**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**:

1. Calcium oxide, a simple ionic solid consisting of one calcium ion, Ca2+ and one oxide ion, O2- has the chemical formula: **CaO** not **Ca2O2.**
2. Calcium chloride, a simple ionic solid consisting of one calcium ion, Ca2+ and two chloride ions, 2Cl- has the chemical formula:**CaCl2**.
3. Sodium sulfate with two sodium ions, 2Na+ and one sulfate ion, (SO4)2- has the chemical formula: **Na2SO4**.

**Covalent compounds**

1. 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**:

1. Methane, a simple molecule consisting of one carbon atom bonded to four hydrogen atoms, has the chemical formula:**CH4**.
2. Glucose with six carbon atoms, twelve hydrogen atoms and six oxygen atoms has the chemical formula: **C6H12O6**. 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**?

|  |  |  |
| --- | --- | --- |
| **Na2CO3** | **NH4Cl** | **Al2(SO4)3** |
| Na= 2 x 22.99 = 45.9**8**C = 1 x 12.01 = 12.0**1**O = 3 x 16.00 = 48.0**0** | N = 1 x 14.01 = 14.0**1**H = 4 x 1.01 = 4. 0**4**Cl = 1 x 35.45 = 35.4**5** | Al = 2 x 26.98 = 53.9**6**S = 3 x 32.07 = 96.2**1**O = 12 x 16.00 = 192.0**0** |
| (**Formula mass)**  105.9**9** |  (**Formula mass)** 53.5**0** | (**Formula mass)**  342.1**7** |

**Calculate the formula mass of the following ionic compounds:**

**a) NaCl, b) K2CO3, and c) Fe2(CO3)3**.

**Answers:** a) NaCl (**58.45 g/mol** ), b) K2CO3 (**138.2 g/mol**) and c) Fe2(CO3)3 (**294.73 g/mol**)

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

|  |  |  |
| --- | --- | --- |
| **H3PO4** | **H2SO4** | **C6H12O6** |
| H = 3 x 1.01 = 3.0**3**P = 1 x 30.97 = 30.9**7**O = 4 x 16.00 = 64.0**0** | H = 3 x 1.01 = 3.0**3**S = 1 x 32.07 = 32.0**7**O = 4 x 16.00 = 64.0**0** | C = 6 x 12.01 = 72.0**6**H = 12 x 1.01 = 12.1**2**O = 6 x 16.00 = 96.0**0** |
| (**Formula mass)**  98.0**0** | (**Formula mass)**  99.1**0** | (**Formula mass)** 180.1**8** |

**Practice Problems**: Calculate the molecular mass or formula mass of each of the following compounds.
a) SO3  b) KBrO3  c) CaSO4d)(NH4)3PO4    e) Fe(NO3)3     f) C2H5NO2     g) MgS2O3

**Answers** a) SO3 (80.1 g/mol) b) KBrO3 (167.2 g/mol) c)  CaSO4(136.2 g/mol)

d)(NH4)3PO4  (149 g/mol)  e) Fe(NO3)3 (241.8 g/mol)    f) C2H5NO2 (75 g/mol)  g) MgS2O3 (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 x 1023**) 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 x 1023**.

**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 x 1023 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 x 1023.

          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 x 1023. In other words **gram atomic weight** or **gram molecular weight** contains 6.022 x 1023 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 C6H12O6 is 180**.**18 g since Formula mass of C6H12O6 is180**.**18 g/mole. Molar mass contains mole (6.022 x 1023) of formula (C6H12O6) 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.

|  |  |  |
| --- | --- | --- |
| 23.0 g sodium |  or | 1 mole sodium |
| 1 mole sodium | 23.0 g sodium  |

 **Important****conversion factors used in chemical stiochiometry.**

|  |
| --- |
| 1 amu = 1 g/mol |
| 1 amu = 1 g/6.022 x 1023 |
| 1 g = 6.022 x 1023 amu |
| 6.022 x 1023 atoms C = 12.01 grams of carbon (C) |
| **Atoms**gram atomic weight = 6.022 x 1023 atoms 12.01 g of C = 6.022 x 1023 atoms |
| **Molecules**gram molecular weight = 6.022 x 1023 atoms 182.02 g of H2O = 6.022 x 1023 H2O molecules182.02 g of H2O = 2 X 6.022 x 1023 H atoms182.02 g of H2O = 1 X 6.022 x 1023 OH atoms |
| **Ionic compounds**Molar mass = 6.022 x 1023 formula unitsGrams Formula mass = 6.022 x 1023 formula units105.99 gof Na2CO3 = 6.022 x 1023 Na2CO3 formula units105.99 gof Na2CO3 = 2 x 6.022 x 1023 Na+ ions105.99 gof Na2CO3 = 1 x 6.022 x 1023 Cl- ions |
| **Covalent compounds**Molar mass = 6.022 x 1023 moleculesGrams Formula mass = 6.022 x 1023 molecules180.18g of C6H12O6 = 6.022 x 1023 C6H12O6) molecules180.18g of C6H12O6 = 6 x 12.01 g C atoms = 6 X 6.022 x 1023 C atoms180.18g of C6H12O6 = 12 x 1.01 g H atoms = 12 X 6.022 x 1023 C atoms180.18g of C6H12O6 = 6 x 16.00 g O atoms = 6 X 6.022 x 1023 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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 180.1 ~~g Fe~~ | x  |  | 1 mol              |  = 3.225 mol Fe |
|  | 55.85 ~~g Fe~~  |

**b) How many moles of K2SO4 are present in 180.1g of potassium sulfate?**

Formula mass (K2SO4) = 174.26 g/mol

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

Formula mass (K2SO4) = 174.26 g/mole K2SO4 = 1 mol

Conversion factor is 174.26 g K2SO4 = 1 mol K2SO4

Using factor label method:

|  |  |  |  |
| --- | --- | --- | --- |
| 180.1 ~~g K~~~~2~~~~SO~~~~4~~ |  x | 1 mol K2SO4 | = 1.033 mol K2SO4 |
|   1 | 174.26 ~~g K~~~~2~~~~SO~~~~4~~ |

**Moles to grams calculations**

**a) How many grams are in 4.61 mol AlCl3?**

Formula mass (AlCl3) = 133.5 g/mole, Conversion factor is 133.5 g AlCl3 = 1 mol AlCl3

|  |  |  |  |
| --- | --- | --- | --- |
| 4.61 ~~mol AlCl~~~~3~~ |  x | 133.5 g AlCl3  | = **615.5 g AlCl3** |
|   1 | 1 ~~mol AlCl~~~~3~~ |

**b) How many grams are in 0.158 mol IF5?**

Formula mass (IF3) = 220.0 g/mole, Conversion factor is 220.0 g IF5 = 1 mol IF5

|  |  |  |  |
| --- | --- | --- | --- |
| 0.158 ~~mol IF~~~~5~~ |  x | 220.0 g IF5  | = **35.1 g IF5** |
|   1 | 1 ~~mol 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 x 1023 S atoms

|  |  |  |  |
| --- | --- | --- | --- |
| 5.00 ~~mol S~~ |  x | 6.022 x 1023 S atoms | = **3.00 x 1024 S atoms** |
|   1 | 1 ~~mol S~~ |

**Mass of atoms in grams**

**What is the mass of 7.5 x 105 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 1023 atoms 6.022 x 1023 Cu atoms = 63.55 grams Cu Therefore,

|  |  |  |  |
| --- | --- | --- | --- |
| 7.5 x 105 ~~Cu atom~~ | x |   atoms63.55 g Cu | =7.9 x 10-17g Cu |
|   |      6.022 x 1023 ~~Cu atom~~ |

**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** Δ**H:**  A negative value indicates (**exothermic (-)** thatheat given outand 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**, O2.  Most elements in the gas form are diatomic. This could be translated into a chemical equation through following steps:

 **Oxygen + Hydrogen → water**

 **O2(g) + 2 H2(g) → 2 H2O(l);** Δ**H= -572 kJ**

**Interpret the information conveyed by this chemical equation**:

**Reactants and products**: **O2** and **H2** are reactants and **H2O** is the product**.**

**Stoichiometric and coefficients: O2,** **H2** and **H2O** has **1, 1** and **2**, as their stoichiometric coefficients, respectively. They are used to get the mole conversion factors:

**Physical sate of chemicals**: **O2,** **H2** are gases and **H2O** is a liquid at 25°C.

**Degree of reaction completion**: **O2** and **H2** are completely **(→) irreversibly** converted to **H2O (**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 (**hν**) sings are written on top of the arrow **(→).**

**Themochemical data** Δ**H:** 572 kJ of (**exothermic (-)** heat given out per each 2mole of **H2** burned and 2mole of **H2O** 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) Al2(C2O4)3 | b) Ca3(PO4)2 |  c) 2 C6H12O6 | d) 3 Al2(SO4)3 |
| Answers: |
| 2Al atoms6 C atoms12 O atoms | 3 Ca atoms2 P atoms8 O atoms | 12 C atoms24 H atoms12 O atoms | 6 Al atoms9 S atoms36 O atoms |

**Atomic balance** in achemicalequation 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. C2H6(g) + O2(g) **→** CO2(g) + H2O(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- O2(g) **→** Aluminium Oxide-Al2O3

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

Al + O2 **→**Al2O3

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

|  |  |  |
| --- | --- | --- |
| Reactant side: Al + O2 | Product side: Al2O3 | **Conclusion** |
| 1 Al atom2 O atoms | 2 Al atoms3 oxygen atom | Reaction is not balanced. |

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

|  |  |  |
| --- | --- | --- |
| Reactant side: Al + O2 | Product side: Al2O3 | **Conclusion** |
| 1 Al atom2 O atoms | 2 Al atoms3 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 + **3** O2 **→ 2** Al2O3  | Oxygen is balanced.Aluminum is not balanced. |
| 1 Al atom6 O atoms | 4 Al atom6 O atoms |

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

|  |  |  |
| --- | --- | --- |
| Reactant side: Al + **3** O2 | Product side: **2** Al2O3  | **Conclusion** |
| 1 Al atom2 O atoms | 2 Al atoms3 oxygen atom | Aluminum is second element to be balanced. |
|  Al + **3** O2 **→ 2** Al2O3 Place 4 in the place of coefficient of reactant side. | Oxygen is balancedAluminum is balanced |
| 4 Al atom2 O atoms | 4 Al atom2 O atoms |

Balanced chemical equation: Al (s) + **3** O2(g) **→ 2** Al2O3 (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- C2H6(g) + Oxygen- O2(g) **→** Carbon Dioxide- CO2(g) + water- H2O(l)

C2H6(g) + O2(g) **→** CO2(g) + H2O(l)

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

|  |  |  |
| --- | --- | --- |
| Reactant side: C2H6 + O2 | Product side: CO2 + H2O | **Conclusion** |
| 2 C atom6 H atoms2 O atoms | 1 C atom2 H atoms3 O atoms | Reaction is not balanced. |

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

|  |  |  |
| --- | --- | --- |
| Reactant side: C2H6 + O2 | Product side: CO2 + H2O | **Conclusion** |
| 6 H atoms2 O atoms 2 C atom | 2 H atoms3 O atoms 1 C atom | Hydrogen is the first element to be balanced. |
| Multiply coefficient of H on product with 3 to balance H.C2H6 + O2 **→** CO2 + **3** H2O | Hydrogen is balanced.Oxygen is not balanced.Carbon is not balanced. |
| 6 H atoms2 O atoms 2 C atom | 6 H atoms5 O atoms 1 C atom |

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

|  |  |  |
| --- | --- | --- |
| Reactant side: C2H6 + O2  | Product side: CO2+ **3**H2O | **Conclusion** |
| C2H6 + O2 **→**  **2**CO2 + **3** H2OMultiply the coefficient of CO2on product side by 2. | Carbon is the second element to be balanced. |
|  | Hydrogen is balancedCarbon is balanced |
| 6 H atoms4 C atom2 O atoms  | 6 H atoms4 C atom 5 O atoms  |

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

|  |  |  |
| --- | --- | --- |
| Reactant side: C2H6 + O2  | Product side: **2** CO2+ **3**H2O | **Conclusion** |
| C2H6 + **7/2** O2 **→**  **2**CO2 + **3** H2OMultiply the coefficient of O2on reactant side by 7/2. | Carbon is the second element to be balanced. |
|  | Hydrogen is balancedCarbon is balancedOxygen is balanced |
| 6 H atoms2 C atom7 O atoms  | 6 H atoms2 C atom 7 O atoms  |
| To make the coefficient 9/2 a whole number multiply all by 2. 2 C2H6 + **7** O2 **→**  **4** CO2 + **6**  H2O | Hydrogen is balancedCarbon is balancedOxygen is balanced |
| 12 H atoms4 C atom14 O atoms  | 12 H atoms4 C atom 14 O atoms  |

Balanced chemical equation: 2 C2H6 + **7** O2 **→**  **4** CO2 + **6**  H2O

**Practice Problem**   Indicate whether the following equations are balanced as written.

2 KNO3  +  10 K --->  6 K2O  +  N2 **Answer:** Atoms ofall elementsBalanced.

2 NH3  +  O2  --->   N2  +  3 H2O **Answer: Except O atoms**, N and H atomsare balanced.

SF4  + 3 H2O  --->  H2SO3  + 4 HF  **Answer:** Atoms ofall elementsBalanced.

4 BF3  + 3 H2O  --->  H3BO3  + 3 HBF4 Atoms ofall elementsBalanced.

3 Cl2  +  6 NaOH  --->  5 NaCl  +  NaClO3  +  3 H2O   Atoms ofall elementsBalanced.

**Practice Problem   Balance the following equations**.

TiCl4  +  H2O  --->   TiO2  +  HCl    **Answer:** Stoichiometric coefficients**:** 1, 4, 1, 4

C4H10  +  O2  --->   CO2  +  H2O    **Answer:** Stoichiometric coefficients**:** 2, 13, 8, 10

WO3  +  H2  --->  W  + H2O     **Answer:** Stoichiometric coefficients**:** 1, 3, 1, 3

Al4C3  +  H2O  --->  Al(OH)3  +  CH4 **Answer:** Stoichiometric coefficients**:** 1, 12, 4, 3

Al2(SO4)3  +  NaOH ---> Al(OH)3  +  Na2SO4 **Answer:** Stoichiometric coefficients**:** 1, 6, 2, 3

Ca3P2  +  H2O  --->  Ca(OH)2  +  PH3 **Answer:** Stoichiometric coefficients**:** 1, 6, 3, 2

Cl2O7  + H2O  --->  HClO4 **Answer:** Stoichiometric coefficients**:** 1, 1, 2

MnO2  +  HCl  --->  MnCl2  +  Cl2  +  H2O  **Answer:** Stoichiometric coefficients**:** 1, 4, 1, 1, 2

Fe  +  O2  --->  Fe3O4 **Answer:** Stoichiometric coefficients**:** 3, 2, 1

C5H12  +  O2 --->  CO2  +  H2O    **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:

 **O2(g) + 2 H2(g) → 2 H2O(l)**

**Stoichiometric and coefficients of O2,** **H2** and **H2O** 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** **O2, 2 H2** and **2** **H2O**.

1) **1 mol O2 = 2 mol H2**; **2 mol H2 = 2 mol H2O** and 3) **1 mol O2 = 2 mol H2O**

They are used in converting moles one chemical to another in the equation.

**What are the mole conversion factors in the following equation**?

 **4 NH3(g) + 5 O2(g) ------> 4 NO(g) + 6 H2O(g)**

1) 4 mol NH3 = 5 mol O2

2) 4 mol NH3 = 4 mol NO or 1 mole NH3 = 1 mole NO

3) 4 mol NH3 = 6 mol H2O or 2 mol NH3 = 3 mol H2O

4) 5 mol O2 = 4 mol NO

5) 5 mol O2 = 6 mol H2O

**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:

**4 NH3(g) + 5 O2(g) → 4 NO(g) + 6 H2O(g)**

a) moles of NO(g) from 2 moles of NH3(g) and **excess O2(g)**.

 Get the mole conversion factor for NH3 and NO : 1 mole NH3 = 1 mole NO

|  |  |  |  |
| --- | --- | --- | --- |
| 2 ~~mol of NH~~~~3~~ |  x | 1 mol NO | = **2 mol NO** |
|   1 | 1 ~~mol of NH~~~~3~~ |

b) moles of H2O(g) from 3 moles of O2(g) and **excess NH3(g)**.

 Get the mole conversion factor for O2 and H2O: 5 mole O2 = 6 mole H2O

|  |  |  |  |
| --- | --- | --- | --- |
| 3 ~~mol of O~~~~2~~ |  x | 6 mol H2O | = **3.6 mol H2O** |
|   1 | 5 ~~mol of O~~~~2~~ |

**Practice problems**: Given the balanced chemical equation:

 **2 C8H18 (l) +  25  O2 → 16 CO2  +  18 H2O**

a) How many **moles of H2O** are produced when 2.81 moles of octane is burned?

 (**Answer**: 25.3 mol of H2O)
b) How many **grams of H2O** are produced when 2.81 moles of octane is burned?

 (**Answer**: 455.4 mol of H2O)

c) How many **moles of CO2** are produced when 4.06 moles of oxygen is consumed?

 (**Answer**: 2.60 mol of CO2)
d) How many **grams of CO2** are produced when 4.06 moles of oxygen is consumed?

 (**Answer**: 114.4 mol of CO2)

**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:

**4 NH3(g) + 5 O2(g) → 4 NO(g) + 6 H2O(g)**

a) **How many grams of** **grams of NO(g)** is produced from 38.08 grams of NH3(g) and **excess O2(g)**.

 First convert 38.08 grams of NH3 to moles by diving grams by formula mass (NH3 = 17.04 g/mol), get the mole conversion factor for NH3 and NO: 1 mole NH3 = 1 mole NO, convert mole NH3 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:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 38.08 ~~g NH~~~~3~~ | x | ~~1 mol NH~~~~3~~ | x | 1 ~~mol NO~~ | x | 30.01 g NO | = **67.1 g NO** |
|   1 | 17.04 ~~g NH~~~~3~~ | 1 ~~mol NH~~~~3~~ | 1 ~~mol NO~~ |

b) **How many grams of H2O(g)** is produced from 48.0 g of O2(g) and **excess NH3(g)**.

 Get, the formula masses (H2O= 18.02 g/mol and O2 = 32.00 g/mole) the mole conversion factor for moles O2 to H2O: 5 mole O2 = 6 mole H2O

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 48.0 ~~g O~~~~2~~ | x | 1 ~~mol O~~~~2~~ | x | 6 ~~mol H~~~~2~~~~O~~ | x | 18.02 ~~g H~~~~2~~~~O~~ | = **32.44 g H2O** |
|   1 | 32.00 ~~g O~~~~2~~ | 5 ~~mol O~~~~2~~ | 1 ~~mole H~~~~2~~~~O~~ |

**Practice problem**: Given the balanced chemical equation:

 **C7H8   +   3  HNO3   --->   C7H5N3O6    +   3 H2O**

What **mass of nitric acid**, in grams, is required to react with 454 g of C7H8?

 (**Answer**: 932.4 g of HNO3)

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