Thermo Ch. 6 Notes

Entropy is an extensive property (not path dependent)

$$S_2 - S_1 = \left(\int_1^2 \frac{\delta Q}{T} \right)_{\substack{int \\ rev}} \qquad dS = \left(\frac{\delta Q}{T} \right)_{\substack{int \\ rev}}$$

↳ the change in entropy

- since entropy is property, change in entropy of system in going from one state to another is same for <u>all</u> processes, both internally reversible and irreversible, between these two states

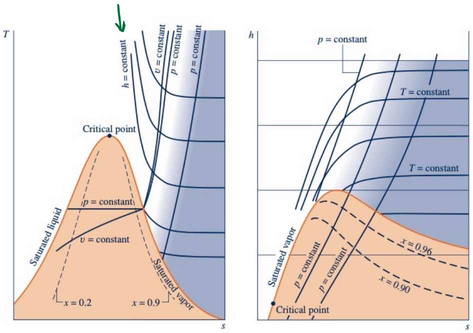
specific entropy of a 2-phase liq-vapor mixture calculated using x

$$s = (1-x)s_f + x s_g = s_f + x(s_g - s_f)$$

$$x = \frac{u - u_f}{u_g - u_f}$$

Temperature-Entropy Diagram

constant enthalpy line



- in superheated vapor region constant specific volume lines have a steeper slope than constant pressure lines
- in superheated vapor region, constant specific enthalpy lines become nearly horizontal as pressure is reduced
  - ↳ enthalpy determined primarily by temp $h(T,p) \approx h(T)$
  - ↳ ideal gas model suitable here
- for superheated states outside shaded area, both temp and pressure required to evaluate enthalpy, and IGM not suitable

TdS Equations

- developed by considering pure, simple compressible system undergoing an internally reversible process

$$(\delta Q)_{\substack{int \\ rev}} = dU + (\delta W)_{\substack{int \\ rev}}$$

for simple compressible

$$(\delta W)_{\substack{int \\ rev}} = p\,d\forall \qquad (\delta Q)_{\substack{int \\ rev}} = T\,dS$$

$$T\,dS = dU + p\,d\forall$$

$$H = U + p\forall \longrightarrow T\,dS = dH - \forall\,dp$$

$$T\,ds = du - p\,dv$$

$$T\,ds = dh - v\,dp$$

if press constant changing from sat. liq to sat vap then

$$ds = \frac{dh}{T} \Rightarrow s_g - s_f = \frac{h_g - h_f}{T}$$

incompressible substance

$$\boxed{s_2 - s_1 = c \ln \frac{T_2}{T_1}}$$

entropy change of ideal gas (assuming constant spec. heat)

$$\boxed{\begin{aligned} s_2 - s_1 &= c_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{v_2}{v_1}\right) \\ s_2 - s_1 &= c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right) \end{aligned}}$$

s° only depends on temp (for ideal gas only)

$$\boxed{\begin{aligned} s_2 - s_1 &= s^\circ(T_2) - s^\circ(T_1) - R \ln\left(\frac{P_2}{P_1}\right) \\ s_2 - s_1 &= \bar{s}^\circ(T_2) - \bar{s}^\circ(T_1) - \bar{R} \ln\left(\frac{P_2}{P_1}\right) \end{aligned}}$$

s° only depends on temp

TABLE 6.1

Ideal Gas Model Review

Equations of state:

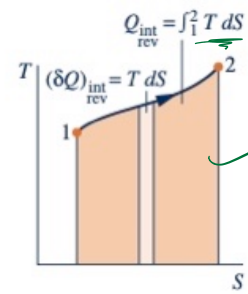
$$pv = RT \quad (3.32)$$
$$pV = mRT \quad (3.33)$$

Changes in u and h:

$$u(T_2) - u(T_1) = \int_{T_1}^{T_2} c_v(T)\,dT \quad (3.40)$$

$$h(T_2) - h(T_1) = \int_{T_1}^{T_2} c_p(T)\,dT \quad (3.43)$$

Constant Specific Heats	Variable Specific Heats
$u(T_2) - u(T_1) = c_v(T_2 - T_1)$ (3.50) $h(T_2) - h(T_1) = c_p(T_2 - T_1)$ (3.51) See Tables A-20, and A-20E for c_v and c_p data.	$u(T)$ and $h(T)$ are evaluated from Tables A-22 for air (mass basis) and Tables A-23 for several other gases (molar basis).

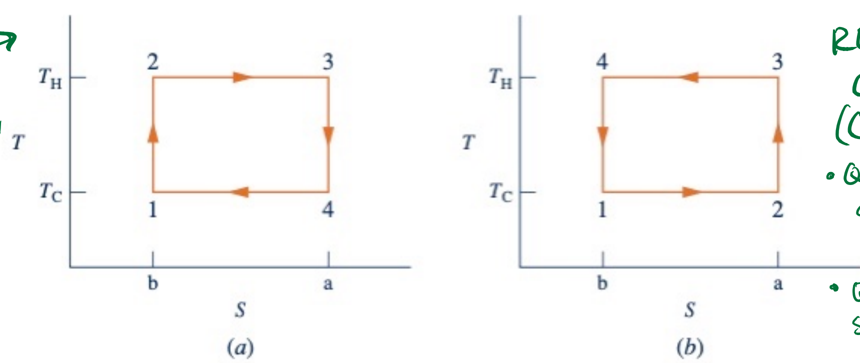


int. rev.

area is Q

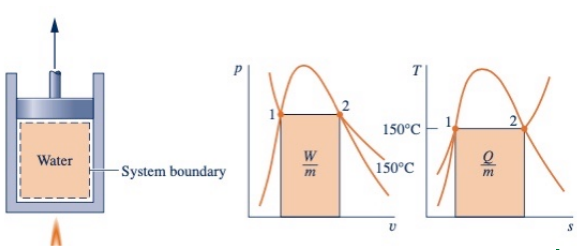
$$\eta = \frac{W_{cycle}}{Q} = \frac{(T_H - T_C)(S_3 - S_2)}{T_H(S_3 - S_2)} = 1 - \frac{T_C}{T_H}$$

POWER CYCLE



REF/PUMP CYCLE (CARNOT)

- Q xferred in; S↑ during 1→2 @ T_c
- Q xferred out, S↓ during 3→4



H_2O sat liq → sat vap (int rev.)

$$\frac{W}{m} = \int_1^2 p\,dv = p(v_2 - v_1)$$

$$\frac{Q}{m} = \int_1^2 T\,ds = T(s_2 - s_1)$$

Entropy Balance

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma$$

entropy change   entropy xfer   entropy production

* direction of entropy xfer is same as direction of heat xfer
  - (+) means entropy xferred in
  - (−) means entropy xferred out
* (+) σ means irreversibilities present
  $\sigma = 0$ means no internal irreversibilities
* ΔS can be (+), (−), or ϕ

$$\Delta S]_{isol} = \sigma_{isol}$$

$$\Delta S_{sys} + \Delta S_{sur} = \sigma_{isol}$$

Isentropic Processes → constant ENTROPY

IDG: for 2 states having same specific entropy

$$0 = s^\circ(T_2) - s^\circ(T_1) - R\ln\left(\frac{p_2}{p_1}\right)$$

For air only:

$$\frac{p_2}{p_1} = \frac{e^{s^\circ(T_2)/R}}{e^{s^\circ(T_1)/R}} \Rightarrow \frac{p_2}{p_1} = \frac{p_{r2}}{p_{r1}} \quad \text{for } s_1 = s_2$$

$$v = \frac{RT}{p} \Rightarrow \frac{v_2}{v_1} = \left(\frac{RT_2}{p_2}\right)\left(\frac{p_1}{RT_1}\right) = \left(\frac{RT_2}{p_r(T_2)}\right)\left(\frac{p_r(T_1)}{R(T_1)}\right)$$

$$\frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}} \quad \text{for } s_1 = s_2$$

where $v_{r1} = v_r(T_1)$ and $v_{r2} = v_r(T_2)$

$pv^k = C$ POLYTROPIC
means also ISENTROPIC
w/ k = ratio of sp. heats

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{(k-1)/k} \quad s_1 = s_2,\ \text{constant } k$$

$$\Rightarrow \frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^k$$

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} \quad s_1 = s_2,\ \text{constant } k$$