100416 Exam 1 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)

1) The Reynolds number written for pipe flow is a dimensionless function of the pipe diameter, D, the fluid velocity, u, the fluid density ρ, and the fluid viscosity η.

a) For methyl ethyl ketone at 20ºC (η = 0.00043 ± .00003 kg/(m s) and ρ = 0.805 ± 0.003 g/cm^3) flowing through a pipe of diameter 5.000 ± 0.001 cm and u = 15 cm/s is the flow turbulent or laminar?

b) What is your confidence in the value you have reported for the Reynolds number and does this effect your determination of the type of flow?

c) Draw the chemical structure of methyl ethyl ketone.

2)* In order to determine the reproducibility and error involved in thermocouple measurements, two thermocouples measure the temperature of boiling water as voltages:

Thermocouple A 72.4, 73.1, 72.6, 72.8, 73.0 (millivolts)

Thermocouple B 97.3, 101.4, 98.7, 103.1, 100.4 (millivolts)

a) Determine the mean, range and standard deviation for each thermocouple.

b) Determine a conversion factor to convert the reading to temperature and propagate the calculated error to the temperature.

c) Which thermocouple should you use to measure temperatures near the boiling point of water?

*Modified from Question 2.18 of the R.M. Felder and R.W. Rousseau Text.

3)* Crystal growth rates can be strongly effected by impurities. The following function is proposed by Felder and Rosseau,

$$\frac{G - G_L}{G_0 - G} = \frac{1}{K_L C^m}$$

where G is the crystal growth rate and G_L, G_0, K_L and m are constants.

a) Does the growth rate increase or decrease with impurities?

b) What is the value of growth rate when there are no impurities by this equation? Explain.

c) What is the value of growth rate when there is a high concentration of impurities by this equation? Explain.

d) For $G_0 = 3.00 \times 10^{-3}$ mm/min and $G_L = 1.80 \times 10^{-3}$ mm/min and using the following values calculate the two constants using the method of least squares.

C ppm	50.0	75.0	100.0	125.0	150.0
G x 10^3 mm/min	2.50	2.20	2.04	1.95	1.90

$$m = \frac{s_{xy} - s_x s_y}{s_{xx} - (s_x)^2} \qquad b = \frac{s_{xx} s_y - s_x s_{xy}}{s_{xx} - (s_x)^2}$$

e) Calculate the value for χ^2 for your least squares function.

f) What is the value of the growth rate at an impurity concentration of 0.1 percent?

*Modified from Question 2.37 of the R.M. Felder and R.W. Rousseau Text.

4)* A mixture of methane and air can be ignited at mole percentages of methane between 5% and 15%.

a) Why might this the case, i.e. what happens at lower or higher concentrations?

b) For a mixture of 9.0 mole % methane at flow rate of 700. kg/h needs to be diluted below the flammability limit. Calculate the required flow rate of air in mole/h.

c) Calculate the concentration of oxygen in percent by mass in the product gas.

*Modified from Question 3.23 of the R.M. Felder and R.W. Rousseau Text.

5)* A liquid mixture containing 45% benzene and 55% toluene by mass is fed to a distillation column. A product stream leaving the top of the column contains 95 mole % benzene and a bottom product stream contains 8% of the benzene fed to the column. The volumetric flow rate of the feed stream is 2000L/h and the specific gravity of the feed mixture is 0.872. Determine the mass flow rate of the overhead product stream and the mass flow rate and composition (mass fractions) of the bottom product stream.

*Example 4-3.5 from the R.M. Felder and R.W. Rousseau Text.