

**Exam II**  
**CH 353 Sumer 2007**

Vanden Bout

Name: \_\_\_\_\_

KEI

You can use anything to answer the following except someone else.

Carefully read all the problems. The exam should have 4 questions on 6 pages. The first page has potentially useful information. The last page is for extra writing space.

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \quad R = 8.314 \times 10^{-2} \text{ L bar K}^{-1} \text{ mol}^{-1} \quad R = 8.206 \times 10^{-2} \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$1 \text{ atm} = 1.01325 \text{ bar} \quad T/\text{K} = T/^{\circ}\text{C} + 273.15 \quad 1 \text{ atm-L} = 101.325 \text{ J} \quad 1 \text{ bar-L} = 100 \text{ J}$$

$$dS = \frac{C_v}{T} dT + \frac{\alpha}{\kappa} dV \quad dS = \frac{C_p}{T} dT - V\alpha dP$$

$$\text{for IG this is } dS = \frac{C_v}{T} dT + \frac{nR}{V} dV \quad \text{or } dS = \frac{C_p}{T} dT - \frac{nR}{P} dP$$

$$dH = \left(\frac{\partial H}{\partial T}\right)_P dT + \left(\frac{\partial H}{\partial P}\right)_T dP \quad \left(\frac{\partial H}{\partial T}\right)_P = C_p \quad \left(\frac{\partial H}{\partial P}\right)_T = V - T\left(\frac{\partial V}{\partial T}\right)_P = V(1 - \alpha T)$$

$$dU = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV \quad \left(\frac{\partial U}{\partial T}\right)_V = C_v \quad \left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P = T\frac{\alpha}{\kappa} - P$$

$$\alpha = \frac{1}{V} \left(\frac{\partial V}{\partial T}\right)_P \quad \kappa = -\frac{1}{V} \left(\frac{\partial V}{\partial P}\right)_T \quad \text{For an IG } \alpha = \frac{1}{T} \quad \text{and } \kappa = \frac{1}{P}$$

$$\text{Virial Equation } PV = nRT(1 + B'P) \quad \text{van der Waals equation } \left(P + \frac{a}{V^2}\right)(V - b) = nRT$$

**Please sign at the bottom to certify that you have worked on your own.**  
 I certify that I have worked the following exam without the help of others, and that the work I am turning in is my own.

Signed: \_\_\_\_\_

Signature

Date

1. True/False Circle either T or F for each statement (10 points each)

T  F For an adiabatic process,  $\Delta S_{\text{SYS}}$  can never decrease.  $q=0$   $\Delta S_{\text{Surr}}=0$

T  F At constant T & P,  $\Delta S_{\text{Surr}} = -\Delta H_{\text{SYS}}/T_{\text{SYS}}$  always.  $q = \Delta H$  only at T

T  F A spontaneous endothermic process can never decrease the entropy of the system.

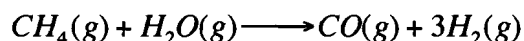
T  F For a reversible process  $\Delta S_{\text{Total}} = 0$ .

T  F For an isothermal reversible expansion of an ideal gas  $\Delta G = 0$ .

$$\Delta H = 0 \quad \Delta S > 0 \quad \Delta G < 0$$

2. Short Answer (25 points each)

What is the standard Gibb's energy for the following reaction at 298K and standard pressure



|                                | $\Delta_f H^\circ$ | $\Delta_f G^\circ$ | $S^\circ$ | $C_p$ |
|--------------------------------|--------------------|--------------------|-----------|-------|
| $\text{CH}_4(\text{g})$        | -74.8              | -50.7              | 186.3     | 35.3  |
| $\text{H}_2\text{O}(\text{g})$ | -241.8             | -228.6             | 188.8     | 33.6  |
| $\text{CO}(\text{g})$          | -110.5             | -137.2             | 197.7     | 29    |
| $\text{H}_2(\text{g})$         | 0                  | 0                  | 130.7     | 28.8  |

$$\begin{aligned} \Delta_r G^\circ &= \Delta_f G^\circ_{\text{CO}(\text{g})} + 3\Delta_f G^\circ_{\text{H}_2} - \Delta_f H^\circ_{\text{H}_2\text{O}(\text{g})} - \Delta_f H^\circ_{\text{CH}_4(\text{g})} \\ &= -137.2 - (-228.6) - (-50.7) \\ \Delta_r G^\circ &= +142.1 \text{ kJ mol}^{-1} \end{aligned}$$

Given that

$$\left(\frac{\partial G}{\partial P}\right)_T = V$$

What is  $\Delta G$  for a change in pressure for  $P_i$  to  $P_f$  for a gas that obeys the equation of state

$$P(V - nb) = nRT$$

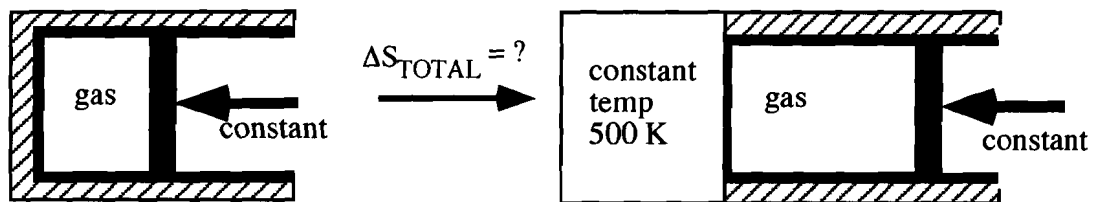
$$V = \frac{nRT}{P} + nb$$

$$\Delta G = \int_{P_i}^{P_f} \left(\frac{\partial G}{\partial P}\right) dP = \int_{P_i}^{P_f} \left(\frac{nRT}{P} + nb\right) dP$$

$$\Delta G = nRT \ln\left(\frac{P_f}{P_i}\right) + nb(P_f - P_i)$$

3. (50 points)

3 moles of an ideal gas ( $C_{V,M} = 3/2R$ ) are initially in an insulated piston at a constant pressure. The volume of the gas is initially 40 L and the temperature and pressure unknown. The piston is then placed in contact with a constant temperature bath at 500 K. Bringing the bath in contact with the piston causes 6.236 kJ of heat to transfer into the piston and causes the gas to expand. Find  $\Delta S_{TOTAL}$  for this process.



$$q = 6.236 \text{ kJ}$$

$$\Delta S_{\text{surround}} = \frac{-6236 \text{ J}}{500 \text{ K}} = -12.47 \text{ J K}^{-1}$$

const P heating  $C_V = 3 \times \frac{3}{2}R = \frac{9}{2}R$

$$C_P = 3 \times \frac{5}{2}R = \frac{15}{2}R$$

$$q = 6236 = \frac{15}{2}R(500 - T_i)$$

$$T_i = \cancel{310} 400$$

$$\Delta S = \int \frac{C_P}{T} dT = C_P \ln\left(\frac{T_f}{T_i}\right)$$

$$\Delta S_{\text{sys}} = \frac{15}{2}R \ln\left(\frac{500}{400}\right) = +13.91 \text{ J K}^{-1}$$

$$\Delta S_{\text{TOTAL}} = +13.91 - 12.47 = +1.44 \text{ J K}^{-1}$$

4. (50 points)

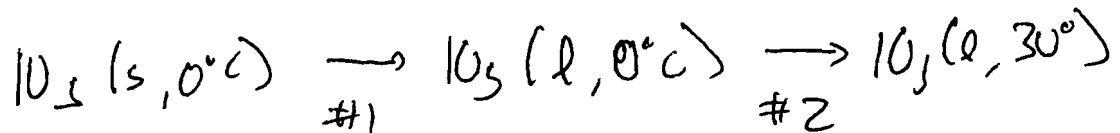
You place 10 g of solid water on a sidewalk one afternoon when it is 30°C outside. The ice melts and the liquid heats up to 30°C. You can assume the ice cube is initially 0°C. What is the change in the entropy of the system, the surroundings, and the universe (total) for this process (ice melting + liquid heating)? (note: in reality this process would also involve some water evaporating. Ignore this effect).

$$C_{p,\text{solid}} = 36 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$C_{p,\text{liquid}} = 75.3 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\Delta_{\text{FUS}}H^\circ = 6.02 \text{ kJ mol}^{-1}$$

$$S^\circ(\text{H}_2\text{O}, \text{liq}, 298\text{K}) = 70 \text{ J K}^{-1} \text{ mol}^{-1}$$



$$q_1 = \frac{10}{18} \times 6.02 = 3344 \text{ J}$$

$$q_2 = \frac{10}{18} \times (75.3)(30) = 1255 \text{ J}$$

$$\Delta S_{1,\text{sys}} = \frac{\Delta H_{\text{sys}}}{T} = \frac{+3344}{273} = +12.25$$

$$\Delta S_{1,\text{sur}} = -\frac{\Delta H}{T} = -\frac{3344}{303} = -11.04$$

$$\Delta S_{2,\text{sys}} = C_p \ln\left(\frac{T_f}{T_i}\right) = \frac{10}{18} (75.3) \ln\left(\frac{303}{273}\right) = +4.36$$

$$\Delta S_{2,\text{sur}} = -\frac{1255}{303} = -4.14$$

$$\Delta S_{\text{sys}} = 12.25 + 4.36 = 16.61 \text{ J K}^{-1}$$

$$\Delta S_{\text{sur}} = -11.04 - 4.14 = -15.18 \text{ J K}^{-1}$$

$$\Delta S_{\text{TOTAL}} = 16.61 - 15.18 = +1.43 \text{ J K}^{-1}$$