# The Mole

Notes and a Glossary of Terms to Remember

- **Mass**: depends on the amount of matter in a substance. Unlike weight it does not depend on gravity. In chemistry we most commonly measure mass in grams.

- **Mole**: a package of 6.02 X $10^{23}$ items, usually molecules.

- **Molar Mass**: the mass of 1 mole of a substance. Molar mass is expressed in $\frac{grams}{mole} = \frac{g}{mole}$. It is the sum of the atomic masses(listed in the periodic table) of the elements in a substance's formula. For example the molar mass of Ne = 20 g/mole. $H_2O$ = [**2** *1 + 1(16)] = 18 g/mole.

- **Avogadro's Number**: a name for 6.02 X $10^{23}$

## Notes:

At the grocery it is often more convenient to buy fruits in dozens, rather than individually. In chemistry partly because molecules are so small, it is better to deal with larger groups of atoms and molecules. This is where a **mole** enters the picture: a mole is a package of approximately 6.02 X $10^{23}$ particles. What's more important is the mass of a mole or molar mass (expressed in grams per mole = g/mole), which of course varies from element to element and from one compound to the next.

The molar mass of H is available in the periodic table = 1.00797 or 1.0 g/mole. Diatomic hydrogen, $H_2$, is 2 X 1.0 g/mole = 2.0 g. Oxygen is 16; $O_2$ = 32 g/mole.

**In class examples:**

Think of the sand bag analogy and find the mass of...

a. 3.0 moles of C

**3.0 moles of C** $\left[\frac{12 g\ of\ C}{mole}\right]$ **= 36 g of C**

b. 0.25 moles of Fe

$$\textbf{0.25 moles of Fe}\left[\frac{56 g\ of\ Fe}{mole}\right] \textbf{ = 14 g of Fe}$$

c. 7.1 moles of $Ca_3(PO_4)_2$

$$\textbf{7.1 moles of } Ca_3(PO_4)_2\left[\frac{310 g\ of\ Ca_3(PO_4)_2}{mole}\right] \textbf{ = 2201g of } Ca_3(PO_4)_2$$

Remember:
I'm a little furry animal that multiplies. If you have moles multiply by molar mass to get mass in grams.

Now for the reverse operation, find the number of moles represented by...

d. 6.0 grams of C

$$\textbf{6.0 grams of C}\left[\frac{mole}{12 g\ of\ C}\right] \textbf{= 6/12 = 0.50 moles of C}$$

e. 138 g of $NO_2$

$$\textbf{138 grams of C}\left[\frac{mole}{46 g\ of\ NO_2}\right] \textbf{= 138/46 = 3 moles of } NO_2$$

f. 1.0 g of $Ca_3(PO_4)_2$

$$\textbf{1.0 grams of } Ca_3(PO_4)_2\left[\frac{mole}{310 g\ of\ Ca_3(PO_4)_2}\right] \textbf{= 1/310 = 0.0032 moles of } Ca_3(PO_4)_2$$

**Extra examples**

**g. How many molecules are in a drop of water = 0.1 ml = 0.1 g?**

**First convert to moles:**

**0.1 g** $\left[\frac{mole}{18\, g\ of\ H_2O}\right]$ **=0.1/18 = 0.00556 moles**

**Then convert to molecules:**

**0.00556 moles** $\left[\frac{6.02 X 10^{23}\ molecules}{mole}\right]$ **=3.34 X10$^{21}$ molecules**

**h. What is the mass of a single molecule of $H_2$?**

**First convert to moles:**

**1 molecule** $\left[\frac{mole}{6.02 X 10^{23}\ molecules}\right]$ **=1/(6.02 X10$^{23}$) = 1.66 X 10$^{-24}$ moles**

**Then convert to grams:**

**1.66 X 10$^{-24}$ moles** $\left[\frac{2(1)\, g\ of\ H_2}{mole}\right]$ **=3.32 X10$^{-24}$ g**

Since moles are directly proportional to molecules, in balanced equations the coefficients can represent molecules or moles:

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

The above equation can be interpreted as saying:

Two moles of hydrogen react with 1 mole of oxygen to produce 2 moles of water.

To obtain the mass of 2 moles of water, we simply the number of moles by molar mass: 2 moles X [2(1) + 16]g/mole = 36 g.
Note that to get the molar mass of a compound, we simply add up the masses of the individual atoms, so the molar mass of water is 18 g/mole.

If you had to convert mass back into moles, you would of course divide mass by molar mass.

Example: 16 g of $O_2$ = 16g/ [32g/mole] = 0.50 moles of $O_2$.

For any equation such as $2\ H_2 + O_2 \rightarrow 2\ H_2O$, the moles are proportional, so that

$$6\ H_2 + 3O_2 \rightarrow 6\ H_2O.$$

By a simple ratio we can solve for any unknown number of moles, as long as we have the balanced equation. For instance: how much water will form from consuming 30 moles of $O_2$?

$$O_2 \rightarrow 2H_2O$$

$\frac{1}{30} = \frac{2}{x}$, note that we obtain the first part of the ratio from the balanced equation, and solving yields an answer of 60 moles of $H_2O$..

Be careful when masses are given. Masses are *not* proportional if moles are not taken into account. The safest thing then is to convert mass into moles before examining the ratio.

**Example**: Given: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$

How many grams of ammonia will form if 4.0 g of hydrogen reacted?

**Solution**: First we obtain the number of moles of hydrogen:
8.0 g / (2 g/mole) = 4 moles of $H_2$. ( note don't use the 3 yet)

$$3\ H_2 \rightarrow 2\ NH_3$$

$$\frac{3}{4} = \frac{2}{x}$$

$x$ = 8/3 = 2.67 moles of $NH_3$.

Finally we convert to grams of ammonia:
2.67 moles of $NH_3$ *[ 14 + 3(1) g/mole] = 45.4 g.

Here is a summary of the possible calculations involving moles:

chemical equation: $xA \rightarrow yB$