Problem 1 (20%)

A liter of ideal gas is enclosed by a jacket containing 1000 g of water. The gas is then reversibly and isothermally compressed by the liquid media from 1 atm to 2 atm. Assume that the water and jacket are incompressible, and the whole system is in thermal equilibrium at 25°C. The heat capacities, C_p, of the gas and water are $6\frac{\text{cal}}{\text{g mol}-\text{K}}$ and $18\frac{\text{cal}}{\text{g mol}-\text{K}}$, respectively. Ln 2=0.693 and the gas constant, R, is $1.987\frac{\text{cal}}{\text{g mol}-\text{K}}$, or $0.082\ \frac{\text{atm}-\text{liter}}{\text{g mol}-\text{K}}$.

(a) Does this process represent positive work being done on the gas or by the gas?

(b) How much is the work in calories?

(c) What is the entropy change of the gas in $\frac{\text{cal}}{\text{K}}$?

(d) What is the entropy change of the water in $\frac{\text{cal}}{\text{K}}$?

(e) What is the entropy change of the universe in $\frac{\text{cal}}{\text{K}}$?

Problem 2 (20%)

(a) Derive $\triangle T_f = K_f \cdot m$ by starting with the free energy condition for equilibrium between pure solid solvent and solution. Assume the solution to be ideal.

(b) What weight of glycerol would have to be added to 1000g of water in order to lower its freezing point 10°C?

Problem 3 (20%)

Partial molar enthalpy data of sulfuric acid is given as follows:

$x_{H_2SO_4}$	$(\hat{H}-\underline{H^0})_{H_2O}$	$(\hat{H}-\underline{H^0})_{H_2SO_4}$
0.2	-4187	46850
0.4	-12810	67660
0.6	-26380	81770
0.8	-31360	84150

When one try to produce 40 mol% sulfuric acid by mixing 80% sulfuric acid with water, there are two ways to do it, adding water gradually to sulfuric acid, or adding sulfuric acid gradually to water. In both cases heat will be released.

(a) Prove that if we add water gradually to sulfuric acid, the rate of heat release will descrease gradually with time.

(b) Prove that if we add sulfuric acid gradually to water, the rate of heat release will increase gradually with time.

(c) Which way is better, in terms of minimizing instantaneous heat release rate.

Problem 4 (20%)

(a) Devise a cell that can be used to measure activity coefficients of $ZnCl_2$.

(b) What is the Nernst equation for your cell?

Standard electrode potentials in water at 25°C

electrode reaction (acid solution)	E^0(volts)
$Zn^{2+} + 2e \rightleftharpoons Zn$	-0.7628
$AgCl + e \rightleftharpoons Ag + Cl^-$	0.2225
$Hg_2Cl_2 + 2e \rightleftharpoons 2Hg + 2Cl^-$	0.2680
$Cl_2 + 2e \rightleftharpoons 2Cl^-$	1.3595

Problem 5 (20%)

A substance A decomposes to form a product P, which itself reacts to form a worthless material M. It is desired to produce P in a dilute solution by using a batch reactor. Both reactions are irreversible and first order. Determine the maximum fraction of A obtainable as P, and the reaction time at which this occurs.