

The Mollier diagram is the $h-s$ diagram

→ $h-s$ diagram is used for isothermal process

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For Internally reversible Isothermal Process only

$$q_{int, rev} = T_0 \Delta s \quad (\text{kJ/kg})$$

$$\begin{aligned} w_{out} = 0 &\rightarrow Q_{in} = 0 \\ w_{in} = 0 &\rightarrow Q_{out} = 0 \end{aligned}$$

for closed system

$$(w_{in} - w_{out}) - (Q_{out} - Q_{in}) = \Delta U$$

Example 8- R134a at 240 kPa and 20°C undergoes an Internally Reversible Isothermal process in a closed system, until it's quality 20% on per unit mass, How much work and heat transfer is required?

$$q_{int, rev} = T_0 (s_2 - s_1)$$

$$w_{in} - w_{out} - (Q_{out} - Q_{in}) = \Delta U$$

state ① super heated and state ② has quality (in saturation)

~~losses~~ (there is Q_{out})

$$w_{in} - Q_{out} = \Delta U \Rightarrow w_{in} = \Delta U + Q_{out}$$

$$\rightarrow T_0 (s_2 - s_1)$$

state ①

240 kPa
20°C

$$\begin{aligned} s_1 &= 1.0134 \text{ kJ/kg} \cdot \text{K} \\ u &= 246.74 \text{ kJ/kg} \end{aligned}$$

R134a

state ②

$x = 0.2$

$T_2 = 20^\circ\text{C}$

$s_2 =$

$u_2 =$

Ex: A 50 kg Iron Block and 20 kg copper block, both initially at 80°C are dropped into a large lake at 15°C , thermal equilibrium is established, Determine the total entropy for this process? $C_{\text{Iron}} = 0.45 \text{ kJ/kg}\cdot\text{K}$, $C_{\text{copper}} = 0.386 \text{ kJ/kg}\cdot\text{K}$

$$\Delta S_{\text{Iron}} = m c \ln \left| \frac{T_2}{T_1} \right| = (50/0.45) \ln \left| \frac{288}{353} \right| = -4.579 \text{ kJ/K}$$

T_2 for Iron Block and copper = 15°C the same temperature of the lake

$$\Delta S_{\text{copper}} = m c \ln \left| \frac{T_2}{T_1} \right| = 20 \times 0.386 \times \ln \left| \frac{288}{353} \right| = -1.571 \text{ kJ/K}$$

$$\Delta S_{\text{lake}} = \frac{Q}{T}, \text{ since } T_1 = T_2 = 15^{\circ}\text{C}$$

$$(w_{\text{in}} - w_{\text{out}}) - (Q_{\text{out}} - Q_{\text{in}}) = \Delta u$$

طاقة حرارية
Iron
copper
لا يوجد طاقة حرارية

$$-Q_{\text{out}} = m_{\text{Iron}} C_{\text{Iron}} \Delta T + m_{\text{copper}} C_{\text{copper}} \Delta T$$

$$-Q_{\text{out}} = 50(0.45)(15-80) + 20(0.386)(15-80)$$

$$Q_{\text{out}} = 1964 \text{ kJ}$$

$$\Delta S_{\text{lake}} = \frac{1964}{(15+273)} = 6.82 \text{ kJ/K}$$

$$\Delta S_{\text{Total}} = \Delta S_{\text{Iron}} + \Delta S_{\text{copper}} + \Delta S_{\text{lake}} = 0.67 \text{ kJ/K}$$

From 1-11
Part 1

Chapter 1
Entropy

Chapter 1
Entropy

Clarius inequality - $\oint \frac{\delta Q}{T} \leq 0$

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$$\Delta S = \frac{\Delta Q}{T}$$

$T = \text{constant}$ (Isothermal)

$$\Delta S = \frac{\Delta Q}{T}$$

reversible processes.
 $S_{\text{gen}} = 0$

$$\Delta S = \oint \frac{\delta Q}{T} + S_{\text{gen}}$$

$S_{\text{gen}} = 0$ irreversible process.

$S_{\text{gen}} > 0$ irrev.

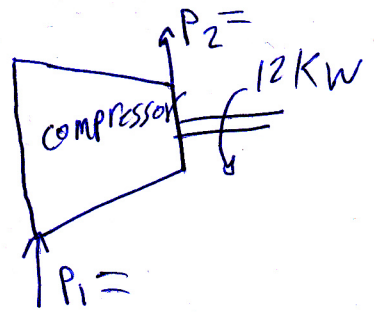
$S_{\text{gen}} = 0$ Reversible. Isothermal processes.

$S_{\text{gen}} < 0$ impossible.

There is No Conservation of entropy

The entropy change of a system can be Negative
but the entropy Generation Cannot !!

Ex:- air is compressed from P_1 to P_2
the temp is maintained constant
at 25°C during this process.



as a result of heat transfer

to the medium at 10°C . find

the rate of entropy change of air?

$$\dot{w}_{in} + \dot{Q}_{in} + \dot{m}(\cancel{ke_1} + \cancel{pe_1} + h_1) = \dot{w}_{out} + \dot{Q}_{out} + \dot{m}(\cancel{ke_2} + \cancel{pe_2} + h_2)$$

at constant temperature of this process
for steady-state devices

$h_1 = h_2$
Ideal Gas

$$\dot{Q}_{out} = \dot{w}_{in} = 12 \text{ kW}$$

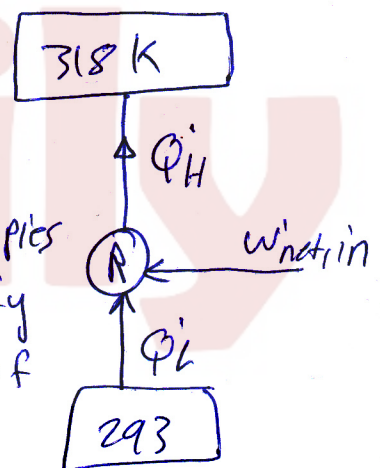
$$\Delta S = \frac{\Delta Q}{T} = \frac{12 \times 10^3}{298} = 0.0403 \text{ kW/K}$$

(جواب)

Ex:- completely Reversible (A.C)

provides 36000 (KJ/h) of a cooling.

calculate the rate at which the entropies
of the two Reservoir change and verify
that this (a.c) satisfies the increase of
Entropy.



$$\left(\frac{Q_H}{Q_L}\right)_{\text{rev, carnot}} = \left(\frac{T_H}{T_L}\right)_{\text{rev, carnot}}$$

$$Q_H = Q_L \left(\frac{T_H}{T_L}\right) = 36000 \left(\frac{318}{293}\right) = 39072 \text{ KJ/h}$$

$$\Delta S_1 = \frac{Q_H}{T_H} = \frac{39072}{318} = +122.87 \text{ KJ/h.K}$$

$$\Delta S_2 = \frac{Q_L}{T_L} = \frac{36000}{293} = -122.87 \text{ KJ/h.K}$$

$\Delta S_1 + \Delta S_2 = 0$

Isentropic Processes

درجہ خالص
مکانیکی

(Internally reversible and adiabatic)

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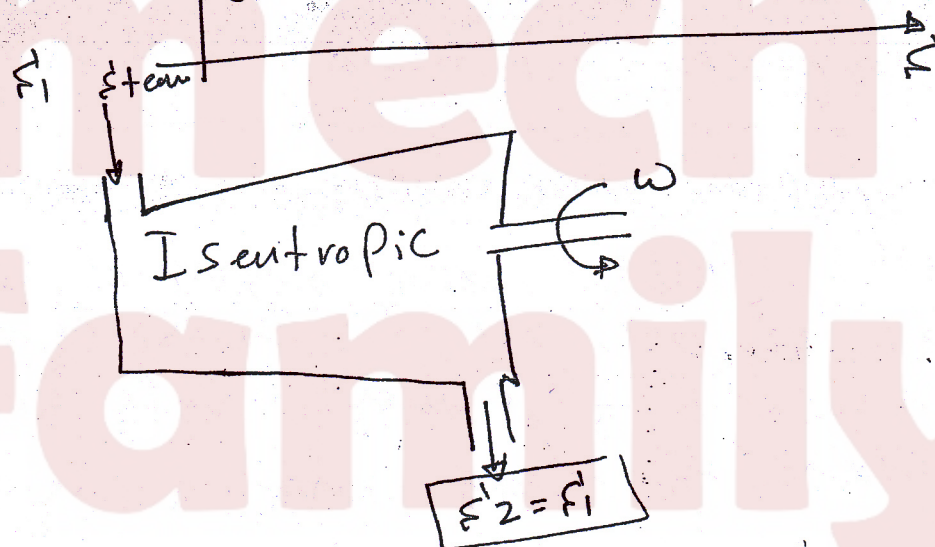
define as: A process during which the entropy remains constant.

* hint we use tables same as chapter 3

Isentropic process:-



* Valid for closed and open systems



$$\Delta s = m(s_2 - s_1)$$

Isentropic

$$\Delta s = 0$$

$$s_2 = s_1 \quad (\text{kJ/kg} \cdot \text{K})$$

For Turbine, Compressor

Minimum work $\Rightarrow$ Isentropic

210

Ex:- R-134a enters an adiabatic compressor as sat. vap at 160 (kPa) at a rate of $2 \text{ m}^3/\text{min}$ ^{compressed} $\Rightarrow P_2 = 900 \text{ kPa}$
 minimum power that must be supplied.

$$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}'(h_1 + \frac{V_1^2}{2} + gz_1) = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}'(h_2 + \frac{V_2^2}{2} + gz_2)$$

$$\dot{W}_{in} = \dot{m}'(h_2 - h_1)$$

state ①

$$P_1 = 160 \text{ kPa} \rightarrow h_1 = h_g = 241.11 \text{ kJ/kg}$$

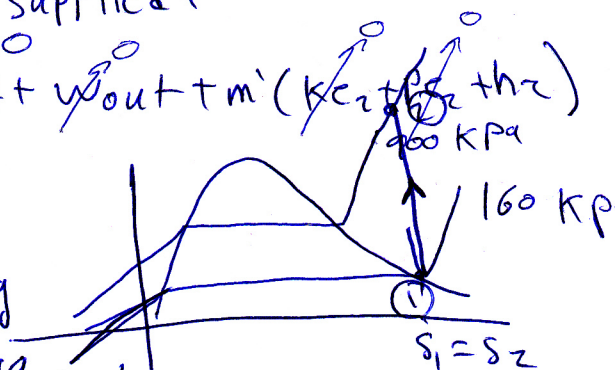
$$x = 1 \rightarrow s_1 = s_g = 0.9419 \text{ kJ/kg}\cdot\text{K}$$

$$v_1 = v_g = 0.12348 \text{ m}^3/\text{kg}$$

state ②

$$P_2 = 900 \text{ kPa} \rightarrow h_2 = 277.06 \text{ kJ/kg}$$

$$s_1 = s_2$$



$$\dot{V} = \frac{2}{60} = \frac{1}{30} \text{ m}^3/\text{s}$$

$$\dot{m}' = \frac{\dot{V}}{v} = \frac{1}{30(0.12348)} = 0.27 \text{ kg/s}$$

$$\dot{W}_{in} = 0.27(277.06 - 241.11) = 9.71 \text{ kW}$$

Ex:- an Insulated piston cylinder device contains 5 L of saturated liquid at constant pressure of 150 (kPa). an electric resistance heater inside the cylinder is now turned on 2200 kJ of energy is transfer to the steam.

Determine the entropy change during this process.

state ①:-

$$V_1 = 5 \text{ L}$$

$$x = 0, \text{ saturated liquid}$$

$$P = 150 \text{ kPa, constant}$$

$$\left. \begin{array}{l} s_1 = s_f = 1.4337 \text{ kJ/kg}\cdot\text{K} \\ h_1 = h_f = 467.13 \text{ kJ/kg} \\ v_1 = v_f = 0.001063 \text{ m}^3/\text{kg} \end{array} \right\}$$

$$m = \frac{5 \times 10^{-3}}{0.001063} = 4.75 \text{ kg}$$



$$(\dot{W}_{in} - \dot{W}_{out}) + (\dot{Q}_{out} - \dot{Q}_{in}) = \Delta U$$

$$\dot{W}_{in} = (\Delta h)m$$

$$\dot{W}_{in} - \dot{W}_{out} = \Delta U \quad \text{but we have const. pressure}$$

$$\text{so } \Delta U + \dot{W}_{out,b} = \Delta h$$

$$\frac{2200}{m} = h_2 - h_1 \Rightarrow h_2 = 930.33 \text{ kJ/kg}$$

$$P_2 = 150 \text{ kPa} \rightarrow s_2 = s_f + x s_{fg} = 2.6384 \text{ kJ/kg}\cdot\text{K}$$

$$x = \frac{h_2 - h_f}{h_{fg}} = \frac{930.33 - 467.13}{2225.7} = 0.208$$

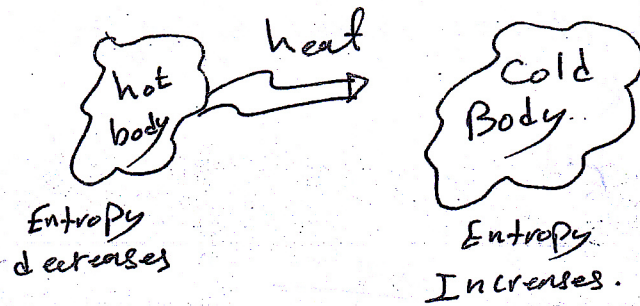
$$\Delta S = m(s_2 - s_1) = 5.72 \text{ kJ/K}$$

③ The third law of thermodynamics -

سب سے کم انتروپی

A pure crystalline substance at absolute zero temperature is in perfect order and its entropy is zero.

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7-8 Entropy change of liquids and solids - "Very Imp"

$$ds = \frac{du}{T} + \frac{Pdv}{T} \implies \text{ev}$$

since $dv=0$ for liquids and solids

$$ds = \frac{du}{T} = \frac{C dT}{T}$$

So, by Integrating

$$s_2 - s_1 = C_{avg} \ln \frac{T_2}{T_1} \quad (\text{kJ/kg} \cdot \text{K})$$

So, for Isentropic for Incompressible substance $\Delta s = 0$

$$s_2 - s_1 = C_{avg} \ln \frac{T_2}{T_1} = 0$$

$$T_2 = T_1$$

also Isothermal

Ex:- ~~10~~
~~15~~

$m = 25 \text{ kg}$ Iron block initially at 350°C is quenched
in an insulated tank that contains 100 kg of water at 18°C , assume the water that vaporized during the process of condensation back in the tank determine the total entropy change during this process?

$$C_{\text{Iron}} = 0.45 \text{ kJ/kg}\cdot\text{K}$$

$$C_{\text{water}} = 4.18 \text{ (kJ/kg}\cdot\text{K}^\circ)$$

Iron block

$$T_1 = 350^\circ\text{C}$$

$$m = 25 \text{ kg}$$

$$T_2 = ??$$

water

$$T_1 = 18^\circ\text{C}$$

$$m = 100 \text{ kg}$$

$$T_2 = ??$$

$$(W_{\text{in}} - W_{\text{out}}) - (Q_{\text{out}} - Q_{\text{in}}) = \Delta U$$
$$\Delta U = 0$$

$$m_{\text{Iron}} \Delta U_{\text{Iron}} + m_{\text{water}} \Delta U_{\text{water}} = 0$$

$$m_I C \Delta T + m_W C \Delta T = 0$$

$$(0.45) 25 (T_2 - 350) + 100 (4.18) (T_2 - 18)$$

$$T_2 = 26.7^\circ\text{C}$$

$$\Delta S_{\text{Iron}} = C \ln \frac{T_2}{T_1} = 0.45 \ln \frac{(26.7 + 273)}{(350 + 273)} = -8.237 \text{ kJ/kg}\cdot\text{K}$$

$$\Delta S_{\text{water}} = 4.18 \times \ln \frac{(26.7 + 273)}{(18 + 273)} = 12.314 \text{ kJ/kg}\cdot\text{K}$$

$$\Delta S_{\text{total}} = \Delta S_{\text{Iron}} + \Delta S_{\text{water}} =$$

7-9] The entropy change of Ideal Gas → will via eqs in this video

9

Constant specific heat

$$s_2 - s_1 = C_{p,avg} \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right)$$

$$s_2 - s_1 = C_{p,avg} \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

where $R = C_p - C_v$

Variable specific heat.

$$s_2 - s_1 = \underbrace{s_2^\circ - s_1^\circ}_{\downarrow} - R \ln\left(\frac{P_2}{P_1}\right)$$

Tables A-27 → A-25

⊛ The entropy of an Ideal Gas depends on both Temperature and pressure.

Example 8

mech
Family

Isentropic process of Ideal gas

در حالت ایده آل
فرایند ایزنتروپیک

$$\Delta S = 0$$

don't forget

II

$$K = \frac{C_p}{C_v} \quad \text{Imp}$$

Constant specific heats

①

Variable specific heat

$$\left(\frac{T_2}{T_1}\right)_{s=\text{const}} = \left(\frac{V_1}{V_2}\right)^{K-1} \quad TV^{K-1} = \text{const}$$

$$\left(\frac{T_2}{T_1}\right)_{s=\text{const}} = \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} \quad (1-K/K) \quad TP = \text{const}$$

$$\left(\frac{P_2}{P_1}\right)_{s=\text{const}} = \left(\frac{V_1}{V_2}\right)^K \quad PV^K = \text{const}$$

② variable specific heats

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

Relative pressure
Table (A-17)

$$\frac{V_2}{V_1} = \frac{V_{r2}}{V_{r1}}$$

Relative Volume