Chapter 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**.

Example 3.1

Gas mixture 10.0% H_2, 40.0% CH_4, 30.0% CO, and 20.0% CO_2, what is the average molecular weight of the gas?

Solution

Basis: 100 kg mol or lb mol of gas

Component	Percent = kg mol or lb mol	Mol wt.	Kg or lb
CO_2	20.0	44.0	880
CO	30.0	28.0	840
CH_4	40.0	16.04	642
H_2	10.0	2.02	20
Total	100.0		2382

$$\text{Average molecular weight} = \frac{2382 \text{ kg}}{100 \text{ kg mol}} = 23.8 \text{ kg/kg mol}$$

Other Method for Solution:

Average molecular weight = 0.2 * 44 + 0.3 * 28 + 0.4 * 16.04 + 0.1 * 2.02 = 23.8 kg/kg mol

Example 3.2

A liquefied mixture has the following composition: (Butane) n-C_4H_{10} 50% (MW=58), (Pentane) n-C_5H_{12} 30% (MW=72), and (hexane) n-C_6H_{14} 20% (MW=86). For this mixture, calculate: (a) mole fraction of each component. (b) Average molecular weight of the mixture.

Solution

Basis: 100 kg

	% = kg	wt fr	MW	kg mol	mol fr
n - C_4H_{10}	50	**0.50**	58	0.86	**0.57**
n - C_5H_{12}	30	**0.30**	72	0.42	**0.28**
n - C_6H_{14}	20	**0.20**	86	0.23	**0.15**
	100	**1.00**		1.51	**1.00**

$$\text{Average molecular weight} = \frac{\text{total mass}}{\text{total mol}} = \frac{100\ \text{kg}}{1.51\ \text{kg mol}} = 66$$

Example 3.3

A medium-grade bituminous coal analyzes as follows:

Component	Percent
S	2
N	1
O	6
Ash	11
Water	3
Residuum	77

The residuum is C and H, and the mole ratio in the residuum is H/C = 9. Calculate the weight (mass) fraction composition of the coal with the ash and the moisture omitted (ash – and moisture – free).

Solution

Take as a basis 100 kg of coal because then percent = kilograms.

Basis: 100 kg of coal

The sum of the S + N + O + ash + water is 2 + 1 + 6 + 11 + 3 = 23 kg

We need to determine the individual kg of **C** and of **H** in the **77 kg** total residuum.

To determine the kilograms of C and H, you have to select a new basis.

Basis: 100 kg mol (Because the H/C ratio is given in terms of moles, not weight)

Component	Mole fraction	kg mol	Mol. wt.	kg	Mass fraction
H	$\frac{9}{1+9} = 0.90$	90	1.008	90.7	0.43
C	$\frac{1}{1+9} = \frac{0.10}{1.00}$	$\frac{10}{100}$	12	$\frac{120}{210.7}$	$\frac{0.57}{1.00}$

H: (77kg) (0.43) = 33.15 kg

C: (77kg) (0.57) = 43.85 kg

Finally, we can prepare a table summarizing the results on the basis of **1 kg of the coal ash-free and water-free**.

Component	kg	Wt. fraction
C	43.85	0.51
H	33.15	0.39
S	2	0.02
N	1	0.01
O	6	0.07
Total	86.0	1.00

Supplementary Problems (Chapter Three):

Problem 1

1 mol of gas containing O_2 20%, N_2 78%, and SO_2 2%, find the composition of the gas on an SO_2 – free basis, meaning gas without the SO_2 in it.

Solution

Basis: 1.00 mol gas

Components	Mol fraction	Mol	Mol SO_2 free	Mol fraction SO_2 free
O_2	0.20	0.20	0.20	0.20
N_2	0.78	0.78	0.78	0.80
SO_2	0.02	0.02		
	1.00	1.00	0.98	1.00

Problem 2

In a ternary alloy such as $Nd_{4.5}Fe_{77}B_{18.5}$ the average grain size is about 30 nm. By replacing 0.2 atoms of Fe with atoms of Cu, the grain size can be reduced (improved) to 17 nm.

(a) What is the molecular formula of the alloy after adding the Cu to replace the Fe?

(b) What is the mass fraction of each atomic species in the improved alloy?

Solution

Basis: 100 g mol (or atoms) of $Nd_{4.5}Fe_{77}B_{18.5}$

(a) The final alloy is $Nd_{4.5}Fe_{76.8}B_{18.5}Cu_{0.2}$.

(b) Use a table to calculate the respective mass fractions.

Component	Original g mol	Final g mol	MW	g	Mass fraction
Nd	4.5	4.5	144.24	649.08	0.126
Fe	77	76.8	55.85	4289.28	0.833
B	18.5	18.5	10.81	199.99	0.039
Cu		0.2	63.55	12.71	0.002
Total	100.0	100.0		5151.06	1.000

Problem 3 (Basic Principles…. Book, Page 87)

Read each of the following problems and select a suitable basis for solving each one. Do not solve the problems.

a. You have 130 kg of gas of the following composition: 40% N_2, 30% CO_2, and 30% CH_4 in a tank. What is the average molecular weight of the gas?

b. You have 25 lb of a gas of the following composition: CH_4 80%, C_2H_4 10%, and C_2H_6 10%. What is the average molecular weight of the mixture? What is the weight (mass) fraction of each of the components in the mixture?

c. The proximate and ultimate analysis of coal is given in the following table. What is the composition of the "Volatile combustible material" (VCM)? Present your answer in the form of the mass percent of each element in the VCM.

Proximate Analysis (%)		Ultimate Analysis (%)	
Moisture	3.2	Carbon	79.90
Volatile combustible material	21.0	Hydrogen	4.85
Fixed carbon	69.3	Sulfur	0.69
Ash	6.5	Nitrogen	1.30
		Ash	6.50
		Oxygen	6.76
Total	100.0	Total	100.00

d. A fuel gas is reported to analyze, on a mole basis, 20% methane, 5% ethane, and the remainder CO_2. Calculate the analysis of the fuel gas on a mass percentage basis.

Solution

(a) A gas requires a convenient basis of 1 or 100 g moles or kg moles (if use SI units).

(b) A gas requires a convenient basis of 1 or 100 lb moles (if use AE units).

(c) Use 1 or 100 kg of coal, or 1 or 100 lb of coal because the coal is a solid and mass is a convenient basis.

(d) Use 1 or 100 moles (SI or AE) as a convenient basis as you have a gas.

Problem 4 (Basic Principles…. Book, Page 88)

Choose a basis for the following problem: Chlorine usage at a water treatment plant averages 134.2 lb/day. The average flow rate of water leaving the plant is 10.7 million gal/day. What is the average chlorine concentration in the treatment water leaving the plant (assuming no reaction of the chlorine), expressed in milligrams per liter?

Solution

Pick one day as a basis which is equivalent to what is given - - two numbers:

(a) 134.2 lb Cl (b) 10.7×10^6 gal water.