

## Class 3

- Happy Friday!
- Terminology
  - Densities, MW, mole and mass fractions, flow rates, and temperatures
  - Pressure stuff next class
- Convert mass fraction to mole fraction
  - Using a basis

## Specific Gravity (SG)

- Definition: Density/Reference Density
- Typical Reference Density = water at 4°C
  - Value: 1 g/cm<sup>3</sup>, 1000 kg/m<sup>3</sup> or 62.43 lb<sub>m</sub>/ft<sup>3</sup>
- SG given at particular temperature (does not have to be the reference temperature)
- To get density from SG:

$$\rho_A = (SG_A)(\rho_{H_2O,ref})$$

## Practice on SG

1. Look up the SG of Toluene in the back of your book
  - Is this for a gas or a liquid?
  - What is the density in lb<sub>m</sub>/ft<sup>3</sup>?
  - What does the “(20°/4°)” in the column heading mean? (see page 44)
2. Look up the SG of water in Table B.1
  - Note the superscript (also on sulfuric acid)

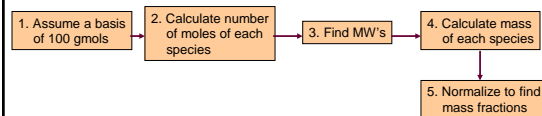
## Mole and Mass Fractions

- Must know what these represent physically!
- Must be able to interchange between the two
- Nomenclature differences: Web and book
  - $x_i$  for mole fraction,  $w_i$  for mass fraction
- Remember: Not all the mole (or mass) fractions are independent. If you have “n” species then “n-1” of the mole fractions are independent. Why?????

## Please specify which type of moles!!!

- You have seen MW expressed in g/mol
  - What about kg/kg-mol?
  - Also lb<sub>m</sub>/lb-mol
- Is the concept of lb-mol new?
  - The book uses “mol” to mean “g-mol”
  - How do you convert from g-mol to lb-mol?
    - 1 lb-mol = 454 g-mol (just like 454 grams in a lb)
  - How many g-mols are in a kg-mol?
    - 1 kg-mol = 1000 g-mol

## Conversion from Mole to Mass Fraction



Compound	$y_i$ (mole fraction)	$n_i$ (mol)	$M_i$ (g/mol)	$m_i$ (g)	$x_i$ (mass fraction)
CO <sub>2</sub>	0.20				
CH <sub>4</sub>	0.50				
C <sub>2</sub> H <sub>6</sub>	0.20				
H <sub>2</sub> O	0.10				
	1.00				

### Conversion from Mole to Mass Fraction

1. Assume a basis of 100 gmols

2. Calculate number of moles of each species

3. Find MW's

4. Calculate mass of each species

5. Normalize to find mass fractions

Compound	y <sub>i</sub> (mole fraction)	n <sub>i</sub> (mol)	M <sub>i</sub> (g/mol)	m <sub>i</sub> (g)	x <sub>i</sub> (mass fraction)
CO <sub>2</sub>	0.20	20			
CH <sub>4</sub>	0.50	50			
C <sub>2</sub> H <sub>6</sub>	0.20	20			
H <sub>2</sub> O	0.10	10			
<b>Total</b>	1.00	100			

### Conversion from Mole to Mass Fraction

1. Assume a basis of 100 gmols

2. Calculate number of moles of each species

3. Find MW's

4. Calculate mass of each species

5. Normalize to find mass fractions

Compound	y <sub>i</sub> (mole fraction)	n <sub>i</sub> (mol)	M <sub>i</sub> (g/mol)	m <sub>i</sub> (g)	x <sub>i</sub> (mass fraction)
CO <sub>2</sub>	0.20	20	44.0		
CH <sub>4</sub>	0.50	50	16.0		
C <sub>2</sub> H <sub>6</sub>	0.20	20	30.0		
H <sub>2</sub> O	0.10	10	18.0		
<b>Total</b>	1.00	100			

### Conversion from Mole to Mass Fraction

1. Assume a basis of 100 gmols

2. Calculate number of moles of each species

3. Find MW's

4. Calculate mass of each species

5. Normalize to find mass fractions

Compound	y <sub>i</sub> (mole fraction)	n <sub>i</sub> (mol)	M <sub>i</sub> (g/mol)	m <sub>i</sub> (g)	x <sub>i</sub> (mass fraction)
CO <sub>2</sub>	0.20	20	44	880	
CH <sub>4</sub>	0.50	50	16	800	
C <sub>2</sub> H <sub>6</sub>	0.20	20	30	600	
H <sub>2</sub> O	0.10	10	18	180	
<b>Total</b>	1.00	100		2460	

### Conversion from Mole to Mass Fraction

1. Assume a basis of 100 gmols

2. Calculate number of moles of each species

3. Find MW's

4. Calculate mass of each species

5. Normalize to find mass fractions

Compound	y <sub>i</sub> (mole fraction)	n <sub>i</sub> (mol)	M <sub>i</sub> (g/mol)	m <sub>i</sub> (g)	x <sub>i</sub> (mass fraction)
CO <sub>2</sub>	0.20	20	44	880	0.358
CH <sub>4</sub>	0.50	50	16	800	0.325
C <sub>2</sub> H <sub>6</sub>	0.20	20	30	600	0.244
H <sub>2</sub> O	0.10	10	18	180	0.073
<b>Total</b>	1.00	100		2460	1.000

## Average Molecular Weight

Formula:  $\bar{M} = \sum y_i M_i$       Units:  $\frac{\text{mol}_A}{\text{mol}_{\text{mix}}} \frac{\text{g}_A}{\text{mol}_A} + \frac{\text{mol}_B}{\text{mol}_{\text{mix}}} \frac{\text{g}_B}{\text{mol}_B} = \frac{\text{g}_{\text{mix}}}{\text{mol}_{\text{mix}}}$

Should this be mole or mass fraction?

## How Do You Convert From Mass Fraction To Mole Fraction?

- Basis: 100 grams
- Compute mass of each species
- Divide by MW<sub>i</sub> to get moles<sub>i</sub>
- Sum number of moles
- Compute mole fraction

## Example Problem

A coal gasifier produces 5000 lb/hr of syngas, composed of 35 mol% CO and 65 mol% H<sub>2</sub>.

Find: Mass flow rate of CO in lb/hr.

Strategies:

- Find species mass fractions, Get species mass flow rates
- Find  $MW_{avg}$ , Convert mass flow rate to total molar flow rate, Get species molar flow rate, Convert back to species mass flow rate



## Work Problem on Board

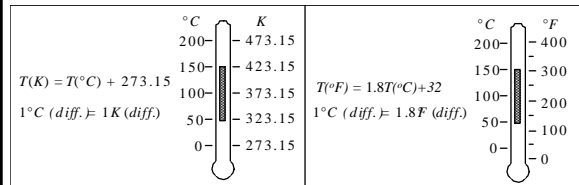
## Dry Basis

compound	$y_i$	$M_i$ (g/mol)
CO <sub>2</sub>	0.015	44
CH <sub>4</sub>	0.820	16
C <sub>2</sub> H <sub>6</sub>	0.040	30
H <sub>2</sub> O	0.125	18

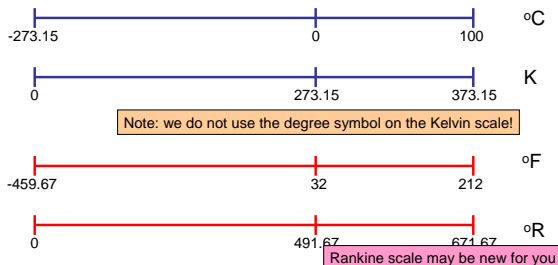
Assume basis of 100 gmols of "wet" gas

compound	$n_i$	$y_i'$
CO <sub>2</sub>	1.5	$1.5/87.5 = 0.017$
CH <sub>4</sub>	82.0	$82/87.5 = 0.937$
C <sub>2</sub> H <sub>6</sub>	4.0	$4/87.5 = 0.046$
H <sub>2</sub> O	12.5	-----
Total	100.0	
Total (dry)	87.5	1.000

## Temperature



## Temperature Scales



Should be able to convert between scales!!  
You must use an absolute temperature scale when you multiply or divide temperatures!!!