1- Reversible Constant-Pressure Process

In this process, the pressure remains constant.

From the 1st law of Thermodynamics (closed system)

$q - w = u_2 - u_1$

$Q - W = m\,(u_2 - u_1)$

w, W = sum of all forms of works

$W = W_b + W_e + W_m + \ldots.$

(boundary, electrical, mechanical, etc.)

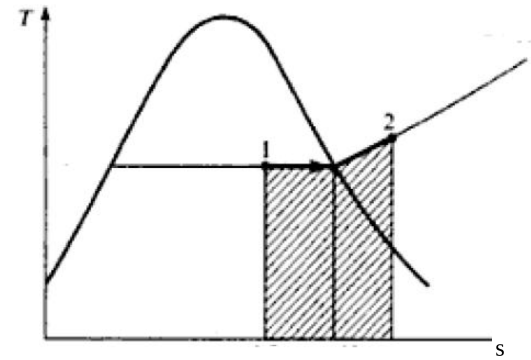
The boundary work is

$w_b = P(v_2 - v_1)$

$W_b = m\,P(v_2 - v_1)$

$q - (w_e + w_m + ..) = h_2 - h_1$

$Q - (W_e + W_m + ..) = m(h_2 - h_1)$



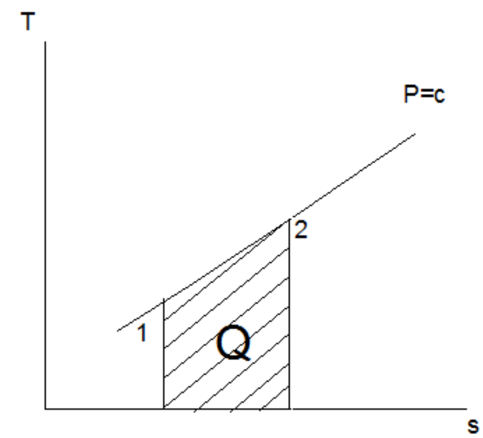
For perfect gas:

$q - (w_e + w_m + ..) = h_2 - h_1 = C_p\,(T_2 - T_1)$

$Q - (W_e + W_m + ..) = m(h_2 - h_1) = mC_p\,(T_2 - T_1)$

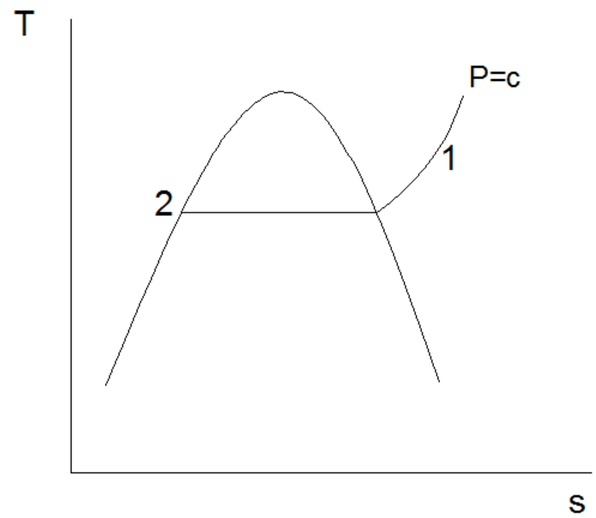
$$s_2 - s_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_{\text{int}\,rev} = \int_1^2 \frac{C_p\,dT}{T} = C_p \ln\left(\frac{T_2}{T_1}\right)$$

$$S_2 - S_1 = m(s_2 - s_1) = mC_p \ln\left(\frac{T_2}{T_1}\right)$$



Ex: Steam at 0.1 bar, 100 °C is to be condensed completely by a reversible constant pressure process. Calculate the heat rejected per unit mass and the change of entropy?

Sol:



P_1=0.1 bar, T_1=100 °C

$Q=?, \Delta s = s_2 - s_1 = ?,$

q=h_2-h_1

State 1:

P_1=0.1 bar=10 kPa=0.01 MPa, T_1=100 °C

At P_1=P_{sat} = 10 kPa, T_{sat} = 45.81 °C

Since T_1> T_{sat}, the steam is superheated

h_1=2687.5 kJ/kg

s_1=8.4489 kJ/kg.K

State 2:

P_2=P_1 = 10 kPa and the steam completely condensed

At P_2=P_{sat} = 10 kPa

h_2=h_f=191.81 kJ/kg

s_2=s_f=0.6492 kJ/kg.K

q=h_2-h_1=2687.5-191.81= 2495.69 kJ/kg

$\Delta s = s_2 - s_1 = 8.4489 - 0.6492 = 7.7997\ kJ/kg.K$

Ex: 1 m^3, 1.03 bar of air is heated reversibly at constant pressure from 15 to 300 °C, and is then cooled reversibly at constant volume back to the initial temperature. Calculate the net heat flow and the overall change of entropy. Take C_p=1.005 kJ/kg.K, C_v=0.718 kJ/kg.K and R=0.287 kJ/kg.K

Sol:

V_1=1 m^3, P_1=1.03 bar, T_1=15 °C, T_2= 300 °C (process 1-2 is constant pressure process)

T_3=T_1=15 °C (process 2-3 is constant volume process)

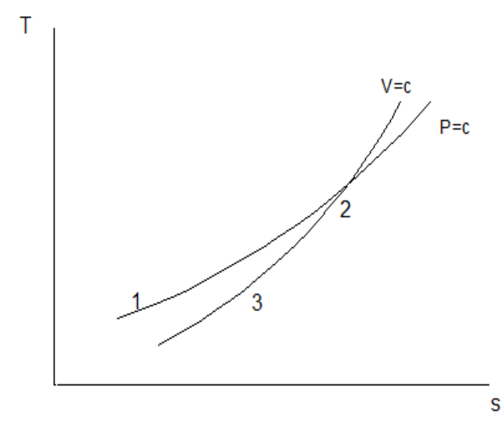
$Q_{net}=Q_{12}+Q_{23} = m\,C_p(T_2-T_1)+ m\,C_v(T_3-T_2)$

$Q_{net}=m\,(C_p(T_2-T_1)+ C_v(T_3-T_2))$

$\Delta s = (s_2 - s_1) + (s_3 - s_2)$

$P_1V_1=mRT_1$

$m=P_1V_1/RT_1=1.03*100*1/(0.287*288)=1.246\ kg$



$Q_{net}=m\ (C_p(T_2-T_1)+\ C_v(T_3-T_2))$

$\quad =1.246(1.005(300-15)+0.718(15-300))=101.91\ kJ$

$$\Delta S=(S_2-S_1)+(S_3-S_2)$$

$$S_2-S_1=m(s_2-s_1)=mC_p\ln\left(\frac{T_2}{T_1}\right)=1.246*1.005\ln\left(\frac{300+273}{15+273}\right)=0.861\ kJ/K$$

$$S_3-S_2=m(s_3-s_2)=mC_v\ln\left(\frac{T_3}{T_2}\right)=1.246*0.718\ \ln\left(\frac{15+273}{300+273}\right)=-0.615\ kJ/K$$

$$\Delta S=(S_2-S_1)+(S_3-S_2)=0.861+(-0.615)=0.201\ kJ/K$$