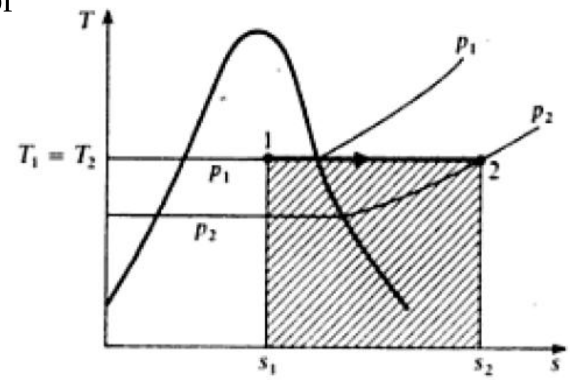
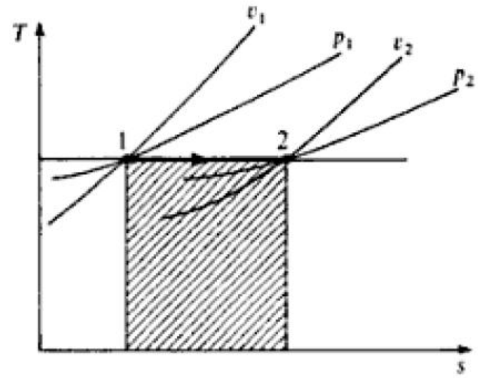
3-Reversible Constant-Temperature (Isothermal) Process

In this process, the temperature remains constant.
A reversible isothermal process will appear as a horizontal line on a T-s diagram, and the area under the line must represent the heat flow during the process.





$q=T(s_2-s_1)$

$Q=m\,T(s_2-s_1)$

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.)

For perfect gas only,
$u_2-u_1=0$
Therefore,

$$q = w = RT\ln(\frac{P_1}{P_2}) = RT\ln(\frac{v_2}{v_1}) = T(s_2-s_1)$$

$$Q = W = mRT\ln(\frac{P_1}{P_2}) = mRT\ln(\frac{v_2}{v_1}) = mT(s_2-s_1)$$

Also,
$q=T(s_2-s_1)$

$$\Delta s = s_2 - s_1 = \frac{q}{T} = R\ln(\frac{P_1}{P_2}) = R\ln(\frac{v_2}{v_1})$$

<u>Ex</u>: Dry saturated steam at 100 bar expands isothermally and reversibly to a pressure of 10 bar. Calculate the entropy change, heat supplied and the work done of steam (kJ/kg) during the process.

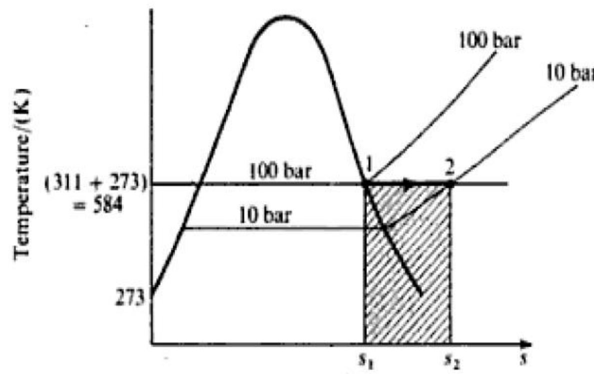
Sol:

P_1=100 bar (Dry saturated)

Isothermal expansion process, P_2=10 bar

$$\Delta s = s_2 - s_1 = ?,\ q=?\ ,\ w=?$$

$$q = T(s_2 - s_1)$$



q - w = u_2-u_1

<u>State1:</u>

Dry saturated at P_1=100 bar=10000 kPa

s_1=s_g=5.6159 kJ/kg.K

u_1=u_g=2545.2 kJ/kg

T_1=T_{sat}=311 ^oC

T	*u₂*	*s₂*
300	*2793.7*	*7.1246*
311	*u*	*s*
350	*2875.7*	*7.3029*

<u>State2:</u>

P_2=10 bar, T_2=T_1=311 ^oC

At P_{sat}= P_2=10 bar=1000 kPa=1 MPa,

T_{sat}=179.88 ^oC

Since T_2> T_{sat}, the steam is superheated

By using linear interpolation:

$$\frac{u_2 - 2793.7}{2875.7 - 2793.7} = \frac{311 - 300}{350 - 300}$$

u_2=2811.74 kJ/kg

$$\frac{s_2 - 7.1246}{7.3029 - 7.1246} = \frac{311 - 300}{350 - 300}$$

s_2=7.1638 kJ/kg

$$\Delta s = s_2 - s_1 = 7.1638 - 5.6159 = 1.5479\ kJ/kg.K$$

$$q = T(s_2 - s_1) = (311 + 273)*1.5479 = 903.97\ kJ/kg$$

q - w = u_2-u_1

w= q-(u_2-u_1) =903.97- (2811.74-2545.2)

w=637.43 kJ/kg

<u>Ex:</u> A 0.03 m^3 of a perfect gas (molecular weight 28 kg/kmol) contained in a cylinder behind a piston is initially at 1.05 bar and 15 ^oC. The gas is

compressed isothermally and reversibly until the pressure is 4.2 bar. Calculate the change of entropy, the heat flow and the work done?

Sol:

V=0.03 m^3, M_w=28 kg/kmol, P_1=1.05 bar, T_1=15 ^oC=288 K, P_2=4.2 bar

Isothermal compression process

$\Delta s = s_2 - s_1 = ?,$ q=? , w=?

$$\Delta s = s_2 - s_1 = R\ln(\frac{P_1}{P_2}) = R\ln(\frac{v_2}{v_1})$$

R=R_o/M_w=8.31447/28=0.297 kJ/kg.K

m=P_1V_1/RT_1=1.05*100*0.03/ (0.297*288)=0.0368 kg

$$\Delta S = S_2 - S_1 = mR\ln(\frac{P_1}{P_2}) = 0.0368 * 0.297\ln\left(\frac{1.05}{4.2}\right) = -0.1515\,kJ/K$$

$$Q = T\,\Delta S = 288 * (-0.01515) = -4.363\ \ kJ$$

W=Q=-4.363 kJ (work done on the system)