You may use a calculator, but no other aides during the examination. Read the examination over before beginning. There are 5 questions each worth 20 points. It may be prudent to begin with the questions about which you are most confident. Then of the remaining questions work the ones you are most confident, etc. If you need more space, use the back of these sheets. Please indicate you are doing so in the space provided for the answer. A list of useful expressions is provided at the end of the exam.

Some questions have multiple parts. If you do not know the answer to the first part, you can receive significant partial credit on later parts by indicating how you would use the earlier answer if you had it, for example by using a variable to represent that answer.

You must show work to receive full credit

Notes added in Wi 1999: This exam was written several years ago when the material covered for the first exam was similar to that covered this year. That year I had more qualitative questions than I usually put on an exam. You can expect that on the midterm exam at least 30% of the questions will be qualitative (e.g. no numerical manipulations required) and at least 30% will closely resemble problems you saw on the problem sets.
1. Alcoholic fermentation by microorganisms involves the decomposition of \(\alpha\)-D-glucose \([C_6H_{12}O_6(s)]\) into ethanol \([C_2H_5OH(l)]\) and carbon dioxide \([CO_2(g)]\)

   (a) (10 points) Calculate \(\Delta H\) at 298.15 K and 1 atm. [A list of \(\Delta H\) values is provided at the back of the exam.]

   (b) (10 points) Calculate the change in internal energy for this reaction at 298.15 K. You may assume that all gases behave ideally.
2. A certain gas at 19.0 atm and 300. K has a compressibility of 1.19.

(a) (5 points) What is the molar volume of the gas under these conditions?

(b) (10 points) If the equation of state for this gas is

\[ p = \frac{RT}{V_m - b} \]  \hspace{1cm} (1)

what is the value of \( b \) for our gas?

(c) (5 points) If we treat Eq. (1) as an approximation to the van der Waals equation of state, what does the value of \( b \) tell us about the gas? When will the approximation of Eq. (1) be most valid?
3. For each of the following processes, state whether each of the thermodynamic quantities $q$, $w$, $\Delta U$ and $\Delta H$ are greater than, less than or equal to zero. Briefly explain your answers:

(a) (6 points) A perfect gas expands adiabatically against a constant pressure of 1 atm.

(b) (7 points) A perfect gas expands isothermally from an initial volume $V_1$ to a final (larger) volume $V_2$.

(c) (7 points) A perfect gas sample undergoes a reversible isothermal expansion from an initial state A ($V_i, p_i, T_i$) to a new state B ($V_f, p_f, T_f$). Then the sample is heated with $V = \text{cnst.}$ until the pressure is returned to its initial value. Now the system is in state C ($V_f, p_i, T_C$). Finally the system is cooled with $p = \text{cnst.}$ until the volume is returned to its initial value and the sample is now in state A ($V_i, p_i, T_i$).
4. For this problem, you will be studying the reversible isothermal expansion of 1.00 mol Ar at 273 K, where the equation of state is approximated by the Virial series

\[ p = \frac{nRT}{V} \left(1 + \frac{nB}{V} + \frac{Cn^2}{V^2}\right) \]  

(2)

and \( B = -0.0217 \text{ L/mol} \) and \( C = 0.0012(\text{L/mol})^2 \).

(a) (15 points) Evaluate the work done on the Ar when it is expanded from a volume of 2. L to a final volume of 10 L.

(b) (5 points) Compare this to a amount of work that would have been done if Ar had behaved ideally.
5. For each of the following statements, signify agreement or disagreement. For either answer provide support in the form of a statement, an explanation, an equation or a derivation.

(a) (5 points) A general expression for expansion work is given by \( w = p_{ex} \Delta V \).

(b) (5 points) A perfect gas cannot liquify (undergo a gas to liquid phase transition).

(c) (5 points) An ideal gas expansion or compression which is both adiabatic and isothermal is not possible.

(d) (5 points) The internal energy of a real gas sample depends only on its temperature.
The following problem on kinetic molecular theory have been added, since there were no problems on this subject on the original exam:

6. Use what you know from kinetic molecular theory to determine (i) In which flask will \( c_{rms} \) be larger?, and (ii) In which flask will the frequency of collisions of He atoms with a wall of the container be larger? for the following situations (you must explain your results with words and/or equations to receive full credit):

(a) Two flasks with volumes \( V_1 \) and \( V_2 \) (with \( V_2 > V_1 \)) contain the same number of helium atoms at the same temperature.

(b) What if equal numbers of He atoms were put into flasks of the same volume but with temperatures \( T_1 \) and \( T_2 \) where \( T_2 > T_1 \)

(c) Equal number of moles of He and Ne are placed in the two flasks of equal volume and at the same temperature.