Given a mass of magnesium in grams, 0.200g, determine the mass of magnesium oxide that would be obtained. The chemical reaction to form magnesium oxide is:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

Some approaches to answer this question will be developed in future weeks. Common approaches to solve this question involve the **Law of Conservation of Mass** (not enough data given above), the **Law of Definite Proportions**, and **stoichiometry**. The third approach, stoichiometry, involves counting atoms. The counting unit for atoms and molecules is the mole (abbreviated mol).

The mole counts items in groups of 6.02×10^{23}, similar to the dozen counting items in groups of 12. A mole of chemical provides enough substance to use in the lab. Many chemists work with fractions of a mole. One mole is the amount of substance that contains as many particles as there are in exactly 12g of ^{12}C. Applying this definition gives the relationship 1 mol $^{12}C = 6.02 \times 10^{23}$ atoms ^{12}C. In general, 1 mol = 6.02×10^{23} items (or Avogadro's number of items).

Example: How many items are represented by the following 1 dozen donuts and 1 mole of donuts?
Solution: 1 dozen donuts equals 12 donuts. 1 mole of donuts equals 6.02×10^{23} donuts (or Avogadro's number).

Periodic Table: Atomic Mass Units and Grams Per Mole

Atomic masses from the periodic table give the mass in grams for 1 mole of atoms and the mass in atomic mass units (amu) for one atom of substance.

Example: Using the information in the statement above, what number of grams equals 1 amu?
Solution: Reading the sentence for atomic masses gives these relationships, where X represents the mass:

$$\frac{X\ g}{1\ mol} = \frac{X\ amu}{1\ atom} = \text{atomic mass}$$

Divide both sides by X

$$\frac{1\ g}{1\ mol} = \frac{1\ amu}{1\ atom}$$

Solve for amu

$$1\ amu = \frac{1\ g}{1\ mol} * \frac{1\ atom}{1}$$

Use Avogadro's number (1 mol = 6.02×10^{23} atoms) to change units of mol to atoms on the right side

$$1\ amu = \frac{1\ g}{1\ mol} * \frac{1\ atom}{1} * \frac{1\ mol}{6.02 \times 10^{23}\ atoms}$$

Cancel the units

$$1\ amu = \frac{1\ g}{\cancel{mol}} * \frac{\cancel{atom}}{1} * \frac{1\ \cancel{mol}}{6.02 \times 10^{23}\ \cancel{atoms}}$$

to give 1 amu = $1/6.02 \times 10^{23}$ g or $1\ amu = 1.66 \times 10^{-24}$g.

Example: What is the mass of 1.0 mol of Mg?
Solution: The atomic mass of Mg is 24.305 amu/1 atom = 24.305 g/1 mol.

$$1.0 \text{ mol Mg} * \frac{24.305 \text{g Mg}}{1 \text{ mol Mg}} = 24 \text{g Mg}$$

Example: Convert 13.0g of Al to moles.
Solution: The atomic mass of aluminum is 26.982 g/1 mol.

$$13.0 \text{ g Al} * \frac{1 \text{ mol Al}}{26.982 \text{g Al}} = 0.482 \text{g Al}$$

Example: How many moles and how many atoms is 0.200g Mg.
Solution:

$$0.200 \text{g Mg} * \frac{1 \text{ mol Mg}}{24.305 \text{g Mg}} = 4.95371 \times 10^{21} = 8.23 \times 10^{-3} \text{ mol Mg.}$$

$$0.200 \text{g Mg} * \frac{1 \text{ mol Mg}}{24.305 \text{g Mg}} * \frac{6.02 \times 10^{23} \text{ atoms Mg}}{1 \text{ mol Mg}} = 4.95 \times 10^{21} \text{ atoms Mg.}$$

Law of Conservation of Mass: total mass remains constant during a chemical reaction. Total mass of reactants = total mass of products.
Law of Definite Proportions: All samples of a compound have the same atomic composition (or) all samples have the same proportions by mass of the elements present.
Law of Multiple Proportions: When two or more different compounds of the same two elements are compared, the masses of one element that combine with a fixed mass of the second element are in the ratio of small whole numbers.

Example: Given that mass of magnesium used is 0.200g and the mass of oxygen used is 0.132g, determine the mass of magnesium oxide that would be obtained from this reaction: $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
Solution: Using the Law of Conservation of Mass, the mass of the products is the same as the mass of reactants. The mass of magnesium oxide formed equals the mass of magnesium used plus the mass of oxygen used: 0.200g + 0.132g = 0.332g of MgO formed. A disadvantage of the Law of Conservation of Mass is that all but one of the masses must be known for a chemical reaction. For example, the Law of Conservation of Mass did not work using the data in the first example on the first page of these notes because only one of the three masses was known.

The next class will show the solution to the previous question using the Law of Definite Proportions.

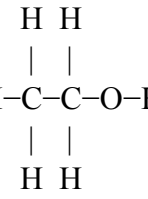
Molecular mass: sum of masses of atoms in a molecular formula, typically in amu (u).
Molar mass: mass of 1 mole of molecules or atoms in grams (g) or g/mol.
Molecular Formula: gives atomic (or mole) composition of substance.

Example: Find the molar mass of ethanol (drinking alcohol): C_2H_6O
Solution: It may be helpful to make a table of atoms, atom counts, molar masses, subtotals, and grand total

Atom	number mol	molar mass g/mol	subtotal g/mol	Calculation
C	2	12.011	24.022	2 mol C * 12.011g C/mol C= 24.022g C
H	6	1.008	6.048	6 mol H * 1.008g H/mol H = 6.048g H
O	1	15.999	15.999	1 mol O * 15.999g O/mol O= 15.999g O

Molar mass of ethanol is			46.069g C_2H_6O/1 mol C_2H_6O or 1 mol C_2H_6O = 46.069g C_2H_6O.	

Example: What is molar mass of MgO
Answer: 40.304g/1mol

Types of Formulas	Ethanol	Detail Shown
molecular formula	C_2H_6O	gives atomic composition
condensed formula	CH_3CH_2OH	above plus some structural detail
structural formula		above plus more structural detail

Empirical Formula: shows the reduced whole number ratio of elements in a formula.

Compound	Molecular Formula	Molar Mass	Empirical Formula	Molar Mass	Ratio of mass of empirical formula to molecular formula
octane	C_8H_{18}	114.232	C_4H_9	57.116	2
ethanol	C_2H_6O	46.069	C_2H_6O	46.069	1
glucose	$C_6H_{12}O_6$	180.156	CH_2O	30.026	6

Example: 18 grams of glucose ($C_6H_{12}O_6$) contains how many moles of glucose?
Solution:

$$18\text{g } C_6H_{12}O_6 * \frac{1 \text{ mol } C_6H_{12}O_6}{180.156\text{g } C_6H_{12}O_6} = 0.10 \text{ mol } C_6H_{12}O_6.$$

Example: 18 grams of glucose ($C_6H_{12}O_6$) contains how many molecules of glucose? atoms of H?
Solution: See example above for the first step.

$$0.10 \text{ mol } C_6H_{12}O_6 * \frac{6.02\text{x}10^{23} \text{ molecules } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 6.0\text{x}10^{22} \text{ molecules } C_6H_{12}O_6.$$

$$6.0\times10^{22}\ \text{molecules } C_6H_{12}O_6 * \frac{12\ \text{atoms H}}{1\ \text{molecule } C_6H_{12}O_6} = 7.2\times10^{23}\ \text{atoms H}$$

Example: The empirical formula of a compound is HO. What is the molecular formula if its molar mass is 34?
Solution: The molar mass of the empirical formula is 1.008 + 15.999 = 17.007. The ratio of masses between the molecular and empirical formulas is 34/17.007 = 2 (to two SD). There are 2 empirical formula units in the molecular formula, so the molecular formula is H_2O_2, which is hydrogen peroxide.