Student Name__________________________________(Place on all pages in case they get separated)

Chemical Engineering Thermodynamics

1. The van der Waals equation is $P = \frac{RT}{V-b} - \frac{a}{V^2}$.

(a) Express the unit of "b" in mol and m?

(b) Express the unit of "a" in J, m and mol?

2. Consider a homogeneous liquid phase that is an ammonia water solution, and a homogeneous gas phase that contains ammonia and water vapor.

(a) How many phases are present in this system?

(b) Using Gibbs Phase Rule, determine how many intensive thermodynamic properties are needed to fix the state of this system?

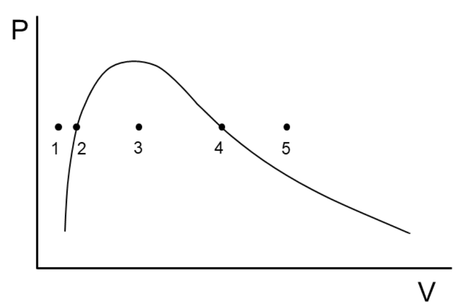
(c) Give examples of intensive thermodynamic properties that would fix the state of this system.

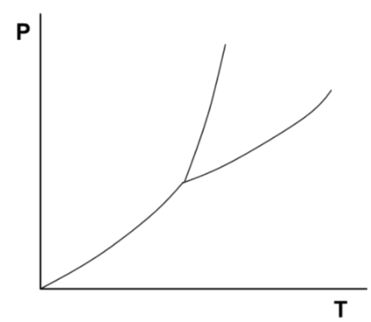
3. Draw P-V diagram and indicate regions in the PV diagram where the following property estimation is most appropriate to be applied: (a) Ideal gas law; (b) Virial equation; (c) van der Waals equation

4. Five states of a pure substance are marked in the PV diagram.

(a) Name these five states.

(b) Mark the correlated locations in the PT diagram





5. (a) If a large stone is dropped from a cliff 10m high, how fast will it be going when it hits the ground? Note: According the first law, the total quantity of energy, should be constant. That is for the above process: $\Delta E_K + \Delta E_P = 0$.

(b) Consider now an equivalent mass of water initially at 25°C. How hot would the water end up if its internal energy is increased by the same amount as the change in kinetic energy from part (a) above. Additional data: Energy in the amount of 4,184 J kg^{-1} is required for a temperature rise of 1°Cin water.

6. You wish to pump water flowing steadily in rate of 1000 cm^3/s from a well (z=0) to your house on the top of a hill (z=300m).
(a) What is the minimum power (in kW, and in hp) needed by the pump, neglecting the friction between the flowing water and the pipe?
(b) If the electricity cost is 12 cents per kilowatt hour what would you be paying annually if you pump water 1 hour daily.

7. One-gram mole of a gas at a temperature of 25°C and a pressure of 1 bar (the initial state) is to be heated and compressed in a frictionless piston and cylinder to 300°C and 10 bar (the final state). Compute the total heat, work and internal energy required along each of the following paths:

Path A: Isothermal compression to 10 bar, and then isobaric heating to 300°C.
Path B: Isobaric heating to 300°C followed by isothermal compression to 10 bar.
Path C: A compression in which PV^γ = constant, where $\gamma = C_P/C_V$, followed by an isobaric cooling or heating, if necessary, to 300°C.

For simplicity, the gas is assumed to be ideal with C_P = 38 J/mol K.

8. Ten moles of ethylene are to be compressed isothermally from their initial state (P = 21.7 bar, T = 25 ºC, and V = 1000 cm^3/mol) to 100 cm^3/mol. Under these conditions, the behavior of the gas is well described by the van der Waals equation of state.
Estimate the pressure (in bar) at the final state. <u>Note</u>: Use Appendix B to obtain T_C and P_C values for ethylene.

9. Ethylene glycol is prepared by the hydrolysis of ethylene oxide in the reaction shown below:

Ethylene oxide (g) + water (l) → Ethylene glycol (l)

Consider a single-pass process where ethylene oxide is combined with water to generate ethylene glycol. In the process, the molar water to ethylene ratio entering the reactor is 5 and the reaction proceeds with 90% conversion of the entering ethylene oxide. The reactants (gaseous ethylene oxide and liquid water) enter the reactor at 80 ºC. If the reactants are stored at 25 ºC and must be heated to 80 ºC before entering the reactor,
a) Determine the amount of heat that must be provided to the process per mole of ethylene oxide in the feed stream and
b) Determine the amount of heat that must be provided to the process per mole of ethylene glycol produced in the final product stream