Due:  
In class, Friday  
September 14, 2018

Name(s) (up to three students per homework set):  
1.  
2.  
3.  

PSU ID (abc123)

For instructor or TA use only:

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M E 405  
Fall Semester, 2018  
Homework Set # 2  

Professor J. M. Cimbala

1. (10 pts) Appendix A.1 of the Heinsohn/Cimbala text lists the OSHA PEL of various chemicals from both 1989 and 1997 for comparison. It shows that the PEL is sometimes revised with time, due to new health data and studies.  
(a) For example, the PEL of diethylamine was raised from 10 to 25 PPM between 1989 and 1997. What does this imply – did the scientists at OSHA realize that diethylamine is less hazardous or more hazardous than previously thought?  
(b) Look up the current PEL of diethylamine to see if it has changed any further since 1997. Discuss. What does this imply about the perception of risk between now and approximately three decades ago?  
(c) Search Appendix A.1 – are there any chemicals for which the PEL has decreased between 1989 and 1997? Note: Be careful not to compare ceiling values or STEL (short term exposure levels) with the TWA (time-weighted average) PEL, as this is not a valid comparison – compare only OSHA PELs. Discuss the overall perception of risk in that approximate decade between 1989 and 1997.

2. (30 pts) The amount of carbon dioxide in the atmosphere is growing and is approximately 410 PPM right now. Consider a sample of humid air as an ideal gas mixture that consists of the following gases, in percent by volume: O₂ (20.22%), N₂ (75.36%), H₂O (4.379%), and CO₂ (0.0410%). The gas mixture is at a total pressure of 97.6 kPa, and the temperature is 35.0°C. Note: To calculate the molecular weight of each molecule, use data from the on-line periodic chart on the course website for greatest accuracy and consistency. I suggest that you use Excel or Matlab or some other software to avoid calculation errors and for neatness; Excel is especially useful for these kinds of repetitive calculations with summations, etc. Give all answers to at least 4 significant digits.  
(a) Calculate the mol fraction of each species, both as a unitless number and in “units” of PPM. Verify that \( \Sigma y_j = 1 \), and \( \Sigma y_j, \text{PPM} = 1000000 \).  
(b) Calculate the partial pressure of each species in kPa. Verify that \( \Sigma P_j = P \).  
(c) Calculate the mass fraction of each species. Verify that \( \Sigma f_j = 1 \).  
(d) Calculate the mass concentration (\( c_j \)) of each species in mg/m³.  
(e) Calculate the total (or average) molecular weight of the gas mixture (\( M_t \)).  
(f) Calculate the specific gas constant for this gas mixture (\( R_t \)).  
(g) Calculate the percentage difference between \( R_t \) for this particular gas mixture and that of standard dry air, \( R_{air} \).  
(h) Calculate the total (or average) density for this gas mixture (\( \rho \)).  
(i) Assuming standard saturation pressure values for water vapor in air, calculate the relative humidity of this air (\( RH \)) as a percentage.

3. (15 pts) A term you may hear occasionally in a weather report is “dew point temperature”, \( T_{dew} \). Dew point temperature is related to relative humidity, but is not discussed in our textbook.  
(a) Define dew point temperature in your own words, and explain its relationship to relative humidity. (You may use the Internet, a book on meteorology, or any other source of information.)  
(b) Suppose the air is at \( T = 30.0°C \) and the relative humidity is 50.0%. Calculate \( T_{dew} \), showing all your work. Explain the physical significance of this temperature.  
(c) Explain why, on a hot summer day, our comfort level decreases with increasing dew point temperature.

Note: There is another page. →
4. (15 pts) A thermometer with a first-order time constant of 6.60 seconds is taken from ice water and plunged immediately into boiling water. The thermometer behaves like a first-order dynamic system.

(a) Calculate how long it takes (in seconds) for the thermometer to read 50°C.
(b) Repeat for 90°C.
(c) Repeat for 99.9°C.
(d) Use a computer (Excel, Matlab, whatever…) to make a nice plot of temperature vs. time for $t = 0$ to 50 s.

5. (15 pts) A common mineral in the soil is feldspar ($KAl_2Si_3O_8$), a molecule formed from potassium (K), aluminum (Al), silicon (Si), and oxygen (O). Feldspar interacts with water and carbon dioxide in the following way:

$$aKAlSi_3O_8 + bH_2O + cCO_2 \rightarrow dH_4Al_2Si_2O_9 + eSiO_2 + fKHCO_3$$

(a) Find mathematical expressions for molar coefficients $b$, $c$, $d$, $e$, and $f$ in terms of $a$ (e.g., $b = 2a$ or $b = a/3$, etc.).
(b) Let (arbitrarily) $a = 2$, and write the chemical equation, properly balanced.
(c) Use Matlab, EES, Excel (or some other mathematical or equation solving program of your choice) to solve for $b$, $c$, $d$, $e$, and $f$ for the case in which $a = 2$. Print out your solution and verify that your results agree with those of Part (b).

6. (15 pts) A mixture of phenol vapor and air flows in a duct. The temperature and pressure of the gas mixture in the duct are 300°C and 90.0 kPa, respectively, and the mol fraction of phenol is 4.50 PPM. The actual volume flow rate is 2.00 ft³/min (ACFM).

(a) Calculate the standard volume flow rate (in SCFM) and also in units of m³/s.
(b) Calculate the standard mass concentration of the phenol in units of mg/m³. In other words, if the gas mixture were at STP conditions, calculate the mass concentration.
(c) Calculate the actual mass concentration of the phenol in units of mg/m³.
(d) Finally, calculate the mass flow rate of the phenol in units of mg/hour using both actual conditions and STP conditions. Do you get the same answer? Should you? Explain.