The exam is a closed book examination. There are five equally weighed problems on this exam and you must answer them all to receive full credit.

Useful formulas and information are attached after the last problem statement.

The majority of the credit on a problem is obtained by properly setting-up the solution. Accordingly, focus your attention on outlining the setting-up the solution and describing your approach. Attempt to carry the solution to completion, but don’t get stuck in algebraic details at the expense of the activities mentioned above.

Instructions:

1. Your code test number is ____________. Write this number clearly on each page of your answer sheets.

2. Write your name and code test number on the slip of paper provided and hand this into the proctor. Do not write your name anywhere else on the test or answer sheets.

3. Use the answer sheets provided for your solutions and number each page of your solution to each problem sequentially. Keep the solution to each problem on separate sheets of paper. This will allow grading of the problems simultaneously and anonymously so that the results can be returned to you rapidly. Please write on one side of the answer sheets only. Clearly indicate your solution.

4. When you are finished with the exam, staple each solution separately and place it in the stack for that problem number. Turn your exam and any scratch work into the proctor.
**Thermo Problem 1.**

For the system methanol (1) /methyl acetate (2), the following equations provide a reasonable correlation for the partial excess free energies:

\[
\begin{align*}
\mathcal{G}_1^{E} / RT &= A x_2^2 \\
\mathcal{G}_2^{E} / RT &= A x_1^2
\end{align*}
\]

where \( A = 2.771 - 0.00523 \times T \) (where \( T \) is in units of K)

In addition the following form of the Antoine equation can be used in this model:

\[
\ln P_{1\text{sat}} = B - \left[ \frac{C}{(T-D)} \right] \quad \text{(where } T \text{ is in units of K and } P_{\text{sat}} \text{ is in kPa)}
\]

where for methanol (1): \( B = 16.59158 \), \( C = 3643.31 \); and \( D = 33.424 \)

for methyl acetate (2): \( B = 14.25326 \); \( C = 2665.54 \); and \( D = 53.424 \)

1. Calculate the azeotropic pressure and azeotropic composition for \( T = 318.15 \text{K} \)

2. What type of azeotrope do you observe (maximum P, minimum P, heterogeneous). Explain

3. Based on the azeotrope that forms, do you expect methanol-methanol interactions to be weaker or stronger than methanol-methyl acetate under these conditions. Explain.
Thermo Problem 2.

At 900 K, the reaction
\[ \text{CO}_2 (g) + \text{C} \text{ (solid)} \rightarrow 2 \text{CO (g)} \]
comes to equilibrium. For the standard states shown above, and a standard state pressure of 1 atm for the gas phase, the equilibrium constant \( K = 0.178 \).

a. Determine the mole fraction of \( \text{CO} \), \( y_{\text{CO}} \), at equilibrium at 10 atm assuming the gas phase is an ideal gas.

b. Suppose at this pressure, it is desired to not produce any solid C. What is the maximum possible \( y_{\text{CO}} \) where carbon will not form?
Thermo Problem 3.

One mol of water (1) is mixed with one mol of ethanol (2). At 42.05°C, the heat of mixing is -343.088 J, the partial pressure of water above this solution is 0.821 $P_1^{\text{sat}}$ and that of ethanol is 0.509 $P_2^{\text{sat}}$.

a. Calculate the activity and activity coefficient of water and ethanol for the liquid solution.

b. Calculate the entropy of mixing for this solution.
Thermo Problem 4.

Nitrogen gas is being withdrawn at the rate of 4.5 g/s from a 0.15 m³ cylinder, initially containing the gas at a pressure of 10 bar and 320 K. The cylinder does not conduct heat, nor does the cylinder’s temperature change during the emptying process. Nitrogen can be considered an ideal gas with $C_p = 30$ J/mol-K.

What is the simplified, unsteady energy balance that describes this system?
What will be the temperature and pressure of the gas in the cylinder after five minutes?
What will be the rate of change of the gas temperature at this time?
Thermo Problem 5.

A vessel divided into two parts by a partition contains 5 moles of nitrogen gas at 75 C and 30 bar on one side and 1 mole of argon gas at 130 C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is

the final temperature?
the final pressure?
the entropy change?

Assume nitrogen to be an ideal gas with $C_v = 5R/2$ and argon to be an ideal gas with $C_v = 3R/2$. $R = 83.15$ bar-cm$^3$/mol-K