(P3.1)

(a) the number of microstates is 2^N (pg 91, typo in given answer, printings 1-3)

(b) 3 particles total

$\Rightarrow p_{\{2H,1T\}} = \frac{3!}{2!*1!} = 3$ number microstates of specific arrangement (macrostate)

probability = (# microstates of specific arrangement)/(total # of microstates)

$$prob = \frac{3}{2^3} = \frac{3}{8}$$

(c) # microstates.

$$p_{\{2H,2T\}} = \frac{4!}{2!*2!} = 6$$

$$p_{\{3H,2T\}} = \frac{5!}{3!*2!} = 10$$

$$p_{\{4H,2T\}} = \frac{6!}{4!*2!} = 15$$

$$p_{\{3H,3T\}} = \frac{6!}{3!*3!} = 20$$

(d)

macrostate		# of microstates*
H	T	
0	8	1
1	7	8
2	6	28
3	5	56
4	4	70
5	3	56
6	2	28
7	1	8
8	0	1

* number of microstates = $\frac{8!}{m!(8-m)!}$

total number of microstates is 2^8 = 256, which is the same as the sum from the table.

portion of microstates (probability) for requested configurations:

{5:3} = 56/256 = 0.219 = 22%

{4:4} = 70/256 = 0.273 = 27%

{3:5) = 22% like {5:3}

probability of any one of the three most evenly distributed states = 22% + 27% + 22% = 71%

(e) for 8 particle system, Stirling's approx will not apply

$\Delta \underline{S}/k = \ln(p\{4:4\}/p\{5:3\}) = \ln(70/56) = 0.223$

(P3.3) 15 molecules in 3 boxes, molecules are identical

$$p_j = \frac{N!}{\prod_{i=1} m_{ij}!} \quad \text{.....Eqn. 3.4}$$

$$p_1 = \frac{15!}{9!4!2!} = 75075$$

$$p_2 = \frac{15!}{(5!)^3} = 756756$$

$$\frac{\Delta S}{k} = \ln\left[\frac{p_2}{p_1}\right] = 2.31$$

(P3.4) two dice.

$\frac{\Delta S}{k} = ??$ for going from double sixes to a four and three.

$\Rightarrow$ for double sixes, we have probability of 1/6 for each dice.

$$\Rightarrow p_1 = \frac{2!}{\left(\frac{1}{6}\right)*\left(\frac{1}{6}\right)}$$

for one four and one three $\Rightarrow$ probability applied for 1/6 for each one in each dice,

$$\Rightarrow p_2 = \frac{2!}{\left(\frac{1}{6}\right)*\left(\frac{1}{6}\right)}*2$$

$$\frac{\Delta S}{k} = \ln\left(\frac{p_2}{p_1}\right) = \ln 2 = 0.693$$

(P3.5) $\Delta S = ??$

Assume Nitrogen is an Ideal gas $\Rightarrow$ $PV = RT$ ……. Eqn. 1.15

$$\Rightarrow P_1 = \frac{8.314(cm^3 * MPa/mole-K)*300K}{23(L/mole)*(1000cm^3/1L)} = 0.108MPa$$

Similarly $\Rightarrow P_2 = 0.00723MPa$

$$\Delta S = Cp\ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1} \quad \text{…… Eqn. 3.23}$$

$$Cp = \frac{7R}{2} \text{ …..(ig)}$$

$$\Delta S = \frac{7R}{2}*\ln\frac{400}{300} - 8.314*\ln\frac{0.00723}{0.108} = 30.88J/mole-K = 1.07kJ/kg-K$$

(P3.6) (a) m-balance: $dn^{in} = -dn^{out}$

S-balance:

$$\frac{d(nS)^{in}}{dt} = -S^{out}\frac{dn^{out}}{dt} \Rightarrow n^{in}dS^{in} + S^{in}dn^{in} = -S^{out}dn^{out}$$

But physically, we know that the leaking fluid is at the same state as the fluid in the tank; therefore, the S-balance becomes:

$(ndS + Sdn)^{inside} = -(Sdn)^{out}$, and $dn^{inside} = -dn^{out}$ so $\Delta S = 0$

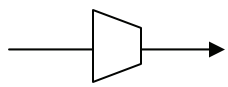
from the steam table .

State	P(Mpa)	T^{o}C	H(kJ/kg)	S(kJ/kg*K)
1(in)	1	400	3264.5	7.4669
2 (out)	0.1	***120.8***	2717.86	7.4669

At 1 bar =	0.1 MPa
T	S
100	7.361
120.8	**7.4669**
150	7.6148

By interpolation, implies **T = 120.8^{o}C**

(P3.7) (a) Steady-state flow, ΔH = Ws



Start 1 mole basis:

$x_1 = 0.333, x_2 = 0.667, adiabatic, Cp = x_1Cp_1 + x_2Cp_2$, Cp for each is the same anyway.

$MW = x_1MW_1 + x_2MW_2 = 0.333(12+16) + 0.667*2 = 10.66(g/mole)$

R = 1.987BTU/lbmol-R.

$$\Delta H = W_S = \int_{T_1}^{T_2} CpdT = \frac{7}{2} * R * (1100 - 100)^{\circ}R$$

$$\Rightarrow \Delta H = 6954.5 BTU/lbmol$$

$$\& \ \dot{m} = 1 ton/h = 2000 lb/h.$$

$$\& \ MW = 10.66 lb/lbmol$$

$$\Rightarrow \Delta H = \frac{2000lb}{h} * \frac{lbmol}{10.66lb} * \frac{6954.5BTU}{lbmol}$$

$$\Rightarrow \Delta H = W_S = 1{,}305{,}000 = 1.3*10^6 BTU/h$$

(b) $\eta = ??$ of the compressor.

To find the efficiency of the compressor, $\Rightarrow S_1 = S_2$

But the enthalpy and the internal energy will change which gives a change in the Work. $\Rightarrow \eta = \frac{W_S'}{W_S} = ??$

$$\Delta S = 0 = Cp \ln \frac{T_2'}{T_1} - R \ln \frac{P_2}{P_1}$$

$$\Rightarrow Cp \ln \frac{T_2'}{T_1} = R \ln \frac{P_2}{P_1}$$

$$\Rightarrow \left(\frac{T_2'}{T_1}\right)^{Cp} = \left(\frac{P_2}{P_1}\right)^{R}$$

$$\Rightarrow T_2' = \left(\frac{P_2}{P_1}\right)^{\frac{R}{Cp}} * T_1$$

$$\Rightarrow T_2' = \left(\frac{100}{5}\right)^{\frac{2}{7}} * 559R$$

$$T_2' = 1315R$$

$$\& \ \Delta H' = Cp(T_2' - T_1) = 6.95(1315 - 559) \Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{5258}{6955} = 0.76$$

$$\Rightarrow \Delta H' = 5258 BTU / lbmol$$

(P3.8) Adiabatic, steady-state open system ⇒ Q = 0, &(Cp/R = 7/2)…… ig

$$W = \int_{300}^{625} CpdT = \frac{7R}{2} * (625 - 300) = 9457.175 kJ / kmole * \frac{1 kmole}{28 kg} = 337.76 kJ / kg$$

$$\eta = ??$$

$$\Delta S = 0 \Rightarrow \frac{T_2'}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{R}{Cp}}$$

$$\Rightarrow T_2' = 533.5K$$

$$\Rightarrow \Delta H' = Cp\left(T_2' - T_1\right) = \left(\frac{7 * 8.314}{2}\right) * \left(533.5 - 300\right)$$

$$\Rightarrow \Delta H' = 6794.77 kJ / mol$$

$$\Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{6794.77 kJ / kmol}{337.76 kJ / kg * 28 kg / kmol} = 0.718$$

$$\Rightarrow \eta = 71.8\%$$

(P3.9) work required per kg of steam through this compressor?
By looking at the steam table in the back of the book

P(MPa)	T(^{O}C)	H(kJ/kg)	S(kJ/kg-K)
0.8	200	2839.7	6.8176
4	500	3446	7.0922

$$W = \Delta H = 3446 - 2839.7 = 606.3 kJ / kg$$

now find W' = ??

ΔS = 0 (reversible), ⇒ look in the steam table (@P = 4.0MPa) to find a similar value for S = 6.8176kJ/kg-K, if this value is not available so find it by interpolation.

H(kJ/kg)	S(kJ/kg-K)
3214.5	6.7714
H' = ??	S' = 6.8176
3331.2	6.9386

$$\Rightarrow \frac{3331.5 - H'}{3331.2 - 3214.5} = \frac{6.9386 - 6.8176}{6.9386 - 6.7714}, \Rightarrow H' = 3246.7$$

$$\Rightarrow \Delta H' = W' = 3246.7 - 2839.7 = 407 kJ/kg$$

$$\Rightarrow \eta = \frac{407}{606.3} = 0.67, \Rightarrow \eta = 67\%$$

(P3.10)@ P = 2.0 MPa & T = 600°C, ⇒ H = 3690.7 kJ/kg, S = 7.7043kJ/kg-K (Steam table)

	T^{O}C	H_L(kJ/kg)	ΔH^{vap}(kJ/kg)
steam table	20	83.91	2453.52
Interpolation	**24**	**100.646**	**2444.098**
steam table	24	104.83	2441.68

$$H = H_L + q(\Delta H^{Vap}) = 1006.46 + 0.98 * (2441.68) = 2493k.49 J/kg$$

$$\Rightarrow W_S = \Delta H = 3690.7 - 2493.49 = 1197.21 kJ/kg$$

$$\eta = ??\ , \quad \eta = \frac{\Delta H}{\Delta H'} = \frac{W}{W'},$$

⇒ ΔS = 0 (reversible), ⇒look for S in the sat'd temp. steam table and find H by interpolation, $\Rightarrow W' = 1408.0 kJ/kg$

$$\Rightarrow \eta = \frac{1197.2}{1408.0} = 0.8503, \Rightarrow \eta = 85\%$$

(P3.11)

$$P_1 = 0.1 MPa, Sat'd_{vap}$$

$$P_2 = 10 MPa$$

$$T_2 = 1100^{O} C$$

State	P(MPa)	T(^{O}C)	H(kJ/kg)	S(kJ/kg-K)
1	0.1	99.61	2674.95	7.3589
2'	10		**4062.53**	*7.3589*
2	10	1100	4870.3	8.0288

interpolation for above table:

H'$_2$ = 4062.53	(interpolation)
H(kJ/kg)	**S(kJ/kg-K)**
3992	7.2916
4062.53	*7.3589*
4114.5	7.4085

$$\Rightarrow \Delta H = W_S = 4870.3 - 2674.95 = 2195.35 kJ/kg$$

mass flow rate = 1 kg/s

$$\Rightarrow \dot{W}_S = 2195.35 kJ/s = 2195350 watt$$

$$\& \; 1 watt = 0.001341022 hp$$

$$\Rightarrow \dot{W}_S = 2944.01 hp$$

$$\& \; \Delta H' = 4062.53 - 2674.95 = 1387.58 kJ/kg$$

$$\Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{1387.58}{2195.35} = 0.63$$

$$\Rightarrow \eta = 63.2\%$$

(P3.12)Ethylene gas is to be continuously compressed from an initial state of 1 bar and 20° C to a final pressure of 18 bar in an adiabatic compressor. If compression is 70% efficient compared with an isentropic process, what will be the work requirement and what will be the final temperature of the ethylene? Assume the ethylene behaves as an ideal gas with CP = 44 J/mol-K (ANS. 13.4 kJ/mol, 596K)

Ebal: $\Delta H = W$.

Sbal: $\Delta S^{rev} = 0 \Rightarrow \left(\frac{T_2^{rev}}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\left(\frac{R}{Cp}\right)} \Rightarrow T_2^{rev}$ = (20+273)*18^(8.314/44) = 506K.

$W^{rev} = C_p(T_2^{rev} - T_1)$ = 44*(506-293) = 9372J/mol => W_{act} = 9372/0.85 = 13.4kJ/mol

$W^{act} = C_p(T_2^{act} - T_1)$ = 13400 => T_2^{act} = (13400/44)+293 = 597K

(P3.13) Through the valve $\Rightarrow H^{in} = H^{out}$

$$P^{in} = 3MPa \quad P^{out} = 0.1MPa \qquad T_{out} = 110^O C = 383.15K$$

(By interpolation) Find H^{out} from steam table.

$$\frac{150-110}{150-100} = \frac{2776.6 - H^{out}}{2776.6 - 2675.8}$$

$\Rightarrow H^{out}$ **= 2695.96 kJ/kg**

At 3MPa table use same value for $\boldsymbol{H^{in}}$ to find $\boldsymbol{S^{in}}$

$\Rightarrow$ By interpolation $\frac{2856.5 - 2695.96}{2856.5 - 2803.2} = \frac{6.2893 - S^{in}}{6.2893 - 6.1856}$

$\Rightarrow$ $\boldsymbol{S^{in}}$ **= 5.976kJ/kg-K**

The process should be irreversible. To find S^{out}, interpolate using temperature at 0.1 MPa:

$$\frac{150-110}{150-100}=\frac{7.6148-S^{out}}{7.6148-7.3610}$$

S^{out} = 7.4118 kJ/kg-K, since $S^{out}>S^{in}$ entropy has been generated. The entropy balance is:

$$0=S^{in}\dot{m}^{in}-S^{out}\dot{m}^{out}+\underline{\dot{S}}_{gen}$$