1.2 Moles, Density and Concentration

1.2.1 Mole

In the SI system a mole is composed of 6.022 x 10^{23} (**Avogadro's number**) molecules. To convert the number of moles to mass and the mass to moles, we make use of the **molecular weight** – the mass per mole:

$$\text{Molecular Weight (MW)} = \frac{\text{Mass}}{\text{Mole}}$$

Thus, the calculations you carry out are

$$\text{the g mol} = \frac{\text{mass in g}}{\text{molecular weight}}$$

$$\text{the lb mol} = \frac{\text{mass in lb}}{\text{molecular weight}}$$

and

Mass in g = (MW) (g mol)

Mass in lb = (MW) (lb mol)

For example

$$\frac{100.0 \text{ g } H_2O}{} \left| \frac{1 \text{ g mol } H_2O}{18.0 \text{ g } H_2O} \right. = 5.56 \text{ g mol } H_2O$$

$$\frac{6.0 \text{ lb mol } O_2}{} \left| \frac{32.0 \text{ lb } O_2}{1 \text{ lb mol } O_2} \right. = 192 \text{ lb } O_2$$

- **<u>The atomic weight</u>** of an element is the mass of an atom based on the scale that assigns a mass of exactly 12 to the carbon isotope ^{12}C.
- A **<u>compound</u>** is composed of more than one atom, and the molecular weight of the compound is nothing more than the sum of the weights of atoms of which it is composed.

<u>Example 8</u>

What is the molecular weight of the following cell of a superconductor material? (The figure represents one cell of a larger structure.)

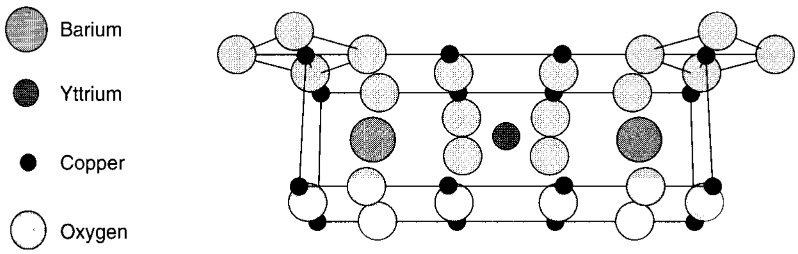

Figure E2.1

Solution

Element	Number of atoms	Atomic weights	Mass (g)
Ba	2	137.34	2(137.34)
Cu	16	63.546	16(63.546)
O	24	16.00	24(16.00)
Y	1	88.905	1(88.905)
		Total	1764.3

The molecular weight of the cell is 1764.3 g/g mol.

Example 9

If a bucket holds 2.00 lb of NaOH (MW=40), how many

a) Pound moles of NaOH does it contain?

b) Gram moles of NaOH does it contain?

Solution

(a) $$\frac{2.00 \text{ lb NaOH}}{} \left| \frac{1 \text{ lb mol NaOH}}{40.0 \text{ lb NaOH}} \right. = 0.050 \text{ lb mol NaOH}$$

(b$_1$) $$\frac{2.00 \text{ lb NaOH}}{} \left| \frac{1 \text{ lb mol NaOH}}{40.0 \text{ lb NaOH}} \right| \frac{454 \text{ g mol}}{1 \text{ lb mol}} = 22.7 \text{ g mol}$$

(b$_2$) $$\frac{2.00 \text{ lb NaOH}}{} \left| \frac{454 \text{ g}}{1 \text{ lb}} \right| \frac{1 \text{ g mol NaOH}}{40.0 \text{ g NaOH}} = 22.7 \text{ g mol}$$

Example 10

How many pounds of NaOH (MW=40) are in 7.50 g mol of NaOH?

Solution

$$\frac{7.50 \text{ g mol NaOH}}{} \left| \frac{1 \text{ lb mol}}{454 \text{ g mol}} \right| \frac{40.0 \text{ lb NaOH}}{1 \text{ lb mol NaOH}} = 0.661 \text{ lb NaOH}$$

1.2.2 Density

Density is the ratio of mass per unit volume, as for example, kg/m^3 or lb/ft^3. Density has both a numerical value and units. **Specific volume** is the inverse of density, such as cm^3/g or ft^3/lb.

$$\rho = \text{density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

$$\hat{V} = \text{specific volume} = \frac{\text{volume}}{\text{mass}} = \frac{V}{m}$$

For example, given that the density of n-propyl alcohol is 0.804 g/cm^3, what would be the volume of 90.0 g of the alcohol? The calculation is

$$\frac{90.0\ g}{} \left| \frac{1 \text{ cm}^3}{0.804\ g} \right. = 112 \text{ cm}^3$$

❖ In a packed bed of solid particles containing void spaces, the bulk density is

$$\rho_B = \text{bulk density} = \frac{\text{total mass of solids}}{\text{total empty bed volume}}$$

❖ A homogeneous mixture of two or more components, whether solid, liquid, or gaseous, is called a **solution**. For some solutions, the density of the solution is

$$V = \sum_{i=1}^{n} V_i \qquad \text{where } n = \text{number of components}$$

$$m = \sum_{i=1}^{n} m_i$$

$$\rho_{\text{solution}} = \frac{m}{V}$$

For others you cannot.

Specific Gravity

Specific gravity is commonly thought of as a dimensionless ratio.

$$\text{sp.gr. of } A = \textbf{specific gravity} \text{ of } A = \frac{(\text{g/cm}^3)_A}{(\text{g/cm}^3)_{ref}} = \frac{(\text{kg/m}^3)_A}{(\text{kg/m}^3)_{ref}} = \frac{(\text{lb/ft}^3)_A}{(\text{lb/ft}^3)_{ref}}$$

- The reference substance for **liquids** and **solids** normally is **water**.
- The density of water is **1.000 g/cm^3, 1000 kg/m^3, or 62.43 lb/ft^3 at 4°C**.
- The specific gravity of **gases** frequently is referred to **air**, but may be referred to other gases.

For Example If dibromopentane (DBP) has a specific gravity of 1.57, what is the density in (a) g/cm^3? (b) lb$_m$/ft^3? and (c) kg/m^3?

(a)
$$\frac{1.57\,\frac{\text{g DBP}}{\text{cm}^3}}{1.00\,\frac{\text{g H}_2\text{O}}{\text{cm}^3}} \left| \frac{1.00\,\frac{\text{g H}_2\text{O}}{\text{cm}^3}}{} \right. = 1.57\,\frac{\text{g DBP}}{\text{cm}^3}$$

(b)
$$\frac{1.57\,\frac{\text{lb DBP}}{\text{ft}^3}}{1.00\,\frac{\text{lb H}_2\text{O}}{\text{ft}^3}} \left| \frac{62.4\,\frac{\text{lb H}_2\text{O}}{\text{ft}^3}}{} \right. = 97.97\,\frac{\text{lb DBP}}{\text{ft}^3}$$

(c)
$$\frac{1.57\text{g DBP}}{\text{cm}^3} \left| \left(\frac{100\text{ cm}}{1\text{ m}}\right)^3 \right| \frac{1\text{ kg}}{1000\text{ g}} = 1.57 \times 10^3\,\frac{\text{kg DBP}}{\text{m}^3}$$

or

$$\frac{1.57\,\frac{\text{kg DBP}}{\text{m}^3}}{1.00\,\frac{\text{kg H}_2\text{O}}{\text{m}^3}} \left| \frac{\frac{1.00 \times 10^3\text{kg H}_2\text{O}}{\text{m}^3}}{} \right. = 1.57 \times 10^3\,\frac{\text{kg DBP}}{\text{m}^3}$$

Example 11

If a 70% (by weight) solution of glycerol has a specific gravity of 1.184 at 15°C, what is the density of the solution in (a) g/cm^3? (b) lbm/ft^3? and (c) kg/m^3?

Solution

(a) (1.184 g glycerol/ cm^3)/(1 g water/ cm^3) * (1 g water/ cm^3) = 1.184 g solution/cm^3.

(b) (1.184 lb glycerol/ft^3)/(1 lb water/ft^3) * (62.4 lb water/ft^3) = 73.9 lb solution/ft^3.

(c) (1.184 kg glycerol/m^3)/(1 kg water/m^3) * (1000 kg water/m^3) = 1.184 * 10^3 kg solution/m^3.

The specific gravity of petroleum products is often reported in terms of a hydrometer scale called °API. The equation for the API scale is

$$°\text{API} = \frac{141.5}{\text{sp.gr.}\frac{60°\text{F}}{60°\text{F}}} - 131.5 \qquad (\text{API gravity}) \qquad (2.1)$$

or

$$\text{sp.gr.}\frac{60°}{60°} = \frac{141.5}{°\text{API} + 131.5} \qquad (2.2)$$

The **volume** and therefore the **density** of petroleum products vary with **temperature**, and the petroleum industry has established 60 °F as the standard temperature for volume and API gravity.

Example 12

In the production of a drug having a molecular weight of 192, the exit stream from the reactor flows at a rate of 10.5 L/min. The drug concentration is 41.2% (in water), and the specific gravity of the solution is 1.024. Calculate the concentration of the drug (in kg/L) in the exit stream, and the flow rate of the drug in kg mol/min.

Solution

Take 1 kg of the exit solution as a basis for convenience.

Basis: 1 kg solution

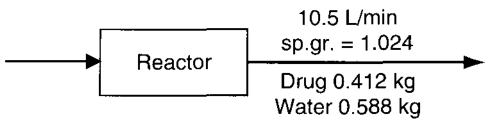

Figure E2.5

$$\text{density of solution} = \frac{1.024\frac{\text{g soln}}{\text{cm}^3}}{1.000\frac{\text{g H}_2\text{O}}{\text{cm}^3}}\left|\frac{1.000\frac{\text{g H}_2\text{O}}{\text{cm}^3}}{}\right. = 1.024\frac{\text{g soln}}{\text{cm}^3}$$

$$\frac{0.412 \text{ kg drug}}{1.000 \text{ kg soln}}\left|\frac{1.024 \text{ g soln}}{1 \text{ cm}^3}\right|\frac{1 \text{ kg}}{10^3 \text{ g}}\left|\frac{10^3\text{cm}^3}{1 \text{ L}}\right. = 0.422 \text{ kg drug/L soln}$$

To get the flow rate, take a different basis, namely 1 minute.

Basis: 1 min = 10.5 L solution

$$\frac{10.5 \text{ L soln}}{1 \text{ min}}\left|\frac{0.422 \text{ kg drug}}{1 \text{ L soln}}\right|\frac{1 \text{ kg mol drug}}{192 \text{ kg drug}} = 0.023 \text{ kg mol/min}$$

Flow Rate

For continuous processes the **flow rate** of a process stream is the rate at which material is transported through a pipe. The **mass flow rate** ($\dot{m}$) of a process stream is the **mass** (**m**) transported through a line per unit **time** (**t**).

$$\dot{m} = \frac{m}{t}$$

The **volumetric flow rate** **(F)** of a process stream is the **volume (V)** transported through a line per unit **time**.

$$F = \frac{V}{t}$$

The **molar flow** ($\dot{n}$) **rate** of a process stream is the number of **moles** (**n**) of a substance transported through a line per unit **time**.

$$\dot{n} = \frac{n}{t}$$

Mole Fraction and Mass (Weight) Fraction

- **Mole fraction** is simply the number of moles of a particular compound in a mixture or solution divided by the total number of moles in the mixture or solution.
- This definition holds for **gases**, **liquids**, and **solids**.
- Similarly, the **mass (weight) fraction** is nothing more than the **mass (weight)** of the compound divided by the total mass (weight) of all of the compounds in the mixture or solution.

Mathematically, these ideas can be expressed as

$$\text{mole fraction of } A = \frac{\text{moles of } A}{\text{total moles}}$$

$$\text{mass (weight) fraction of } A = \frac{\text{mass of } A}{\text{total mass}}$$

Mole percent and **mass (weight) percent** are the respective fractions times **100**.

Example 13

An industrial-strength drain cleaner contains 5 kg of water and 5 kg of NaOH. What are the mass (weight) fractions and mole fractions of each component in the drain cleaner container?

Solution

Basis: 10 kg of total solution

Component	kg	Weight fraction	Mol. Wt.	kg mol	Mole fraction
H_2O	5.00	$\frac{5.00}{10.0} = 0.500$	18.0	0.278	$\frac{0.278}{0.403} = 0.69$
NaOH	5.00	$\frac{5.00}{10.00} = 0.500$	40.0	0.125	$\frac{0.125}{0.403} = 0.31$
Total	10.00	1.000		0.403	1.00

The kilogram moles are calculated as follows:

$$\frac{5.00 \text{ kg } H_2O}{} \left| \frac{1 \text{ kg mol } H_2O}{18.0 \text{ kg } H_2O} \right. = 0.278 \text{ kg mol } H_2O$$

$$\frac{5.00 \text{ kg NaOH}}{} \left| \frac{1 \text{ kg mol NaOH}}{40.0 \text{ kg NaOH}} \right. = 0.125 \text{ kg mol NaOH}$$

Adding these quantities together gives the total kilogram moles.

Example 14

In normal living cells, the nitrogen requirement for the cells is provided from protein metabolism (i.e., consumption of the protein in the cells). When individual cells are commercially grown, $(NH_4)_2SO_4$ is usually used as the source of nitrogen. Determine the amount of $(NH_4)_2SO_4$ consumed in a fermentation medium in which the final cell concentration is 35 g/L in a 500 L volume of the fermentation medium. Assume that the cells contain 9 wt. % N, and that $(NH_4)_2SO_4$ is the only nitrogen source.

Solution

Basis: 500 L solution containing 35 g/L

$$\frac{500\ \text{L}}{}\left|\frac{35\ \text{g cell}}{\text{L}}\right|\frac{0.09\ \text{g N}}{1\ \text{g cell}}\left|\frac{1\ \text{g mol N}}{14\ \text{g N}}\right. \times \frac{1\ \text{g mol }(NH_4)_2SO_4}{1\ \text{g mol N}}\left|\frac{132\ \text{g }(NH_4)_2SO_4}{1\ \text{g mol }(NH_4)_2SO_4}\right. = 14{,}850\ \text{g }(NH_4)_2SO_4$$

Analyses of Multi Components Solutions and Mixtures

The **composition of gases** will always be presumed to be given in **mole percent** or **fraction** unless specifically stated otherwise.

The **composition of liquids** and **solids** will be given by **mass (weight) percent** or **fraction** unless otherwise specifically stated.

For Example Table below lists the detailed composition of dry air (composition of air 21% O_2 and 79% N_2).

Basis 100 mol of air

Component	Moles = percent	Mol. wt.	Lb or kg	Weight %
O_2	21.0	32	672	23.17
N_2	79.0	28.2	2228	76.83
Total	100		2900	100.00
The average molecular weight is 2900 lb/100 lb mol = 29.0, or 2900 kg/100 kg mol = 29				

1.2.3 Concentration

Concentration generally refers to the quantity of some substance per unit volume.

a. Mass per unit volume (lb of solute/ft^3 of solution, g of solute/L, lb of solute/barrel, kg of solute/m^3).
b. Moles per unit volume (lb mol of solute/ft^3 of solution, g mol of solute/L, g mol of solute/cm^3).
c. Parts per million (**ppm**); parts per billion (**ppb**), a method of expressing the concentration of extremely dilute solutions; **ppm is equivalent to a mass (weight) fraction for solids and liquids** because the total amount of material is of a much higher order of magnitude than the amount of solute; it is a **mole fraction for gases**.
d. Parts per million by volume (ppmv) and parts per billion by volume (ppbv)
e. Other methods of expressing concentration with which you may be familiar are molarity (g mol/L), molality (mole solute/kg solvent), and normality (equivalents/L).

Example 14

The current OSHA 8-hour limit for HCN (MW = 27.03) in air is 10.0 ppm. A lethal dose of HCN in air is (from the Merck Index) 300 mg/kg of air at room temperature. How many mg HCN/kg air is 10.0 ppm? What fraction of the lethal dose is 10.0 ppm?

Solution

Basis: 1 kg mol of the air/HCN mixture

The 10.0 ppm is $\dfrac{10.0 \text{ g mol HCN}}{10^6(\text{air} + \text{HCN})\text{g mol}} = \dfrac{10.0 \text{ g mol HCN}}{10^6 \text{ g mol air}}$

a. $$\frac{10.0 \text{ g mol HCN}}{10^6 \text{ g mol air}}\left|\frac{27.03 \text{ g HCN}}{1 \text{ g mol HCN}}\right|\frac{1 \text{ g mol air}}{29 \text{ g air}}\left|\frac{1000 \text{ mg HCN}}{1 \text{ g HCN}} \times \frac{1000 \text{ g air}}{1 \text{ kg air}} = 9.32 \text{ mg HCN/kg air}\right.$$

b. $\dfrac{9.32}{300} = 0.031$

__Example 15__

A solution of HNO_3 in water has a specific gravity of 1.10 at 25°C. The concentration of the HNO_3 is 15 g/L of solution. What is the

a. Mole fraction of HNO_3 in the solution?

b. ppm of HNO_3 in the solution?

Solution

Basis: 1 L of solution

$$\frac{15 \text{ g } HNO_3}{1 \text{ L soln}}\left|\frac{1 \text{ L}}{1000 \text{ cm}^3}\right|\frac{1 \text{ cm}^3}{1.10 \text{ g soln}} = 0.01364\frac{\text{g } HNO_3}{\text{g soln}}$$

Basis: 100 g solution

The mass of water in the solution is: 100 - 0.0134 = 99.986 g H_2O.

		g	MW	g mol	mol fraction
a.	HNO_3	0.01364	63.02	2.164×10^{-4}	3.90×10^{-5}
	H_2O	99.986	18.016	5.550	1.00
	Total			5.550	1.00

b. $\dfrac{0.01364}{1} = \dfrac{13{,}640}{10^6}$ or 13,640 ppm

__Example 16__

To avoid the possibility of explosion in a vessel containing gas having the composition of 40% N_2, 45% O_2, and 15% CH_4, the recommendation is to dilute the gas mixture by adding an equal amount of pure N_2. What is the final mole fraction of each gas?

Solution

The basis is 100 moles of initial gas

Composition	*Original Mixture mol%*	*After Addition N_2*	**Final Mixture Mole Fraction**
N_2	40 → + 100	140	140/200 = 0.70
O_2	45	45	45/200 = 0.23
CH_4	15	15	15/200 = 0.07
Total	100	200	1.00

Questions

1. Answer the following questions true or false:
   a. The pound mole is comprised of 2.73 x 10^{26} molecules
   b. The kilogram mole is comprised of 6.022 x 10^{26} molecules.
   c. Molecular weight is the mass of a compound or element per mole.
2. What is the molecular weight of acetic acid (CH3COOH)?
3. For numbers such as 2 mL of water + 2 mL of ethanol, does the sum equal to 4 mL of the solution?
4. Answer the following questions true or false:
   a. The inverse of the density is the specific volume.
   b. Density of a substance is the mass per unit volume.
   c. The density of water is less than the density of mercury.
5. A cubic centimeter of mercury has a mass of 13.6 g at Earth's surface. What is the density of mercury?
6. What is the approximate density of water at room temperature in kg/m^3?
7. For liquid HCN, a handbook gives: sp. gr. $10^{\circ}C/4^{\circ}C$ = 1.2675. What does this statement mean?
8. Answer the following questions true or false:
   a. The density and specific gravity of mercury are the same.
   b. Specific gravity is the ratio of two densities.
   c. If you are given the value of a reference density, you can determine the density of a substance of interest by multiplying by the specific gravity.
   d. The specific gravity is a dimensionless quantity.
9. A mixture is reported as 15% water and 85% ethanol. Should the percentages be deemed to be by mass, mole, or volume?
10. Answer the following questions true or false:
    a) In engineering practice the compositions of liquids and solids are usually denoted in weight (mass) fraction or percent.
    b) In engineering practice the composition of gases is usually denoted in mole fraction or percent.
    c) e. A pseudo-average molecular weight can be calculated for a mixture of pure components whether solid, liquid, or gases.
11. Do parts per million denote a concentration that is a mole ratio?
12. Does the concentration of a component in a mixture depend on the amount of the mixture?
13. Pick the correct answer. How many ppm are there in 1 ppb? (a) 1000, (b) 100, (c) 1, (d) 0.1, (e) 0.01, (f) 0.001?
14. How many ppb are there in 1 ppm?
15. Does 50 ppm represent an increase of five times a value of 10 ppm?

Answers:

1. (a) T; (b) T; (c) T
2. 60.05
3. No
4. (a) T; (b) T; (c) T
5. 13.6 g/cm^3
6. 1000 kg/m^3

7. The statement means that the density at 10°C of liquid HCN is 1.2675 times the density of water at 4°C.
8. (a) F – the units differ; (b) T; (c) T; (d) F.
9. Mass
10. (a) T; (b) T; (c) T
11. For gases but not for liquids or solids.
12. No
13. 0.001
14. 1000
15. No (4 times)

Problems

1. Convert the following:
    a) 120 g mol of NaCl to g.
    b) 120 g of NaCl to g mol.
    c) 120 lb mol of NaCl to lb.
    d) 120 lb of NaCl to lb mol.
2. Convert 39.8 kg of NaCl per 100 kg of water to kg mol of NaCl per kg mol of water.
3. How many lb mol of $NaNO_3$ are there in 100 lb?
4. The density of a material is 2 kg/m^3. What is its specific volume?
5. An empty 10 gal tank weighs 4.5 lb. What is the total weight of the tank plus the water when it is filled with 5 gal of water?
6. If you add 50 g of sugar to 500 mL of water, how do you calculate the density of the sugar solution?
7. For ethanol, a handbook gives: sp. gr. 60°F = 0.79389. What is the density of ethanol at 60°F?
8. The specific gravity of steel is 7.9. What is the volume in cubic feet of a steel ingot weighing 4000 lb?
9. The specific gravity of a solution is 0.80 at 70°F. How many cubic feet will be occupied by 100 lb of the solution at 70°F?
10. A solution in water contains 1.704 kg of HNO_3/kg H_2O, and the solution has a specific gravity of 1.382 at 20°C. What is the mass of HNO_3 in kg per cubic meter of solution at 20°C?
11. Forty gal/min of a hydrocarbon fuel having a specific gravity of 0.91 flows into a tank truck with a load limit of 40,000 lb of fuel. How long will it take to fill the tank in the truck?
12. Pure chlorine enters a process. By measurement it is found that 2.4 kg of chlorine pass into the process every 3.1 minutes. Calculate the molar flow rate of the chlorine in kg mol/hr.
13. Commercial sulfuric acid is 98% H_2SO_4 and 2% H_2O. What is the mole ratio of H_2SO_4 to H_2O?
14. A compound contains 50% sulfur and 50% oxygen by mass. Is the empirical formula of the compound (1) SO, (2) SO_2, (3) SO_3, or (4) SO_4?
15. How many kg of activated carbon (a substance used in removing trace impurities) must be mixed with 38 kg of sand so that the final mixture is 28% activated carbon?
16. A gas mixture contains 40 lb of O_2, 25 lb of SO_2, and 30 lb of SO_3. What is the composition of the mixture in mole fractions?
17. Saccharin, an artificial sweetener that is 3000 times sweeter than sucrose, is composed of 45.90% carbon, 2.73% hydrogen, 26.23% oxygen, 7.65% nitrogen, and 17.49% sulfur. Is the molecular formula of saccharin (a) $C_{14}H_{10}O_6N_2S_2$, (b) $C_5H_7O_3NS$, (c) $C_8H_9O_2NS$, and (d) $C_7H_5O_3NS$?

18. A mixture of gases is analyzed and found to have the following composition: CO_2 12.0%, CO 6.0%, CH_4 27.3%, H_2 9.9% and N_2 44.8%. How much will 3 lb mol of this gas weigh?
19. A liquefied mixture of n-butane, n-pentane, and n-hexane has the following composition: n-C_4H_{10} 50%, n-C_5H_{12} 30%, and n-C_6H_{14} 20%. For this mixture, calculate:
    a) The weight fraction of each component.
    b) The mole fraction of each component.
    c) The mole percent of each component.
    d) The average molecular weight of the mixture.
20. How many mg/L is equivalent to a 1.2% solution of a substance in water?

Answers:

1. (a) 7010 g; (b) 2.05 g mol; (c) 7010 lb; (d) 2.05 lb mol
2. 0.123 kg mol NaCl/kg mol H_2O
3. 1.177 lb mol
4. 0.5 m^3/kg
5. 46.2 lb
6. Measure the mass of water (should be about 500g) and add it to 50 g. Measure the volume of the solution (will not be 450 mL). Divide the mass by the volume.
7. 0.79389 g/cm^3 (assuming the density of water is also at 60°F)
8. 8.11 ft^3
9. 2 ft^3
10. 870 kg HNO_3/m^3 solution.
11. 132 min
12. 0.654 kg mol/hr
13. 9
14. SO_2
15. 14.8 kg
16. O_2 0.62; SO_2 0.19; SO_3 0.19
17. (d)
18. 72.17 lb
19. (a) C_4: 0.50, C_5: 0.30, C_6: 0.20; (b) C_4: 0.57, C_5: 0.28, C_6: 0.15; (c) C_4: 57, C_5: 28, C_6: 15; (d) 66.4 kg/kg mol
20. 12000 mg/L .

1.3 Choosing a Basis

- A **basis** is a reference chosen by you for the calculations you plan to make in any particular problem, and a proper choice of basis frequently makes the problem much easier to solve.
- The **basis** may be a **period of time** such as **hours**, or a given **mass of material**, such as **5 kg** of CO_2, or some other convenient quantity.
- For **liquids** and **solids** in which a **mass (weight)** analysis applies, a convenient basis is often **1 or 100 lb or kg**; similarly, **1 or 100 moles** is often a good choice for a **gas**.