Quiz 4
Chemical Engineering Thermodynamics
February 12, 2015

1)
P4.2 Twenty molecules are contained in a piston + cylinder at low pressure. The piston moves such that the volume is expanded by a factor of 4 with no work produced of any kind. Compute $\Delta \underline{S}/k$.

2) Answer part (a) in BTU/hr, $R = 1.987$BTU/lbmol-R. . 459.67 °R = 0 °F.
P4.7 A mixture of $1CO{:}2H_2$ is adiabatically and continuously compressed from 5 atm and 100°F to 100 atm and 1100°F. Hint: For this mixture, $C_P = x_1 C_{P1} + x_2 C_{P2}$.

(a) Estimate the work of compressing 1 ton/h of the gas. (C_P = 7/2R)
(b) Determine the efficiency of the compressor.

3) R = 8.314 J/(mole °K)
4.5 When a compressed gas storage tank fails, the resultant explosion occurs so rapidly that the gas cloud can be considered adiabatic and assumed to not mix appreciably with the surrounding atmosphere. Consider the failure of a 2.5-m^3 air storage tank initially at 15 bar. Atmospheric pressure is 1 bar, $C_P = 7R/2$. Provide an estimate by assuming reversibility.

(a) Calculate the work done on the atmosphere. Does the reversibility approximation overestimate or under-estimate the actual work?
(b) A detonation of 1 kg of TNT releases about 4.5 MJ of work. Calculate the equivalent mass of TNT that performs the same work as in part (a).

Answers Quiz 4
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1)
P4.2 Twenty molecules are contained in a piston + cylinder at low pressure. The piston moves such that the volume is expanded by a factor of 4 with no work produced of any kind. Compute $\Delta \underline{S}/k$.

(P4.2) Initial (each x represents 5 molecule)

xxxx	

Final

x	x
x	x

Create a space with a three empty boxes for the initial state. The number of molecules is too small to use Stirling's approximation.
p1 = 20!/(20!0!0!0!) = 1
p2 = 20!/(5!5!5!5!) = 20*19*18*17*16*15*14*13*12*11*10*9*8*7*6/(5*4*3*2)^3 = 11732745024
ΔS/k = ln(p2/p1) = ln(11732745024) = 23.18

Or you could say $\Delta S/k = N \ln(V_2/V_1) = 20 \ln(4) = 27.7$
Entropy is less for the first solution because you have confined each group of 5 to a box of ¼ the total size. When these are free to move between boxes they are more random increasing S by about 4.

2) Answer part (a) in BTU/hr, $R = 1.987$BTU/lbmol-R.

P4.7 A mixture of $1CO{:}2H_2$ is adiabatically and continuously compressed from 5 atm and 100°F to 100 atm and 1100°F. Hint: For this mixture, $C_P = x_1 C_{P1} + x_2 C_{P2}$.

(a) Estimate the work of compressing 1 ton/h of the gas. ($C_P = 7/2$R)
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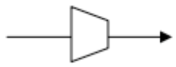
(P4.7) (a) Steady-state flow, $\Delta H = Ws$



Start 1 mole basis:

$x_1 = 0.333, x_2 = 0.667, adiabatic, Cp = x_1 Cp_1 + x_2 Cp_2$, Cp for each is the same anyway.

$MW = x_1 MW_1 + x_2 MW_2 = 0.333(12+16) + 0.667*2 = 10.66(g/mole)$

R = 1.987BTU/lbmol-R.

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

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

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

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

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

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

(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. $\Rightarrow \eta = \frac{W_S'}{W_S} = ??$

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

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

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

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

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

$$T_2' = 1315R$$

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

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

3) R = 8.314 J/(mole °K)

4.5 When a compressed gas storage tank fails, the resultant explosion occurs so rapidly that the gas cloud can be considered adiabatic and assumed to not mix appreciably with the surrounding atmosphere. Consider the failure of a 2.5-m^3 air storage tank initially at 15 bar. Atmospheric pressure is 1 bar, $C_P = 7R/2$. Provide an estimate by assuming reversibility.

(a) Calculate the work done on the atmosphere. Does the reversibility approximation over-estimate or under-estimate the actual work?

(b) A detonation of 1 kg of TNT releases about 4.5 MJ of work. Calculate the equivalent mass of TNT that performs the same work as in part (a).

(4.05) When a compressed gas storage tank fails, the resulting explosion...

a) $n\Delta U = nC_v(T^f - T^i) = \underline{W}_{EC}$

n and the initial temperature are not given, but P and $\underline{V}$ are given.

$P\underline{V}/R = nT$ and $V^f = V^i(P^i/P^f)^{Cv/Cp}$, since the system is considered closed (no mixing with surrounding air, $\underline{V}^f = \underline{V}^i(P^i/P^f)^{Cv/Cp}$.

$\underline{V}^f = 2.5(15/1)^{5/7} = 17.3\ m^3$, $(nT)^f = 0.1$ MPa$(17.3E6cm^3)/8.314 = 2.081E5$ molK

$(nT)^i = 1.5$ MPa$(2.5E6cm^3)/8.314 = 4.510E5$ molK

$n\Delta U = 5*8.314/2*(2.081E5-4.510E5) = \underline{-5.049\ E6\ J} = \underline{W}_{EC}$

b) 5.049E6J/(4.5E6 J/[kg TNT]) = 1.12 kg TNT