Due:
In class, Friday
October 19, 2018

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

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For instructor or TA use only:

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1. (15 pts) Mountaintop Chemical Corporation makes fiberglass products that require the use of methyl ethyl ketone (MEK). Suppose a leak occurs in the plant overnight. When the workers arrive the next morning, the MEK concentration is 330 mg/m³, and increases throughout the day, according to the following equation:

\[ c(t) = c_0 \left[ 1 + \left( \frac{t}{t_{\text{const}}} \right)^{0.33} \right] \]

where \( c_0 = 330 \text{ mg/m}^3 \) is the initial mass concentration, \( t_{\text{const}} = 2.0 \text{ hours} \) is a time constant, and \( t \) is also measured in hours. The plant is at high elevation, and the atmospheric pressure is only 90. kPa. The temperature inside the plant is 30°C.

(a) Calculate the 8-hour time-weighted average mass concentration of MEK in mg/m³. Also convert your answer to mol fraction of MEK in units of PPM.

(b) Does this exposure constitute a violation of OSHA standards? Explain why or why not.

(c) Describe the smell of MEK. Will the workers be able to smell the MEK when they first arrive at work?

2. (10 pts) Chemists often like to use the quantity molal volume for a bulk mixture of gases, where molal volume is defined as \( \nu_{\text{molal}} = \frac{V}{n} \), where \( V \) is the total or bulk volume and \( n \) is the total number of mols. For a particular species \( j \) in a gas mixture, they define species molal volume as \( \nu_{\text{molal,}\ j} = \frac{P_jV}{n_j} \), where \( n_j \) is the number of mols of species \( j \).

(a) Starting with the bulk ideal gas law, \( PV = nRT \), write a form of the bulk ideal gas law in terms of \( \nu_{\text{molal}} \).

(b) Starting with the species ideal gas law, \( P_jV = n_jRT \), write a form of the species ideal gas law in terms of \( \nu_{\text{molal,}\ j} \).

(c) Combine your results from Parts (a) and (b) to append Eq. 1.27 in the text, which is repeated here for your convenience,

\[ y_j = \frac{n_j}{n} = \frac{P_j}{P} = \frac{V_j}{V} \]

In other words, add another ratio for mol fraction \( y_j \) in terms of molal volume and species molal volume. For full credit, write out the entire appended equation, namely,

\[ y_j = \frac{n_j}{n} = \frac{P_j}{P} = \frac{V_j}{V} = \frac{\nu_{\text{molal,}\ j}}{\nu_{\text{molal}}} \]

3. (35 pts) A lab contains a total air volume of 55.0 m³. Fresh air ventilation is provided to the room at a rate of one room change per hour. A graduate student is conducting some combustion experiments that produce carbon monoxide (CO) at a rate of 860 mg per hour. Assume there is no CO in the fresh ventilation air, and assume no CO in the lab at \( t = 0 \) when the experiment begins.

(a) Calculate the mol fraction of CO in the room after 2.0 hours (in PPM). Also calculate the steady-state value. Is the steady-state level of carbon monoxide gas in the room “safe” for an 8-hour exposure? Explain.

(b) Suppose the lab were twice the volume, but fresh air is still supplied at one room change per hour. Repeat the calculation of mol fraction (in PPM) after 2.0 hours, and calculate the new steady-state value. Compare with Part (a) results and explain.

(c) In Part (a), it was assumed that the source strength is constant. Suppose instead that the combustion process becomes less intense as the CO level in the room rises. (The combustion process “chores” itself.) Specifically,

\[ S(t) = 860 \text{ mg/hr} \exp \left( -\frac{t}{c_{\text{const}}} \right) \]

where \( c_{\text{const}} = 30. \text{ mg/m}^3 \). Using the room volume of Part (a), calculate PPM of CO at \( t = 2.0 \text{ hours} \) and at \( t = 12.0 \text{ hours} \).

Hint: Excel, Matlab, or some other software of your choice is required for this part. Compare to Part (a) and discuss.

(d) For the Part (c) case, attach a plot of mol fraction in PPM as a function of time from 0 to 12 hours.

Note: There is another page. →
4. (15 pts) An unvented kerosene heater produces carbon monoxide (CO) at a rate of 3.7 grams per hour. Assume STP conditions, and suppose the heater is in a room of volume 42.0 m³. Wall adsorption is negligible, and there is no forced ventilation in the room. The building is near a highway, and the concentration of CO in the outside ambient air is 5.4 mg/m³. The heater has been running long enough that steady-state conditions have been reached. How much outside air infiltration is required (in cubic meters per minute) in order to keep the CO concentration in the room below its PEL? Assume the air in the room is well mixed, and the volume flow rate of exfiltrated air is equal to the volume flow rate of infiltrated air (what goes in must come out). For consistency, use the conversion equation on the equation sheet to convert PEL to mass concentration (this is more accurate than the value of mass concentration at the PEL listed on the MSDS).

5. (25 pts) Joe stores a propane tank for his barbecue grill in his garage (generally not a good idea!). The garage has dimensions 8.0 x 8.0 x 2.2 m, and is not ventilated (assume no infiltration or exfiltration). One hot summer day (T = 95°F and P = 98.0 kPa), 20.0 lbm of propane leaks out through a small crack in the tank. Assume the propane is well-mixed with the air in the room.
   (a) Joe walks into the garage and lights a cigarette. Will Joe’s garage explode?
   (b) Suppose Joe does not light a cigarette, but just walks into the garage. Is the propane level harmful to Joe’s health, even if the propane does not explode? Discuss, bearing in mind that Joe will not stay in the garage all day. Also consider the amount of oxygen displaced by the propane vapors.
   (c) Regardless of your answers to Parts (a) and (b), assume the mol fraction of propane vapor in the garage is 40,000 PPM. Joe turns on a ventilation fan (no sparks are generated), and waits 20 minutes before going into the garage. Calculate the volume flow rate of fresh (supply) air required in order to bring the mol fraction down to the PEL in 20 minutes. Give your final answer in ACFM, and to two digits of precision.