100507 Exam 2 Materials and Energy Balances

ANSWERS ON SEPARATE SHEETS. NAME IN THE UPPER RIGHT CORNER OF EACH PAGE AND NUMBER THE PAGES. (LEAVE (TOP LEFT) ROOM FOR A STAPLE)

(**Gas constant, g, and periodic table are given at the end.**)

1)* Titanium dioxide is produced from an ore that contains ilmenite, $FeTiO_3$, and Fe_2O_3. The ore is digested with sulfuric acid to produce and aqueous solution of titanyl sulfate [$(TiO)SO_4$] and $FeSO_4$. Water is added to hydrolyze titanyl sulfate to H_2TiO_3, which precipitates, and H_2SO_4. The precipitate is then roasted to drive off water and leave a residue of pure TiO_2.

a) Give the chemical structure for ferrous sulfate and ferric sulfate.

b) What happens when an oxidizing agent such as hydrogen peroxide is added to an aqueous solution of ferrous sulfate?

c) Suppose an ore containing 24.3% Ti by mass is digested with an 80% H_2SO_4 solution, supplied in 50% excess of the amount needed to convert all the ilmenite to titanyl sulfate and all the ferric oxide to $Fe_2(SO_4)_3$. Further suppose that 89% of the ilmenite actually decomposes. Calculate the masses (kg) of ore and 80% sulfuric acid solution that must be fed to produce 1000kg of pure TiO_2.

*Modified from Question 4.44 of the R.M. Felder and R.W. Rousseau Text.

2)* Ethanol is produced commercially by the hydration of ethylene. Some of the product is converted to diethyl ether. In this process the feed to the reactor contains ethylene, steam and an inert gas. A sample of the reactor effluent gas is analyzed and found to contain 43.3 mole % ethylene, 2.5 % ethanol, 0.14 % ether, 9.3% inerts and the balance water.

a) Write stoichiometric equations for the two reactions.

b) Take as a basis 100 mole of effluent gas, draw and label a flow chart, and do a degree of freedom analysis based on atomic species.

c) Calculate the molar composition of the reactor feed, the percentage conversion of ethylene, the fractional yield of ethanol and the selectivity of ethanol production relative to ether production.

d) Why is the reactor designed to consume so little reactant? What additional processing steps are likely to take place downstream from the reactor?

*Modified from Question 4.51 of the R.M. Felder and R.W. Rousseau Text.

3)* When a fireplace is used, a draft is induced that causes the hot gases to flow up the stack. The theoretical draft, D (N/m^2) is the difference in the hydrostatic head in the stack and ant the furnace inlet. The actual draft takes in to account pressure losses in the flowing gasses. Let T_s(K) be the average temperature in a stack of height L (m) and T_a the ambient temperature and let M_s and M_a be the average molecular weights of the gases inside and outside the stack. Assume that the pressures inside and outside the stack are both equal to atmospheric pressure, P_a (N/m^2).

a) Use the ideal gas law to obtain an expression for the theoretical draft as a function of P_a, L, g, R, M_a, T_a, M_s and T_s.

b) Describe 3 other methods/equations, discussed in class, that could be used to give a better expression for the theoretical draft.

c) Suppose the gas in a 53- m stack has an average temperature of 655ºK and contains 18 mole% CO_2, 2% O_2, and 80% N_2 with barometric pressure of 755 mm Hg and outside temperature 294ºK. Calculate the theoretical draft (mm Hg) induced in the furnace.

d) How could the draft be improved?

*Modified from Question 5.28 of the R.M. Felder and R.W. Rousseau Text.

4)* a) Explain the relationship between the Clausius-Clapeyron equation and the Arrhenius equation. What is a thermally activated process?

Pure chlorobenzene is contained in a flask attached to an open-end, mercury manometer. When the flask contents are at 58.3ºC the height of the mercury in the arm of the manometer connected to the flask is 747 mm, and that in the arm open to the atmosphere is 52 mm. At 110ºC the mercury levels are 577 mm and 222 mm respectively. Atmospheric pressure is 755 mm Hg.

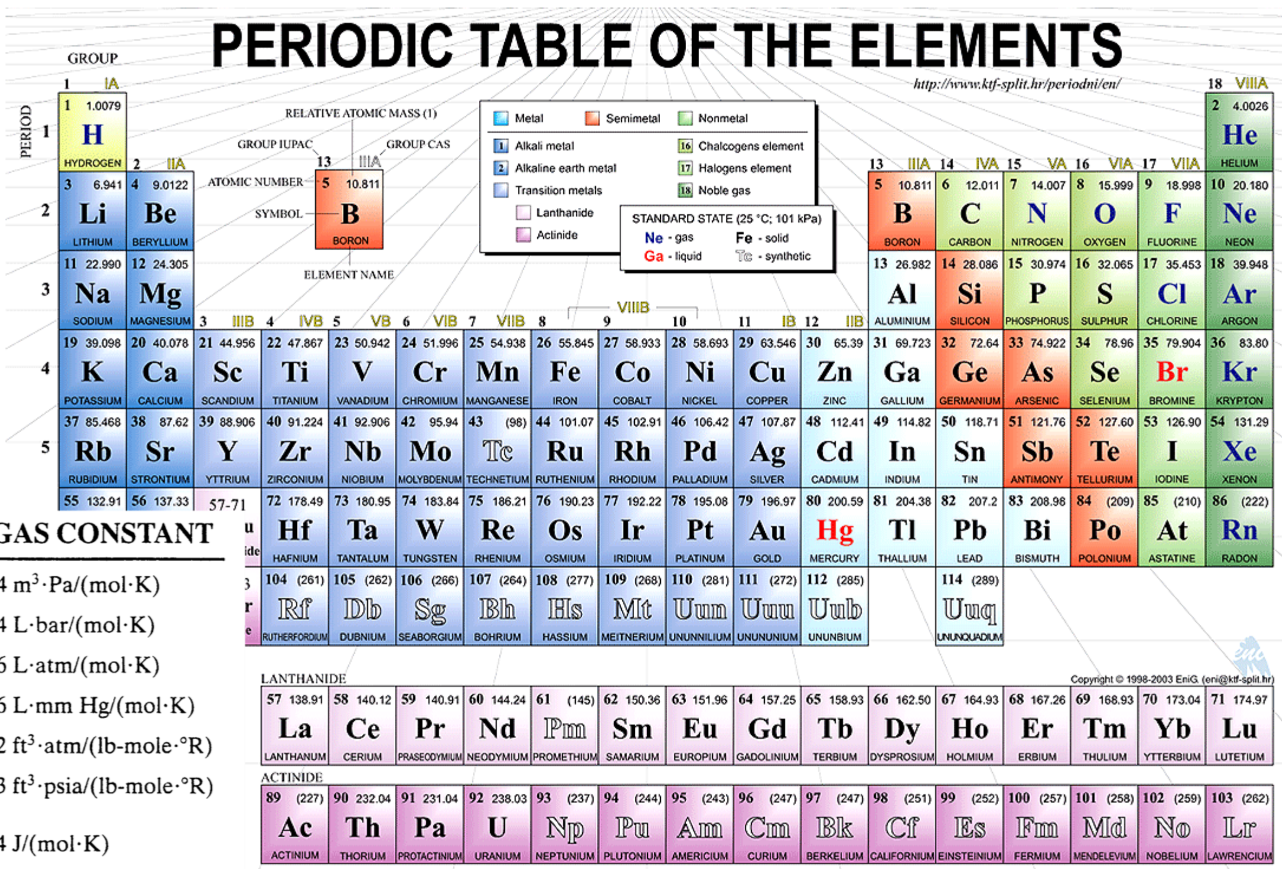
b) Extrapolate the data using the Clausius-Clapeyron equation to estimate the vapor pressure of chlorobenzene at 130ºC.

c) Air saturated with chlorobenzene at 130ºC and 101.3 kPa is cooled to 58.3ºC at constant pressure. Estimate the percentage of the chlorobenzene originally in the vapor that condenses.

d) Summarize the assumptions you made in doing this calculation (Part c).

*Modified from Question 6.12 of the R.M. Felder and R.W. Rousseau Text.

$g = 9.807\ m/s^2$



THE GAS CONSTANT

8.314 $m^3 \cdot Pa/(mol \cdot K)$

0.08314 $L \cdot bar/(mol \cdot K)$

0.08206 $L \cdot atm/(mol \cdot K)$

62.36 $L \cdot mm\ Hg/(mol \cdot K)$

0.7302 $ft^3 \cdot atm/(lb\text{-}mole \cdot °R)$

10.73 $ft^3 \cdot psia/(lb\text{-}mole \cdot °R)$

8.314 $J/(mol \cdot K)$

1.987 $cal/(mol \cdot K)$

1.987 $Btu/(lb\text{-}mole \cdot °R)$