 2(16.0) + 2(1.0)

= **58.3 g/mol**

Molar Mass Example #3:

- Find the molar mass of $MgSO_4{\bullet}7H_2O$.

= Mg + S + 4O + 7(H_2O)

= 24.3 + 32.1 + 4(16.0) + 7(18.0)

= **246.4 g/mol**

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

1) H_2O_2
2) Carbon tetrabromide
3) $(NH_4)_2CO_3$
4) Aluminum sulfate

5) $Ca(NO_3)_2$

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

1) H_2O_2 : **34.0 g/mol**
2) Carbon tetrabromide
3) $(NH_4)_2CO_3$
4) Aluminum sulfate

5) $Ca(NO_3)_2$

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

1) H_2O_2 : **34.0 g/mol**
2) Carbon tetrabromide : **331.6 g/mol**
3) $(NH_4)_2CO_3$
4) Aluminum sulfate
5) $Ca(NO_3)_2$

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

1) H_2O_2 : **34.0 g/mol**
2) Carbon tetrabromide : **331.6 g/mol**
3) $(NH_4)_2CO_3$: **96.0 g/mol**
4) Aluminum sulfate
5) $Ca(NO_3)_2$

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

1) H_2O_2 : **34.0 g/mol**
2) Carbon tetrabromide : **331.6 g/mol**
3) $(NH_4)_2CO_3$: **96.0 g/mol**
4) Aluminum sulfate : **342.3 g/mol**

    $Al_2(SO_4)_3$

5) $Ca(NO_3)_2$

Molar Mass Practice Problems:

- Determine the molar mass of the following compounds:

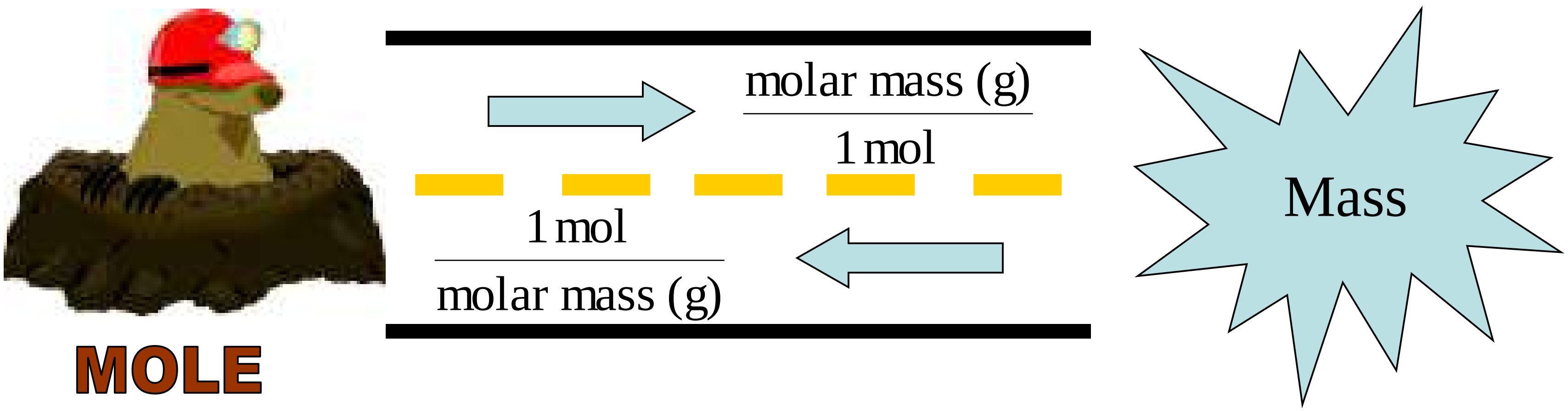
1) H_2O_2 : **34.0 g/mol**
2) Carbon tetrabromide : **331.6 g/mol**
3) $(NH_4)_2CO_3$: **96.0 g/mol**
4) Aluminum sulfate : **342.3 g/mol**

   $Al_2(SO_4)_3$

5) $Ca(NO_3)_2$: **164.1 g/mol**

Mole ⟺ Mass Calculations

1 mole = molar mass (MW) in grams



Molar Mass Example #1:

How many grams are in 7.20 moles of dinitrogen trioxide?

Dinitrogen trioxide = N_2O_3

MW of N_2O_3 = 2N + 3O = 2(14.0) + 3(16.0) = 76.0 g/mol

$$\frac{7.20\text{mol } N_2O_3}{} \times \frac{76.0\text{g}}{1.00\text{mol}} = \boxed{547\text{g } N_2O_3}$$

Molar Mass Example #2:

Find the number of moles in 92.2 g of iron(III) oxide.

Iron (III) oxide = Fe_2O_3

MW of Fe_2O_3 = 2Fe + 3O = 2(55.8) + 3(16.0) = 159.6 g/mol

$$\frac{92.2\text{g } Fe_2O_3}{} \times \frac{1.00\text{mol}}{159.6\text{g}} = \boxed{0.578\text{mol } Fe_2O_3}$$

Gram $\leftrightarrow$ Mole Conversion Practice Problems:

1) How many grams are in 1.77 mol of diphosphorus pentachloride?

2) Find the number of moles in 107.5 g of iron(II) chlorate.

3) Find the number of grams in 3.32 mole of KNO_3.

1) How many grams are in 9.45 mol of diphosphorus pentachloride?

P_2Cl_5 = 239.5 g/mol

$$\frac{9.45 \text{mol } P_2Cl_5}{} \times \frac{239.5 \text{g}}{1.00 \text{mol}} = \boxed{2260 \text{g } P_2Cl_5}$$

2) Find the number of moles in 107.5 g of iron(II) chlorate.

$Fe(ClO_3)_2$ = 222.8 g/mol

$$\frac{107.5\text{g } Fe(ClO_3)_2}{} \times \frac{1.00 \text{ mol}}{222.8 \text{ g}} = 0.4825\,mol\ Fe(ClO_3)_2$$

3) Find the number of grams in 3.32 mole of KNO_3.

KNO_3 = 101.1 g/mol

$$\frac{3.32 \text{mol } KNO_3}{} \times \frac{101.1 \text{g}}{1.00 \text{mol}} = \boxed{336 \text{g } KNO_3}$$

Holy Moley –
I'm glad that is over!