

NAME: \_\_\_\_\_

COURSE 3.00: THERMODYNAMICS OF MATERIALS

90 minute EXAM, Oct 12, 2001

PROBLEM 1 (20 POINTS) \_\_\_\_\_

PROBLEM 2 (20 POINTS) \_\_\_\_\_

PROBLEM 3 (20 POINTS) \_\_\_\_\_

PROBLEM 4 (20 POINTS) \_\_\_\_\_

PROBLEM 5 (20 POINTS) \_\_\_\_\_

TOTAL (100 POINTS) \_\_\_\_\_

You can either write your answer on the question sheets or use separate pages. In each case make sure your answer is clearly marked.

*A neat answer is the sign of a clear mind*

**Question 1**

I have a machine stirring in a bucket with liquid. The bucket is under constant pressure and is insulated from the environment (an adiabatic bucket).

Check of the correct answer.

a) Which of the following statements regarding the enthalpy of the bucket during this process is correct ? The bucket is defined as the physical bucket + the liquid in it.

$$\Delta H_{\text{bucket}} > 0 \quad \underline{\hspace{1cm}} \qquad \Delta H_{\text{bucket}} < 0 \quad \underline{\hspace{1cm}} \qquad \Delta H_{\text{bucket}} = 0 \quad \underline{\hspace{1cm}}$$

b) Which of the following statements regarding the entropy of the bucket during this process is correct ? The bucket is defined as the physical bucket + the liquid in it.

$$\Delta S_{\text{bucket}} > 0 \quad \underline{\hspace{1cm}} \qquad \Delta S_{\text{bucket}} < 0 \quad \underline{\hspace{1cm}} \qquad \Delta S_{\text{bucket}} = 0 \quad \underline{\hspace{1cm}}$$

c) Which of the following statements regarding the enthalpy of the surroundings is correct ?

$$\Delta H_{\text{surr}} > 0 \quad \underline{\hspace{1cm}} \qquad \Delta H_{\text{surr}} < 0 \quad \underline{\hspace{1cm}} \qquad \Delta H_{\text{surr}} = 0 \quad \underline{\hspace{1cm}}$$

d) What is the minimal entropy change that needs to place in the surroundings. ?

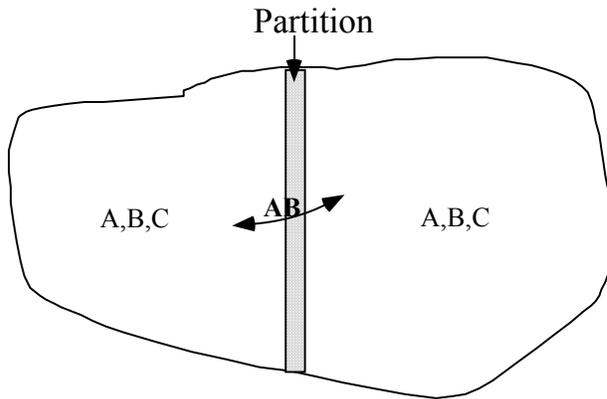
$$\Delta S_{\text{surr}} > 0 \quad \underline{\hspace{1cm}} \qquad \Delta S_{\text{surr}} < 0 \quad \underline{\hspace{1cm}} \qquad \Delta S_{\text{surr}} = 0 \quad \underline{\hspace{1cm}}$$



**Question 3:**

Two system, each containing chemical species A, B and C in different concentrations, are in contact through a semi-permeable wall. The semi-permeable wall does not allow for transport of A, B or C individually, but only allows a pair of molecules A-B to pass through together. The systems can be considered to be at constant temperature and pressure.

Derive the equilibrium conditions imposed on the chemical potentials for this system.



**Question 4:**

In class we derived an expression for  $dS$  in terms of  $dP$  and  $dT$ . Derive two other expressions for  $dS$ : one in terms of  $dT$ ,  $dV$ , another in terms of  $dV$ ,  $dP$ . Write the expressions in terms of heat capacities, compressibilities and coefficients of thermal expansion. Use the symbol  $\alpha$  for thermal expansion,  $\beta$  for compressibility, and  $C$  for heat capacity. If further specification of the property is necessary, please use indices (e.g  $C_p$  is constant pressure heat capacity etc.).

**Problem 5:**

A system has the equation of state  $H = A T$ , where  $A = 100\text{J/K}$ .

Assume this equation of state is valid in the temperature range from 1K to 500K. The system is cooled from 298K to 1K by operating a refrigerator with the high temperature heat release at 298K. The low temperature heat absorption cools the system.

What is the minimum work required to cool this system from 298 K to 1K ?