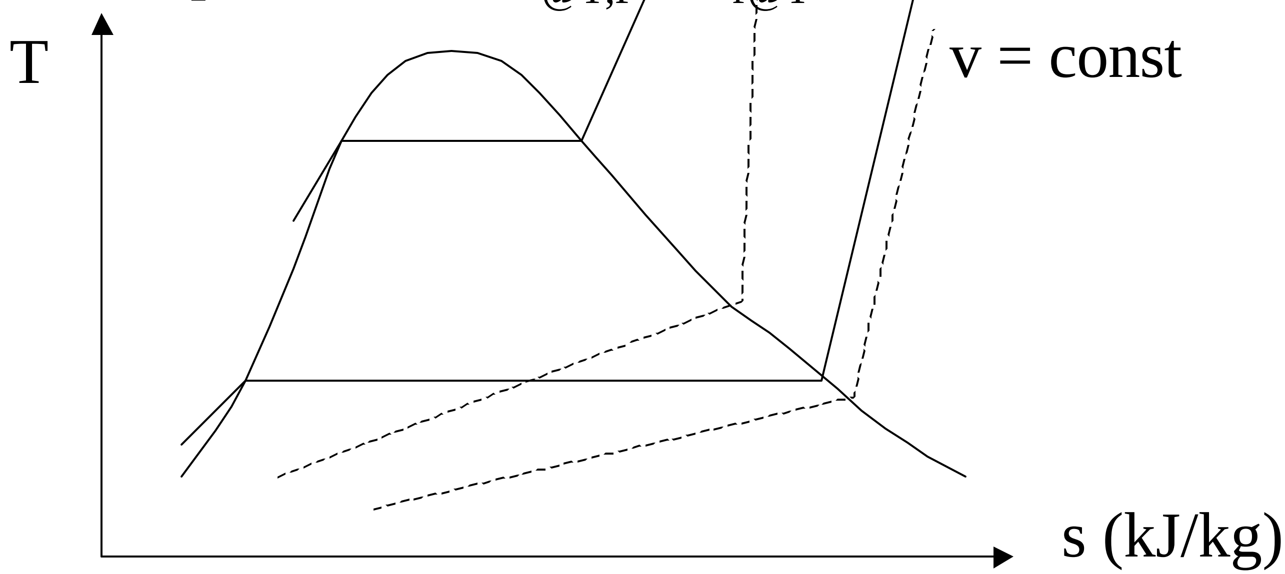
Entropy of a Pure Substance

• Entropy is a thermodynamic property, the value of entropy depends on the state of the system. For example: given T & P, entropy, S, can be obtained from a thermodynamic table just like v, u, h.

• If the state is a mixture of liquid and vapor, the entropy can be determined as: $s = s_f + xs_{fg}$, where x is the quality and s_f and s_{fg} are saturated values listed in the saturation table.

• For an incompressible liquid, the entropy can be approximated by the entropy of the saturated liquid at the given temperature since it is not a function of pressure: $s_{@T,P} \cong s_{f@T}$



Example

A rigid tank contains 5 kg of refrigerant-134a initially at 20°C and 140 kPa. The refrigerant is cooled until its pressure drops to 100 kPa. Determine the entropy change of the refrigerant during this process.

Constant volume process: $v_1=v_2$

initial state: $P_1=140$ kPa, $T_1=20°C$, from table A-10

$s_1=1.0532$(kJ/kg K), $v_1=0.1652$(m^3/kg)

final state: $P_2=100$ kPa, and $v_2=v_1=0.1652$ (m^3/kg)

from table A-9 $v_f=0.0007258$(m^3/kg)

$v_g=0.1917$(m^3/kg)

since $v_f < v_2 < v_g$ it is inside the saturation region

$x_2=(v_2-v_f)/v_{fg}=(0.1652-0.0007258)/0.191=0.865$

from table A-9, $s_f = 0.0678$, $s_g = 0.9395$

$s_2 = s_f + x_2(s_g-s_f)$

$= 0.0678 + 0.865(0.9395-0.0678) = 0.822$

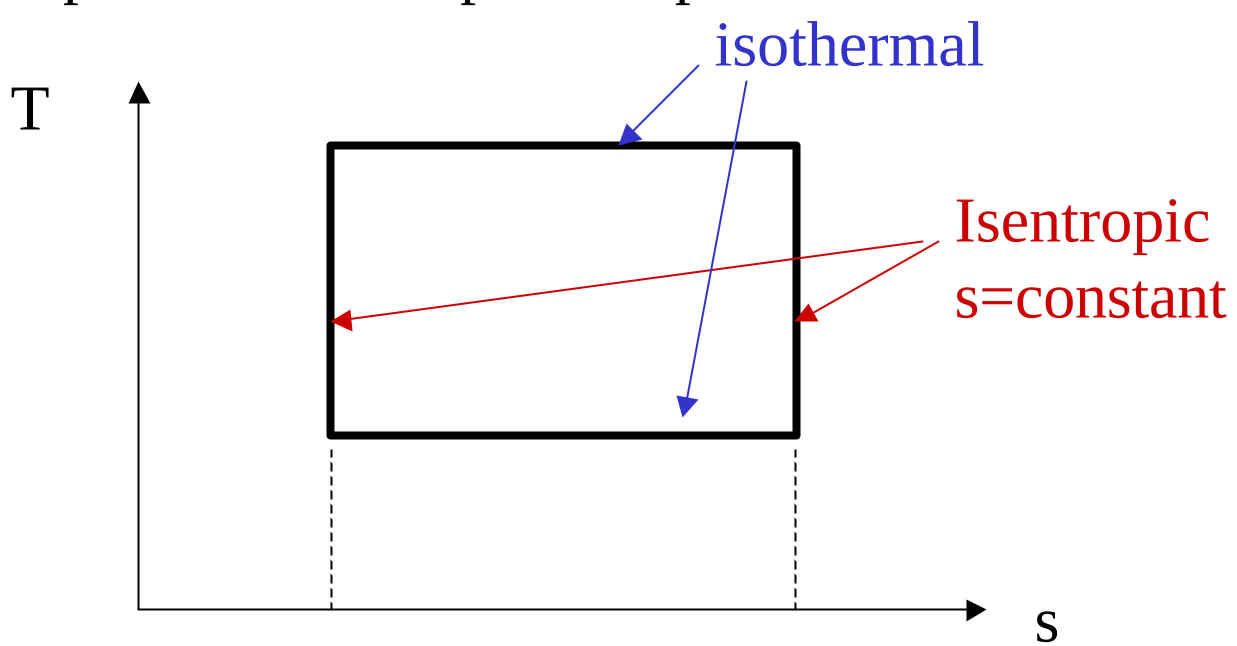
$\Delta S = m(s_2 - s_1) = (5)(-0.231) = -1.157$ (kJ/kg K)

Isentropic Process

• Isentropic process: entropy is a constant, $\Delta s=0$. A reversible, adiabatic process is always isentropic since no entropy generation due to irreversibilities ($s_{gen}=0$) and no change of entropy due to heat transfer ($ds=\delta Q/T=0$).

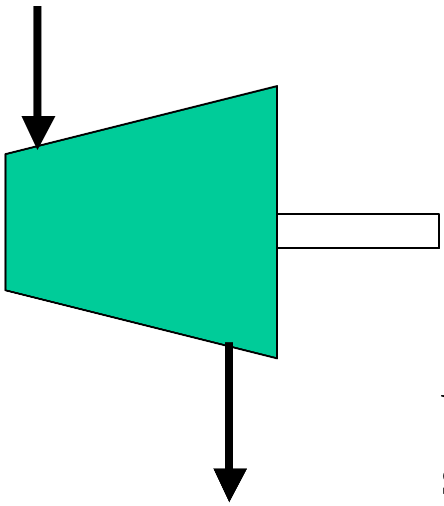
• The reverse is not always true: An isentropic process is not necessary a reversible, adiabatic process. Why?

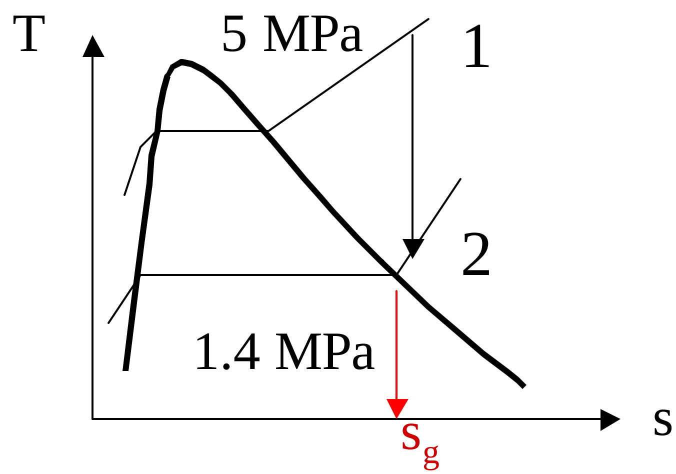
• Carnot cycle consists of two isentropic processes: reversible, adiabatic compression and expansion plus two isothermal processes.



Example

Steam enters an adiabatic turbine at 5 MPa and 450°C and leaves at a pressure of 1.4 MPa. Determine the work output of the turbine per unit mass flowing through the turbine if we can assume the process is reversible and neglect all changes of KE and PE.





$W_{out} = m(h_1\text{-}h_2)$, $W_{out}/m = h_1\text{-}h_2$

state 1: P_1=5 MPa, T_1=450°C, from table A-6

h_1=3316.2(kJ/kg), s_1=6.819(kJ/kg K)

State 2: P_2=1.4 MPa, $s_2=s_1=6.819>s_g=6.469$ @ 1.4 MPa(table A-5),

state 2 is superheated: from table A-6 through interpolation

h_2=2927.2+[(3040.4-2927.2)/(6.9534-6.7467)](6.819-6.7467)=2966.8 (kJ/kg).

$W_{out}/m = h_1\text{-}h_2$ = 349.4 (kJ/kg)