Chapter 6. Chemical Calculations: Formula Masses, Moles, and Chemical Equations
6.1 Formula Masses

Chemical Formula

A chemical formula is a way of showing information about the atoms/ions that make up a particular chemical compound. The subscripts in the chemical formula indicate the number of each type and the ratio of the atoms/ions of each element in the chemical formula.

Ionic compounds

The subscripts in the chemical formula of an ionic compound indicate the ratio of the ions formed by each element in the chemical formula. For ionic compound chemical formula is always **empirical formula** (simple ratio of ion in the formula). These concepts were introduced in the chapter 4. **For example**:

a) Calcium oxide, a simple ionic solid consisting of one calcium ion, Ca^{2+} and one oxide ion, OI^{2-} has the chemical formula: **CaO** not **Ca_2O_2.**

b) Calcium chloride, a simple ionic solid consisting of one calcium ion, Ca^{2+} and two chloride ions, $2Cl^-$ has the chemical formula:**$CaCl_2$**.

c) Sodium sulfate with two sodium ions, $2Na^+$ and one sulfate ion, $(SO4)^{2-}$ has the chemical formula: **Na_2SO_4**.

Covalent compounds

a) The subscripts in the chemical formula of an covalent compound indicate the type and ratio of the atoms of each element in the chemical formula. For **covalent compound,** a compound made up of two or more non-metal combinations, chemical formula is also called the **molecular formula**. It lists the element by its **chemical symbol** and **subscript** indicating the **number** of atoms of each element. These concepts were introduced in the chapter 5.

For example:

b) Methane, a simple molecule consisting of one carbon atom bonded to four hydrogen atoms, has the chemical formula:**CH_4.**

c) Glucose with six carbon atoms, twelve hydrogen atoms and six oxygen atoms has the chemical formula: **$C_6H_{12}O_6$**. This idea was introduced in the chapter 5.

Formula mass

Formula mass is a number expressed in **amu** or **g/mol** units obtained by simply adding up all masses of the atoms that are in the chemical formula. This calculation is based on the idea that mass of atoms is neither created nor destroyed when several atoms react to form a compound (the law of conservation of mass). Therefore we count up the number of atoms of each type in the formula, and add up the total mass. Examples of formula mass calculations are given below.

Calculating formula masses

Examples of calculations of the formula mass **ionic compounds**?

Na_2CO_3	NH_4Cl	$Al_2(SO_4)_3$
Na= 2 x 22.99 = 45.98	N = 1 x 14.01 = 14.01	Al = 2 x 26.98 = 53.96
C = 1 x 12.01 = 12.01	H = 4 x 1.01 = 4. 04	S = 3 x 32.07 = 96.21
O = 3 x 16.00 = 48.00	Cl = 1 x 35.45 = 35.45	O = 12 x 16.00 = 192.00
(**Formula mass**) 105.99	(**Formula mass**) 53.50	(**Formula mass**) 342.17

Calculate the formula mass of the following ionic compounds:
a) NaCl, b) K_2CO_3, and c) $Fe_2(CO_3)_3$.
Answers: a) NaCl (**58.45 g/mol**), b) K_2CO_3 (**138.2 g/mol**) and c) $Fe_2(CO_3)_3$ (**294.73 g/mol**)

Examples of calculations of the formula mass **covalent compounds**?

H_3PO_4	H_2SO_4	$C_6H_{12}O_6$
H = 3 x 1.01 = 3.03	H = 3 x 1.01 = 3.03	C = 6 x 12.01 = 72.06
P = 1 x 30.97 = 30.97	S = 1 x 32.07 = 32.07	H = 12 x 1.01 = 12.12
O = 4 x 16.00 = 64.00	O = 4 x 16.00 = 64.00	O = 6 x 16.00 = 96.00
(**Formula mass**) 98.00	(**Formula mass**) 99.10	(**Formula mass**) 180.18

Practice Problems: Calculate the molecular mass or formula mass of each of the following compounds.
a) SO_3 b) $KBrO_3$ c) $CaSO_4$ d) $(NH_4)_3PO_4$ e) $Fe(NO_3)_3$ f) $C_2H_5NO_2$ g) MgS_2O_3

Answers a) SO_3 (80.1 g/mol) b) $KBrO_3$ (167.2 g/mol) c) $CaSO_4$ (136.2 g/mol)

d) $(NH_4)_3PO_4$ (149 g/mol) e) $Fe(NO_3)_3$ (241.8 g/mol) f) $C_2H_5NO_2$ (75 g/mol) g) MgS_2O_3 (136.5 g/mol)

6.2 The Mole: A Counting Unit for Chemists

Amount of Substance-The mole

Chemical equations are written in terms of ions or atoms. However, we cannot pick ions/atoms individually and do chemical reactions since they are too small. Therefore we always have to use measurable quantities usually in grams as the amounts. To check if we are using proper numbers/ratios of atoms or ions we need a conversion factor to convert grams to atoms represented the stoichiometric coefficients in the chemical equation. Mole is a convenient conversion factor that we use to convert between atoms and grams.

The Mole

Mole is a convenient number (**6.022×10^{23}**) to convert grams into number of atoms or vice versa. Mole is also called the **Chemist's dozen** since it brings atomic particles to a sample size that could handle easily similar/analogy to dozen of eggs.

Avogadro's Number

The name "Avogadro's Number" is just an honorary name attached to the mole when units used are in grams and amu. Avogadro's number is **6.022×10^{23}**.

6.3 The Mass of a Mole

Gram mole: A gram mole of a substance is the **formula mass** in grams of a pure chemical. In a gram mole of any chemical substance there are 6.022×10^{23} formula units of the compound. Of course, if we used some other mass unit defined the mole such as "**pound mole**", the "number" would be different than 6.022×10^{23}.

In a lab the atoms and molecules are weighed in grams even though in the periodic table atomic mass are reported in **amu** or **g/mol**. However, if you take atomic mass in grams the number of atoms is simply 6.022×10^{23}. In other words **gram atomic weight** or **gram molecular weight** contains 6.022×10^{23} atoms or molecules. This number is called Avogadro's number or mole of particles. (simply the **mole**).

6.4 Chemical Formulas and the Mole Concept

Molar mass

Molar mass is defined as the amount of mass of a chemical substance when formula mass is taken grams. For Example, molar mass of $C_6H_{12}O_6$ is 180.18 g since Formula mass of $C_6H_{12}O_6$ is 180.18 g/mole. Molar mass contains mole (6.022×10^{23}) of formula ($C_6H_{12}O_6$) units.

The **atomic mass of** sodium **is 23.0 amu** and **molar mass is 23.0 g/mol**

1 molar mass equals one mole. This gives a convention for creating conversion factors to convert grams to moles.

$$\frac{23.0 \text{ g sodium}}{1 \text{ mole sodium}} \quad \text{or} \quad \frac{1 \text{ mole sodium}}{23.0 \text{ g sodium}}$$

Important conversion factors used in chemical stiochiometry.

1 amu = 1 g/mol
1 amu = 1 g/6.022×10^{23}
1 g = 6.022×10^{23} amu
6.022×10^{23} atoms C = 12.01 grams of carbon (C)
Atoms gram atomic weight = 6.022×10^{23} atoms 12.01 g of C = 6.022×10^{23} atoms
Molecules gram molecular weight = 6.022×10^{23} atoms 182.02 g of H_2O = 6.022×10^{23} H_2O molecules 182.02 g of H_2O = 2 X 6.022×10^{23} H atoms 182.02 g of H_2O = 1 X 6.022×10^{23} OH atoms

Ionic compounds			
Molar mass = 6.022×10^{23} formula units			
Grams Formula mass	= 6.022×10^{23} formula units		
105.99 g of Na_2CO_3	= 6.022×10^{23} Na_2CO_3 formula units		
105.99 g of Na_2CO_3	= $2 \times 6.022 \times 10^{23}$ Na^+ ions		
105.99 g of Na_2CO_3	= $1 \times 6.022 \times 10^{23}$ Cl^- ions		
Covalent compounds			
Molar mass	= 6.022×10^{23} molecules		
Grams Formula mass	= 6.022×10^{23} molecules		
180.18g of $C_6H_{12}O_6$	= 6.022×10^{23} $C_6H_{12}O_6$) molecules		
180.18g of $C_6H_{12}O_6$	= 6 x 12.01 g C atoms	=	6 X 6.022×10^{23} C atoms
180.18g of $C_6H_{12}O_6$	= 12 x 1.01 g H atoms	=	12 X 6.022×10^{23} C atoms
180.18g of $C_6H_{12}O_6$	= 6 x 16.00 g O atoms	=	6 X 6.022×10^{23} C atoms

Grams to moles calculations

a) How many moles of iron (Fe) are present in 180.1g of elemental iron?

a.w. Fe = 55.85 g/mol This is a problem to convert grams to moles. Conversion factor is 55.85 g Fe = 1 mol

$$\frac{180.1\ \cancel{g\ Fe}}{} \times \frac{1\ mol}{55.85\ \cancel{g\ Fe}} = \underline{3.225\ mol\ Fe}$$

b) How many moles of K_2SO_4 are present in 180.1g of potassium sulfate?

Formula mass (K_2SO_4) = 174.26 g/mol

This is a problem to convert **g** to **moles**.

Formula mass (K_2SO_4) = 174.26 g/mole K_2SO_4 = 1 mol

Conversion factor is 174.26 g K_2SO_4 = 1 mol K_2SO_4

Using factor label method:

$$\frac{180.1\ \cancel{g\ K_2SO_4}}{1} \times \frac{1\ mol\ K_2SO_4}{174.26\ \cancel{g\ K_2SO_4}} = \underline{1.033\ mol\ K_2SO_4}$$

Moles to grams calculations

a) How many grams are in 4.61 mol $AlCl_3$?

Formula mass ($AlCl_3$) = 133.5 g/mole, Conversion factor is 133.5 g $AlCl_3$ = 1 mol $AlCl_3$

$$\frac{4.61\ \cancel{mol\ AlCl_3}}{1} \times \frac{133.5\ g\ AlCl_3}{1\ \cancel{mol\ AlCl_3}} = \underline{\mathbf{615.5\ g\ AlCl_3}}$$

b) How many grams are in 0.158 mol IF_5?

Formula mass ($AlCl_3$) = 220.0 g/mole, Conversion factor is 220.0 g IF_5 = 1 mol IF_5

$$\frac{0.158\ \cancel{mol\ IF_5}}{1} \times \frac{220.0\ g\ IF_5}{1\ \cancel{mol\ IF_5}} = \underline{\mathbf{35.1\ g\ IF_5}}$$

Moles to numbers of atoms calculations

How many sulfur atoms are in 5.00 moles of sulfur?

Conversion factor 1 mole S atoms = 6.022×10^{23} S atoms

$$\frac{5.00\ \cancel{mol\ S}}{1} \times \frac{6.022 \times 10^{23}\ S\ atoms}{1\ \cancel{mol\ S}} = \underline{\mathbf{3.00 \times 10^{24}\ S\ atoms}}$$

Mass of atoms in grams

What is the mass of 7.5 x 10^5 atoms of Cu in grams?

This problem requires conversion of atoms to grams. If you remember correctly this is the definition of the mole. 1 mol = 63.55g Cu = gram atomic weight 1 mol = 6.022 x 10^{23} atoms 6.022 x 10^{23} Cu atoms = 63.55 grams Cu Therefore,

$$\frac{7.5 \times 10^5 \text{ ~~Cu atom~~}}{} \times \frac{\text{atoms}63.55 \text{ g Cu}}{6.022 \times 10^{23} \text{ ~~Cu atom~~}} = 7.9 \times 10^{-17} \text{g Cu}$$

6.5 The Mole and Chemical Calculations

When a chemical reaction occurs, it can be described by an equation. A chemical calculations starts with a chemical equation (reaction) which gives formulas of starting and final substances maintaining atomic balance using coefficients that gives the moles of reactants and products represented by their names or by their chemical symbols. In order to use chemical equations in calculations you need to know the information that can be extracted from them.

Chemical Equations: An equation with coefficients and chemical formulas showing the starting and final substances while maintaining atomic balance.

Rules for writing chemical equation.

1. Set down the formula(s) for any substance entering into the reaction. Place a + sign between the formulas as needed and put the yield arrow (→**)** after the last one.
2. Write down the correct formulas for all products formed, placing them to the right of the arrow.
3. Reaction should be **balanced** as described later in section 6.6.

What is in a chemical Equation:

1. Left side shows the **reactants** which enter into a reaction.
2. Right side shows the **products** which are formed by the reaction.
3. **Physical sate of chemicals** in parenthesis after the chemicals: **(g)** for gases, **(l)** for **liquids**, **(s)** for **solids, (aq)** for **water (aqueous) solutions.** Most often we drop this information since they are not important for the gram to mole conversions.
4. **Stoichiometric Coefficients:** The large numbers in front of the chemical formulas that gives the amounts (**moles**) of each substance used and each substance produced.
5. **Themochemical data ΔH:** A negative value indicates (**exothermic (-)** that heat given out and positive value an endothermic(+) heat absorbed. If this data is included in the chemical reaction the physical state of reactants also should be given and the chemical equation is called a **thermochemical equation**.

For example: Hydrogen gas reacts with oxygen gas at 25°C burns to produce water (word description) Note that oxygen gas is **diatomic**, O_2. Most elements in the gas form are diatomic. This could be translated into a chemical equation through following steps:

Oxygen + Hydrogen → water

$$O_2(g) + 2\,H_2(g) \rightarrow 2\,H_2O(l);\ \Delta H = -572 \text{ kJ}$$

Interpret the information conveyed by this chemical equation:

Reactants and products: O_2 and H_2 are reactants and H_2O is the product**.**

Stoichiometric and coefficients: O_2, H_2 and H_2O has **1, 1** and **2**, as their stoichiometric coefficients, respectively. They are used to get the mole conversion factors:

Physical sate of chemicals: O_2, H_2 are gases and H_2O is a liquid at 25°C.

Degree of reaction completion: O_2 and H_2 are completely **(→) irreversibly** converted to H_2O **(**if not **equilibrium** (⇌) where both reactants and products exists in a mixture).
Reaction conditions: reaction is done at 25°C without heating [if heated (Δ) or exposed to light (**h**ν) sings are written on top of the arrow **(→).**
Themochemical data ΔH: 572 kJ of (**exothermic (-)** heat given out per each 2mole of H_2 burned and 2mole of H_2O produced.

6.6 Writing and Balancing Chemical Equations

When you are writing chemical equations they should balanced. This mean the number of atoms of each type on each side (reactant and product) has to be equal. If the equation is not balanced it implies that you are either creating or destroying atoms of elements and this cannot be done by ordinary chemical reactions which should follow law of conservation of atoms/mass. Balancing is an application of the Law of conservation of mass (atoms) which states that in a chemical reaction atoms are neither created nor destroyed.

How many atoms of each element are indicated in one formula unit of each of the following?

a) $Al_2(C_2O_4)_3$	b) $Ca_3(PO_4)_2$	c) 2 $C_6H_{12}O_6$	d) 3 $Al_2(SO_4)_3$
Answers:			
2Al atoms 6 C atoms 12 O atoms	3 Ca atoms 2 P atoms 8 O atoms	12 C atoms 24 H atoms 12 O atoms	6 Al atoms 9 S atoms 36 O atoms

Atomic balance in a chemical equation is achieved by changing coefficients, not subscripts. **Chemical formula** cannot be altered. Count the number of atoms of each type on each side (reactant and product) and if they are not equal equation need to be balanced. Polyatomic ions that are found on both reactant product sides are treated as a unit and are balanced as a whole.

Following steps are followed to ensure that a chemical equation is balances:

1. Pick the first elements to be balanced: Guide lines are finding the element with greatest number of atoms which is found just one compound on each side of the equation or fewer chemicals on the reactant and product side. [e.g. C_2H_6(g) + O_2(g) → CO_2(g) + H_2O(l), Hydrogen picked first then carbon and oxygen is balanced last]. Change the stoichiometric coefficients to balance the atoms of first element using a least common multiplier if not cross place subscripts on reactant and product side of the element.
2. Pick the second elements to be balanced: Next element greater number of atoms which are found only one chemical on the reactant and product side. Change the stoichiometric coefficients to balance atoms without changing coefficients of the first element.
3. Pick the third…fourth elements etc. until all elements are balanced.
4. Repeat step one, recount all Atoms and make sure atoms of each type on each side (reactant and product) and if they are equal chemical equation is balanced.

Example: Solid aluminum metal reacts with oxygen gas burns to produce solid white powder, aluminum oxide (word description). If we convert each of the chemical names into the appropriate symbols, we get the following:

Aluminium + Oxygen → Aluminium Oxide

Aluminium-Al(s) + Oxygen- O_2(g) → Aluminium Oxide-Al_2O_3

This is the chemical equation for the burning of aluminium in oxygen.:

$$Al + O_2 \rightarrow Al_2O_3$$

Check the atomic balance: Count the number of atoms on both sides

Reactant side: $Al + O_2$	Product side: Al_2O_3	**Conclusion**
1 Al atom 2 O atoms	2 Al atoms 3 oxygen atom	Reaction is not balanced.

Step of 1 of balancing: Pick the first element to be balanced…

Reactant side: $Al + O_2$	Product side: Al_2O_3	**Conclusion**
1 Al atom 2 O atoms	2 Al atoms 3 oxygen atom	Oxygen is first element to be balanced.
There is no "least common multiplier" for coefficients and need to cross place subscripts. Place subscripts of the O reactant side in the place of coefficient of reactant side and vise versa. $Al + \mathbf{3}\ O_2 \rightarrow \mathbf{2}\ Al_2O_3$		Oxygen is balanced. Aluminum is not balanced.
1 Al atom 6 O atoms	4 Al atom 6 O atoms	

Step of 2 of balancing: Pick the seconds element to be balanced…

Reactant side: $Al + \mathbf{3}\ O_2$	Product side: $\mathbf{2}\ Al_2O_3$	**Conclusion**
1 Al atom 2 O atoms	2 Al atoms 3 oxygen atom	Aluminum is second element to be balanced.
$Al + \mathbf{3}\ O_2 \rightarrow \mathbf{2}\ Al_2O_3$ Place 4 in the place of coefficient of reactant side.		Oxygen is balanced Aluminum is balanced
4 Al atom 2 O atoms	4 Al atom 2 O atoms	

Balanced chemical equation: Al (s) + **3** O_2(g) → **2** Al_2O_3 (s)

Example: Ethane is a gas burns in oxygen to give carbon dioxide gas and steam which is simply water in gaseous form and condenses to form water droplets. Here is the chemical equation rewritten with the chemical symbols:

Ethane- C_2H_6(g) + Oxygen- O_2(g) → Carbon Dioxide- CO_2(g) + water- H_2O(l)

C_2H_6(g) + O_2(g) → CO_2(g) + H_2O(l)

Check the atomic balance: Count the number of atoms on both sides

Reactant side: C_2H_6 + O_2	Product side: CO_2 + H_2O	**Conclusion**
2 C atom 6 H atoms 2 O atoms	1 C atom 2 H atoms 3 O atoms	Reaction is not balanced.

Step of 1 of balancing: Pick the first element to be balanced…

Reactant side: C_2H_6 + O_2	Product side: CO_2 + H_2O	**Conclusion**
6 H atoms 2 O atoms 2 C atom	2 H atoms 3 O atoms 1 C atom	Hydrogen is the first element to be balanced.
Multiply coefficient of H on product with 3 to balance H. $C_2H_6 + O_2 \rightarrow CO_2 + \mathbf{3}\ H_2O$		Hydrogen is balanced. Oxygen is not balanced. Carbon is not balanced.
6 H atoms 2 O atoms 2 C atom	6 H atoms 5 O atoms 1 C atom	

Step of 2 of balancing: Pick the seconds element to be balanced…

Reactant side: C_2H_6 + O_2	Product side: CO_2 + **3**H_2O	**Conclusion**
$C_2H_6 + O_2 \rightarrow \mathbf{2}CO_2 + \mathbf{3}\ H_2O$ Multiply the coefficient of CO_2 on product side by 2.		Carbon is the second element to be balanced.
		Hydrogen is balanced Carbon is balanced
6 H atoms 4 C atom 2 O atoms	6 H atoms 4 C atom 5 O atoms	

Step of 3 of balancing: Pick the third element to be balanced…

Reactant side: C_2H_6 + O_2	Product side: **2** CO_2 + **3**H_2O	**Conclusion**
$C_2H_6 + \mathbf{5}\ O_2 \rightarrow \mathbf{2}CO_2 + \mathbf{3}\ H_2O$ Multiply the coefficient of O_2 on reactant side by 5.		Carbon is the second element to be balanced.
		Hydrogen is balanced Carbon is balanced Oxygen is balanced
6 H atoms 4 C atom 10 O atoms	6 H atoms 4 C atom 10 O atoms	

Balanced chemical equation: $C_2H_6(g) + \mathbf{5}\ O_2(g) \rightarrow \mathbf{2}CO_2(g) + \mathbf{3}\ H_2O(l)$

Practice Problem Indicate whether the following equations are balanced as written.
2 KNO_3 + 10 K ---> 6 K_2O + N_2 **Answer:** Atoms of all elements Balanced.
2 NH_3 + O_2 ---> N_2 + 3 H_2O **Answer:** **Except O atoms**, N and H atoms are balanced.
SF_4 + 3 H_2O ---> H_2SO_3 + 4 HF **Answer:** Atoms of all elements Balanced.
4 BF_3 + 3 H_2O ---> H_3BO_3 + 3 HBF_4 Atoms of all elements Balanced.
3 Cl_2 + 6 NaOH ---> 5 NaCl + $NaClO_3$ + 3 H_2O Atoms of all elements Balanced.

Practice Problem Balance the following equations.
$TiCl_4$ + H_2O ---> TiO_2 + HCl **Answer:** Stoichiometric coefficients**:** 1, 4, 1, 4
C_4H_{10} + O_2 ---> CO_2 + H_2O **Answer:** Stoichiometric coefficients**:** 2, 13, 8, 10
WO_3 + H_2 ---> W + H_2O **Answer:** Stoichiometric coefficients**:** 1, 3, 1, 3
Al_4C_3 + H_2O ---> $Al(OH)_3$ + CH_4 **Answer:** Stoichiometric coefficients**:** 1, 12, 4, 3
$Al_2(SO_4)_3$ + NaOH ---> $Al(OH)_3$ + Na_2SO_4 **Answer:** Stoichiometric coefficients**:** 1, 6, 2, 3
Ca_3P_2 + H_2O ---> $Ca(OH)_2$ + PH_3 **Answer:** Stoichiometric coefficients**:** 1, 6, 3, 2
Cl_2O_7 + H_2O ---> $HClO_4$ **Answer:** Stoichiometric coefficients**:** 1, 1, 2
MnO_2 + HCl ---> $MnCl_2$ + Cl_2 + H_2O **Answer:** Stoichiometric coefficients**:** 1, 4, 1, 1, 2

$Fe + O_2$ ---> Fe_3O_4 **Answer:** Stoichiometric coefficients**:** 3, 2, 1
$C_5H_{12} + O_2$ ---> $CO_2 + H_2O$ **Answer:** Stoichiometric coefficients**:** 1, 8, 5, 6

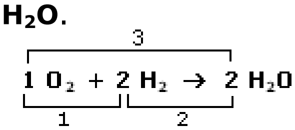
6.7 Chemical Equations and the Mole Concept

One of the most important information that we extract form a chemical equation is the mole conversion factors using stoichiometrci coefficents. For example in the reaction:

$$\mathbf{O_2(g) + 2\,H_2(g) \rightarrow 2\,H_2O(l)}$$

Stoichiometric and coefficients of O_2, H_2 and **H_2O** has **1, 1** and **2**, as their stoichiometric coefficients, respectively. They are used to get the mole conversion factors for chemical calculations:

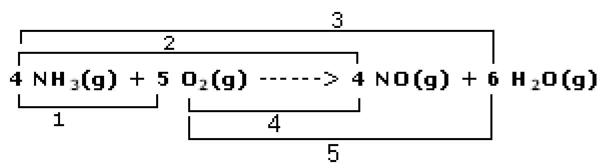
Mole conversion factors are all simple cross combinations of stoichiometric coefficients written in moles: **1 O_2, 2 H_2** and **2 H_2O**.



1) **1 mol O_2 = 2 mol H_2**; **2 mol H_2 = 2 mol H_2O** and 3) **1 mol O_2 = 2 mol H_2O**
They are used in converting moles one chemical to another in the equation.

What are the mole conversion factors in the following equation?

$$\mathbf{4\,NH_3(g) + 5\,O_2(g) \text{------>} 4\,NO(g) + 6\,H_2O(g)}$$



1) 4 mol NH_3 = 5 mol O_2
2) 4 mol NH_3 = 4 mol NO or 1 mole NH_3 = 1 mole NO
3) 4 mol NH_3 = 6 mol H_2O or 2 mol NH_3 = 3 mol H_2O
4) 5 mol O_2 = 4 mol NO
5) 5 mol O_2 = 6 mol H_2O

Converting moles of Reactants to Products

Once you have obtained the mole conversion factors any mole conversions could be carried out using factor label method. There is a **important thing to remember** in mole conversions: If there are more than one reactant. **Never use the element in excess** in mole conversions since it will be some left over at the end of the reaction.

Example: Calculate the following using the chemical equation given below:

$$\mathbf{4\,NH_3(g) + 5\,O_2(g) \rightarrow 4\,NO(g) + 6\,H_2O(g)}$$

a) moles of NO(g) from 2 moles of NH_3(g) and **excess O_2(g)**.
Get the mole conversion factor for NH_3 and NO : 1 mole NH_3 = 1 mole NO

2 ~~mol of NH_3~~ 1 mol NO

$$\frac{\quad\quad}{1} \times \frac{\quad\quad}{1\ \text{mol of } NH_3} = \underline{\textbf{2 mol NO}}$$

b) moles of H_2O(g) from 3 moles of O_2(g) and **excess NH_3(g)**.

Get the mole conversion factor for O_2 and H_2O: 5 mole O_2 = 6 mole H_2O

$$\frac{3\ \text{mol of } O_2}{1} \times \frac{6\ \text{mol } H_2O}{5\ \text{mol of } O_2} = \underline{\textbf{3.6 mol } H_2O}$$

Practice problems: Given the balanced chemical equation:

$$\mathbf{2\ C_8H_{18}\,(l) + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O}$$

a) How many **moles of H_2O** are produced when 2.81 moles of octane is burned?
(**Answer**: 25.3 mol of H_2O)

b) How many **grams of H_2O** are produced when 2.81 moles of octane is burned?
(**Answer**: 455.4 mol of H_2O)

c) How many **moles of CO_2** are produced when 4.06 moles of oxygen is consumed?
(**Answer**: 2.60 mol of CO_2)

d) How many **grams of CO_2** are produced when 4.06 moles of oxygen is consumed?
(**Answer**: 114.4 mol of CO_2)

6.8 Chemical Calculations Using Chemical Equations: Stiochiometry

Stiochiometry is a general word that use for calculation of yield of products starting with certain amount of reactants in grams. The first step in a stoichiometrci calculation is the conversion of grams of reactants moles of reactants by diving with formula mass. Then moles of reactants are converted moles products using mole conversion factor. Finally the grams of products are obtained by multiplying mole of products with formula mass.

Stiochiometry problems involving grams of reactants and products

Example: Calculate the following using the chemical equation given below:

$$\mathbf{4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)}$$

a) **How many grams of grams of NO(g)** is produced from 38.08 grams of NH_3(g) and **excess O_2(g)**.

First convert 38.08 grams of NH_3 to moles by diving grams by formula mass (NH_3 = 17.04 g/mol), get the mole conversion factor for NH_3 and NO: 1 mole NH_3 = 1 mole NO, convert mole NH_3 to mole NO and the convert mole NO to grams of NO by multiplying with by formula mass (NO = 30.01 g/mol) using factor label method:

$$\frac{38.08\ \text{g } NH_3}{1} \times \frac{1\ \text{mol } NH_3}{17.04\ \text{g } NH_3} \times \frac{1\ \text{mol NO}}{1\ \text{mol } NH_3} \times \frac{30.01\ \text{g NO}}{1\ \text{mol NO}} = \underline{\textbf{67.1 g NO}}$$

b) **How many grams of $H_2O(g)$** is produced from 48.0 g of $O_2(g)$ and **excess $NH_3(g)$**.

Get, the formula masses (H_2O= 18.02 g/mol and O2 = 32.00 g/mole) the mole conversion factor for moles O_2 to H_2O: 5 mole O_2 = 6 mole H_2O

$$\frac{48.0\ \cancel{g\ O_2}}{1} \times \frac{1\ \cancel{mol\ O_2}}{32.00\ \cancel{g\ O_2}} \times \frac{6\ \cancel{mol\ H_2O}}{5\ \cancel{mol\ O_2}} \times \frac{18.02\ \cancel{g\ H_2O}}{1\ \cancel{mole\ H_2O}} = \underline{\mathbf{32.44\ g\ H_2O}}$$

Practice problem: Given the balanced chemical equation:

$$\mathbf{C_7H_8 + 3\ HNO_3 \dashrightarrow C_7H_5N_3O_6 + 3\ H_2O}$$

What **mass of nitric acid**, in grams, is required to react with 454 g of C_7H_8?
(**Answer**: 932.4 g of HNO_3)

Chemistry at a Glance: Relationships Involving the Mole Concept
Chemical Connections: Chemical Reactions on an Industrial Scale: Sulfuric Acid