Class 3

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

Business

- For those who added the class late the info materials are on my web page
- Please help me get to know you!
  - I may end up writing a letter of recommendation for you sometime

- Today: Terminology, using a basis
- Next time: Pressure, manometers
- Then: Mass and mole balances
- Then: Thermodynamics, vapor pressure, humidity, energy, heat capacities
- Then: Energy balances

Error in 4th Edition

(early printing)

- See pdf file

A. Terminology Handout

1. Find a friend and go over the sheet
2. Write or remember questions

Specific Gravity (SG)

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

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

$$SG_A = \frac{\rho_A}{\rho_{H_2O,ref}}$$

Practice on SG

1. Look up the SG of Toluene in the back of your book (Table B.1) 0.866
   - Is this for a gas or a liquid?
   - What is the density in lb_m/ft^3? $0.866 \times 62.4\ lb_m/ft^3$
   - 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

y_A x_A

- Must know what these represent physically!
- Must be able to interchange between the two
- Nomenclature differences: Web and book
  - Web uses 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_m/lb-mol
    - MW_{carbon} = 12 g/mol = 12 lb_m/lb-mol = 12 kg/kg-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_m)
    - 1 lb-mol ≠ 1 g-mol
  - How many g-mols are in a kg-mol?
    - 1 kg-mol = 1000 g-mol

Think-Pair-Share

- Composition of air is approximately:
  - 79% N_2, 21% O_2
- How do you find the mass fraction of O_2 in the air?
  - Method
  - Value

B. Class Exercise

- Convert mole fractions to mass fractions
- Why?
  - Most instruments measure mole fractions
  - Balances are done on mass fractions
    - Mass is conserved
    - Moles are not always conserved

$H_2 + ½\ O_2 \rightarrow H_2O$

1.5 moles 1 mole

Gas chromatograph to measure gas phase mole fraction (y_i)

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_i (mole fraction)	n_i (mol)	M_i (g/mol)	m_i (g)	x_i (mass fraction)
CO_2	0.20				
CH_4	0.50				
C_2H_6	0.20				
H_20	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_i (mole fraction)	n_i (mol)	M_i (g/mol)	m_i (g)	x_i (mass fraction)
CO_2	0.20	20			
CH_4	0.50	50			
C_2H_6	0.20	20			
H_20	0.10	10			
Total	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_i (mole fraction)	n_i (mol)	M_i (g/mol)	m_i (g)	x_i (mass fraction)
CO_2	0.20	20	44.0		
CH_4	0.50	50	16.0		
C_2H_6	0.20	20	30.0		
H_20	0.10	10	18.0		
Total	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_i (mole fraction)	n_i (mol)	M_i (g/mol)	m_i (g)	x_i (mass fraction)
CO_2	0.20	20	44	880	
CH_4	0.50	50	16	800	
C_2H_6	0.20	20	30	600	
H_20	0.10	10	18	180	
Total	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_i (mole fraction)	n_i (mol)	M_i (g/mol)	m_i (g)	x_i (mass fraction)
CO_2	0.20	20	44	880	0.358
CH_4	0.50	50	16	800	0.325
C_2H_6	0.20	20	30	600	0.244
H_20	0.10	10	18	180	0.073
Total	1.00	100		2460	1.000

C. Average Molecular Weight

Formula:

$$\overline{M} = \sum y_i M_i$$

Units:

$$\frac{mol_A}{mol_{mix}}\frac{g_A}{mol_A} + \frac{mol_B}{mol_{mix}}\frac{g_B}{mol_B} = \frac{g_{mix}}{mol_{mix}}$$

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_i to get $moles_i$
- Sum number of moles
- Compute mole fraction

Example Problem

A coal gasifier produces 5000 lb_m/hr of syngas, composed of
35 mol% CO and
65 mol% H_2.

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

Strategies:

a. Find species mass fractions,
Get species mass flow rates

b. 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

Which Has More H:

A m^3 of liquid H_2 or a m^3 of gasoline?

1. Approximate gasoline as iso-octane (C_8H_{18})
2. Find densities & MWs
   - Iso-octane (6 kmol/m^3 at 298 K)
   - H_2 (35 kmol/m^3 at 20 K)
3. Find kmols of H per m^3
   - (18 mol H/mol iso-octane) × (6 kmol iso-octane/m^3) = 108 kmol/m^3
   - (2 mol H/mol H_2) × (35 kmol/m^3) = 70 kmol/m^3

Dry Basis

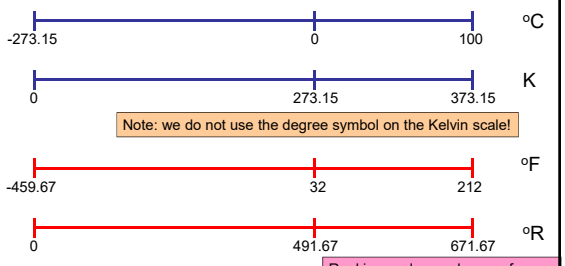
Given y_i on a wet basis, compute y_i on a dry basis

compound	y_i	M_i (g/mol)
CO_2	0.015	44
CH_4	0.820	16
C_2H_6	0.040	30
H_2O	0.125	18

Assume basis of 100 gmols of "wet" gas

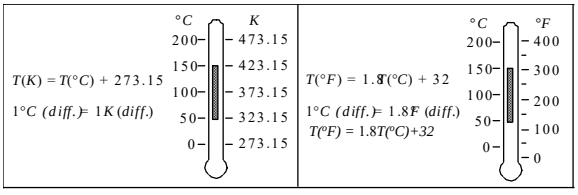
compound	n_i	y_i'
CO_2	1.5	1.5/87.5 = 0.017
CH_4	82.0	82/87.5 = 0.937
C_2H_6	4.0	4/87.5 = 0.046
H_2O	12.5	--------
Total	100.0	
Total (dry)	87.5	1.000

Temperature Scales

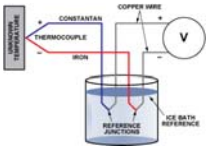


Should be able to convert between scales!!
You must use an absolute temperature scale when you multiply or divide temperatures!!!

Temperature



Thermocouples provide digital temperature values



Temperature Conversions
(Eqns. 3.5-1 thru 4)

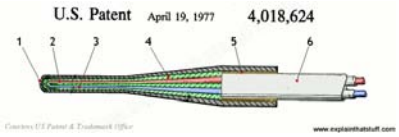
$T(K) = T(°C) + 273.15$

$T(°R) = T(°F) + 459.67$

$T(°R) = 1.8\ T(K)$

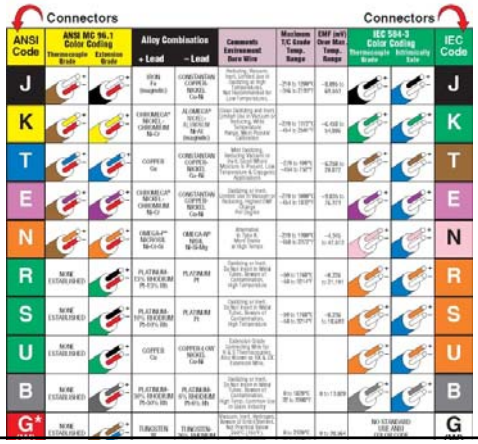
$T(°F) = 1.8\ T(°C) + 32$

Thermocouples



Artwork: Parts of a typical thermocouple.
1) Protective metal sheath (dark gray) made from stainless steel or an alloy (perhaps nickel and chromium);
2) First wire made from one metal (red);
3) Second wire made from a different metal (blue) joined to first wire to make a thermocouple;
4) Insulation (green) made from crushed and compacted mineral oxide. 5) Cement to hold insulation in place;
5) Electrical insulation made from rubber or plastic.

Artwork from US Patent 4,018,624: Thermocouple structure and method of manufacturing same by Silvio J. Rizzolo, courtesy of US Patent and Trademark Office.



Homework Hints

- 3.3 – Work book problem available
- 3.10– Archimedes principle
- 3.16 – A slurry is a mixture of liquid and fine solids
- 3.28 – Hint is given to define error