

Thermodynamics of Fluid Phase Equilibria
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Lecture – 09
Review of entropy

Welcome back. In this lecture, we will be reviewing the concept of entropy. So, let me start with the inequality of Clausius.

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The inequality of Clausius

Consider reversible HE (Carnot) $\oint \delta Q = Q_H - Q_L > 0$

$\oint \frac{\delta Q}{T} = \frac{Q_H}{T_H} - \frac{Q_L}{T_L} = 0$ ← Since for reversible, $(Q_H/Q_L) = T_H/T_L$

Thus for reversible HE $\oint \frac{\delta Q}{T} = 0$

In general (rev/irrev, all cycle) $\oint \frac{\delta Q}{T} \leq 0$

Important inequality, introduced by R. J. E. Clausius $\oint \frac{\delta Q}{T} \leq 0$

Valid for all cycles-reversible or irreversible

Let us consider first reversible heat engine case, which we have discussed in our last lecture, this is nothing but a Carnot heat engine. For Carnot heat engine; we know that Q_H/Q_L is equal to T_H/T_L and as well as we know that for a cyclic process, your δQ is nothing, but $Q_H - Q_L$ which is going to be greater than 0.

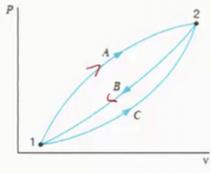
Now, based on this reversible type of concept, you can write it in this way where the δQ by T for a cycle is nothing, but $Q_H/T_H - Q_L/T_L$ and that has to be 0. So, for a reversible heat engine you have a condition that this must be equal to 0.

δQ by T should be equal to 0, in general whether it is a reversible or irreversible for all cycle we can write in this way and this is nothing, but your inequality of Clausius. So, in order for a process to occur this particular inequality must satisfy and this was

proposed by Clausius and is valid for all cycles, whether is reversible or irreversible for both the cases it will be valid.

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Entropy



For a reversible cycle A-B (totally or internally reversible)

$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 \left(\frac{\delta Q}{T}\right)_A + \int_2^1 \left(\frac{\delta Q}{T}\right)_B$$

For another cycle : B-C

$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 \left(\frac{\delta Q}{T}\right)_C + \int_2^1 \left(\frac{\delta Q}{T}\right)_B$$

Subtracting the second equation from first

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_A = \int_1^2 \left(\frac{\delta Q}{T}\right)_C$$

$\underline{\Delta S} = \int_1^2 dS = \left(\frac{\delta Q}{T}\right)_{\text{int rev}} \quad (\text{kJ/K})$
 $\Delta S = s_2 - s_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_{\text{int rev}} \quad (\text{kJ/K})$

- Independent of path for all reversible paths between 1 and 2
- Depends on the end states
- Thus it is property, called entropy, S

Now let us consider Process processes which changes the state condition on a from 1 to 2 and this is drawn on a P v diagram.

So, if you consider reversible cycle A and B which a could be totally or internally reversible, we can write down the cyclic value of $\oint \frac{\delta Q}{T} = 0$, because of the reversible cycle and if you are following 1 to 2 or A plus 2 to 1 on B that could be one particular cycle ; similarly you can take another cycle and you can write the same expression but now on C and B. Using 2 relation you can show clearly that this pointer 2, whether you go from or whether you take a path of A or you have taken the path of C, this should be same in order to have the same value of 0 ok; which essentially means that this term is basically independent of the path and this term which we call it as dS.

Because of the differential Q which essentially means that the delta S from 1 to 2 is independent of whichever path you take, if you integrate it you get basically delta S. So, this is independent of the path only depends on the final state point and this is nothing but the principle of the property ok, that the property depends only on the state condition. So, change in the property also depends only on the initial and a final condition not on the path. So, that is what we defined as the considering this is reversible, we make use of

this internal reversible in a condition that this is true assuming that you have reversible process, now so for the case of let us say isothermal process ok.

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Entropy



Process 1-2
(reversible or
irreversible)

Process 2-1
(internally
reversible)

Isothermal process

$$\underline{\Delta S} = \int_1^2 \left(\frac{\delta Q}{T} \right)_{\text{int rev}} = \int_1^2 \left(\frac{\delta Q}{T_0} \right)_{\text{int rev}} = \frac{1}{T_0} \int_1^2 (\delta Q)_{\text{int rev}}$$

$$\Delta S = \frac{Q}{T_0}$$

A cycle composed of a reversible and an irreversible process

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

$$\int_1^2 \frac{\delta Q}{T} + \int_2^1 \left(\frac{\delta Q}{T} \right)_{\text{int rev}} \leq 0$$

$$\int_1^2 \frac{\delta Q}{T} + S_1 - S_2 \leq 0$$

Where the heat is being supplied and temperature is fixed your delta S uh, in this case of the system will be nothing but since the temperature is fixed will be nothing but simply Q by T 0.

So, for the case of here 750 divided by 300 Kelvin, it comes out to be 2.5 kilo joules per Kelvin. Now let us consider again a cycle. Now in this case you have a reversible and an irreversible process which constitute the cycle. So, we will be making use of the process inequality.

So, let us say 1 to 2 could be reversible or irreversible and 2 to 1 is basically reversible or internally reversible. So, considering this you have 1 to 2 plus 2 to 1 which is internally reversible and this for this we know this is going to be delta S1 minus S2.

So, we can now make use of this expression in order to rewrite in this form ok.

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Increase of entropy

$$S_2 - S_1 \geq \int_1^2 \frac{\delta Q}{T}$$

In differential form

$ds \geq \frac{\delta Q}{T} +$

$$\Delta S_{sys} = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{gen}$$

≥ 0

where the equality holds for an internally reversible process and the inequality for an irreversible process

- Entropy change of a **closed system**, during irreversible process, is always greater than the entropy transfer due to heat transfer between the system and surrounding.
- Some entropy is *generated or created* during an irreversible process, and this generation is due entirely to the presence of irreversibilities (S_{gen})
- S_{gen} , entropy generation, is always a positive quantity or zero (for reversible process), depends on the process.
- Entropy for an isolated system during a process $\Delta S_{isolated} \geq 0$
 always increases or is constant for a reversible process i.e., it never decreases
increase of entropy principle

The entropy change of an isolated system is the sum of the entropy changes of its components, and is never less than zero.

That means, S_2 minus S_1 is greater than equal to $\int_1^2 \delta Q$ by T . So, in the differential form I can write ds greater than equal to $\frac{\delta Q}{T}$. So, which essentially means that entropy is increasing ok, it is not just equal to this but there is another additional terms which are coming which is we call it as generation.

So, for the case of a closed system entropy change during irreversible process is always greater than the entropy transfer due to heat transfer between the system and surrounding ok. So, this is the heat transfer due to heat transfer between the system and surrounding.

So, for the irreversible reversible process there is a certain S generation which is due to irreversibility's that is S generation. Now S generation or entropy generation is always a positive quantity or 0 for reversal process and it depends on the process. Entropy for an isolated system during a process is always greater than equal to 0 that means, because if I isolated you have this would be 0. So, S generation is always greater than or equal to 0 and thus ΔS isolated will be greater than equal to 0.

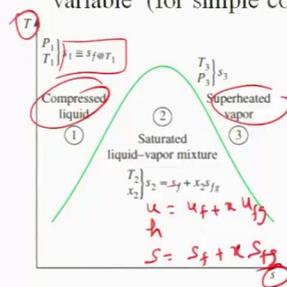
So, in other word, the entropy never decreases entropy always increases or remains constant and this is the concept of increase of entropy principle.

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Entropy change of pure substance

Entropy

- A property, fixed for a state, specified by two intensive variable (for simple compressible system)



Compressible liquid without much data can be approximated to its saturation value

The entropy change of a specified mass m (a closed system) during a process is simply

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

So, as we know based on this the entropy is a property and similar to the other properties you can also make use of thermodynamic tables, the graphs steam table and so forth to understand or to calculate the changes in entropy as in the case of a changes in internal energy or enthalpy ok.

So, this is an example of TS diagram temperature versus entropy specific entropy diagram, so this is be the green line is basically nothing, but vapor liquid equilibrium. So, this is your compressed liquid this is your superheated liquid this is your 2 phase system liquid and vapor in a similar case as you have done that for u for h ok.

If the quality is given for any point in this 2 region 2 you can find out s by simply saying u of f plus x u of f g similarly you can also write s as s f plus x s f g ok. And if you do not have information for the compressed liquid we will make use of the similar approximation as done for enthalpy, that s is nothing but s of saturated fluid at T1 for a given state point.

The entropic change of a specific mass m during a process is simply nothing, but small m multiplied by delta small s. So, this you can connect get it from the tables ok, similar to what you have done that for delta u or delta h ok.

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Isentropic process

The entropy of a fixed mass can be changed by

- heat transfer
- irreversibility

The entropy remains constant for internally reversible and adiabatic process: isentropic process

Isentropic process: $\Delta s = 0$ or $s_2 = s_1$ (kJ/kg·K)

During an internally reversible, adiabatic (isentropic) process, the entropy remains constant.

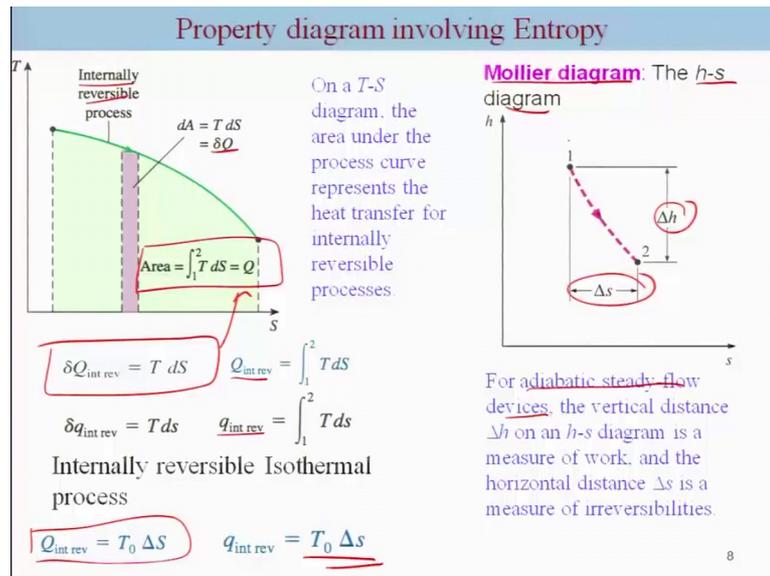
The isentropic process appears as a vertical line segment on a T-s diagram.

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Let me just summarize here the entropy, as I said the entropy changes are due to heat and if there is a flowing condition due to the mass also you can have the entropy change.

So, for the case of a fixed mass the entropy change is due to the heat transfer and due to irreversibility, for the case of a internally reversible system the entropy will remain constant or the entropy remains constant for internally reversible and adiabatic process; that means, when you do not have any heat transfer and when there is no irreversibility ΔS is equal to 0 and this is typically used for turbine case, which we approximate it to isentropic process in this case on a temperature s plot the vertical draw from 1 to 2 would indicate the expansion at a constant entropy ok. So, this will be the process for the case where you have adiabatic process and internal reversible process. So, this is for fixed mass ok.

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So, we can also represent entropy on or entropy changes on a TS diagram for a process, internal reversible process as depicted here represented by the green line from this point to that point; area under the curve is basically associated with the heat supplied to the system and the differential area would be nothing, but dA is equal to $T ds$ is nothing, but δQ . For the internal reversible process δQ is nothing, but $T ds$ and from here of course, this information can be extracted ok.

So, you can find out the heat supplied or heat associated with this by just integrating this $T ds$, you can divide by the mass to get in specific per unit mass values, for a constant temperature system it will be simply $T_0 \Delta S$.

One can also make use of h s diagram which is a Mollier diagram for processes involving adiabatic steady flow in such case the drop in Δh measures the work associated with this steady flow devices and increase in the ΔS is measures, the irreversibility associated with the device ok.

So, this is often also used in order to explain the irreversibility's of the devices ok. Now having done some exercise on this we can take this information particularly for the internal reversible expression of δQ and $T ds$ and plugging in the relation at the first law.

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The Tds relation

$\delta Q_{\text{int rev}} - \delta W_{\text{int rev, out}} = dU$

$T ds = dU + P dv$ (kJ)

$T ds = du + P dv$ (kJ/kg)

$h = u + Pv$

$dh = du + P dv + v dP$

$T ds = dh - v dP$

$\delta q - \delta w = du$

$ds = \frac{du}{T} + \frac{P dv}{T}$

$ds = \frac{dh}{T} - \frac{v dP}{T}$

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So, what we are considering is δq heat supplied minus the work done by the system, is basically the change in the internal energy of the system now we considering internally reversible system ok. So, here we can make use of a $T ds$ and here we can make use of only the boundary work which is associated with the system.

So, if you do that you have this relation which you get or in the per k g you can write it in this form. Now from here we can find out the ds by taking dividing by T and you can find δS by integrating it ok, now you can also make use of the expression of enthalpy and write this expression instead of u you can rewrite in instead of u you can rewrite this expression in terms of h .

So, h is equal to $u + Pv$ in other word dh is equal to $du + P dv + v dP$ you can write du now as dh minus this term and thus you can get this expression. So, from here as I said we can find out ds in terms of changes in the du or changes in the u and v . Here in this case ds is changing can be related to changes in the h and P .

So, if you integrate it and if you know the relations of the internal energy or enthalpy in terms of the pressure in the volume, you should be able to find out the change in the entropy for the simple cases it is easy ok.

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ENTROPY CHANGE OF LIQUIDS AND SOLIDS

$$ds = \frac{du}{T} + \frac{P dv}{T}$$

Since $dv \cong 0$ for liquids and solids

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

since $c_p = c_v = c$ and $du = c dT$

Liquids and solids can be approximated as *incompressible substances* since their specific volumes remain nearly constant during a process.

Liquids, solids: $s_2 - s_1 = \int_1^2 \frac{c(T) dT}{T} \cong c_{avg} \ln \frac{T_2}{T_1}$ (kJ/kg · K)

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So, let us take at the some simple examples.

So, for the case of a liquid and solid for the case of a liquids and solid, we can consider that the volume hardly changes and thus your dv is equal to 0; in that case if you take out this expression in terms of u ds is equal to du by dT ds is equal to du by T , it can be simply written as C because for the case of liquid and C_p you can approximate C_p is equal to C_v is equal to C and thus du is nothing, but C times dT and thus you can get this expression of the ΔS in this form where C can be taken out as an average for the case of idle gas you can write du as $dv C_v dT$ and dh as $C_p dT$.

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THE ENTROPY CHANGE OF IDEAL GASES

From the first $T ds$ relation

$$ds = \frac{du}{T} + \frac{P dv}{T}$$

$$ds = c_v \frac{dT}{T} + R \frac{dv}{v}$$

$$s_2 - s_1 = \int_1^2 c_v(T) \frac{dT}{T} + R \ln \frac{v_2}{v_1}$$

From the second $T ds$ relation

$$ds = \frac{dh}{T} - \frac{v dP}{T}$$

$$dh = c_p dT \quad v = RT/P$$

$$s_2 - s_1 = \int_1^2 c_p(T) \frac{dT}{T} - R \ln \frac{P_2}{P_1}$$

$$\Delta S = \int \frac{c_v}{T} + \int \frac{P dv}{T}$$

$$\begin{aligned} Pv &= RT \\ du &= C_v dT \\ dh &= C_p dT \end{aligned}$$

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Now, this you have 2 expression one is here and the another 1 is here which is based on h you can plug in this appropriately in order to find delta s here ok. So, you can get this expressions in a very simple way, but in general if you want delta S you should be able to integrate this term separately.

For the case of u and similarly you can do that for the case of h and what we need is basically relation of this and since this is something which we are going to focus more in the later part of the course, making use of the volumetric property in order to create this kind of changes in delta S and other thermodynamic properties ok.

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Entropy balance

$$\left(\begin{array}{c} \text{Total} \\ \text{entropy} \\ \text{entering} \end{array} \right) - \left(\begin{array}{c} \text{Total} \\ \text{entropy} \\ \text{leaving} \end{array} \right) + \left(\begin{array}{c} \text{Total} \\ \text{entropy} \\ \text{generated} \end{array} \right) = \left(\begin{array}{c} \text{Change in the} \\ \text{total entropy} \\ \text{of the system} \end{array} \right)$$

Increase in entropy principle

$$S_{in} - S_{out} + S_{gen} = \Delta S_{system}$$

Entropy Change of a System, ΔS_{system}

$$\Delta S_{system} = S_{final} - S_{initial} = S_2 - S_1$$

$\Delta E_{system} = E_{in} - E_{out}$
 $\Delta S_{system} = S_{in} - S_{out} + S_{gen}$

Energy and entropy balances for a system.

So, let us focus now on the entropy balance. Now entropy balance for a given system can be represented in this schematic form where the total entropy entering which is S in minus total entropy living out plus total generation, should be the change in the total entropy of the system ok. In other word on a simpler way S in minus out plus S generation is equal to delta S system and this is basically nothing but the increase in entropy principle.

Whereas delta S system is nothing, but s final minus S initial now what are the different mechanism of entropy transfer? Now beside heat transfer you can have also the due to the mass for the open system .

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Mechanisms of entropy transfer, S_{in} and S_{out}

1 Heat Transfer

Entropy transfer by heat transfer:

$$S_{heat} = \frac{Q}{T} \quad (T = \text{constant})$$

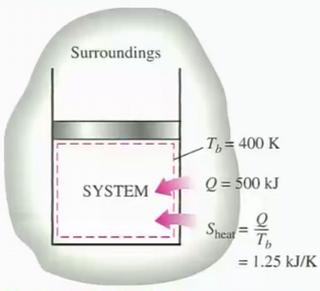
$$S_{heat} = \int_1^2 \frac{\delta Q}{T} \equiv \sum \frac{Q_k}{T_k}$$

Entropy transfer by work

$$S_{work} = 0$$

Entropy is not transferred with work

Entropy generation via friction



Heat transfer is always accompanied by entropy transfer in the amount of Q/T , where T is the boundary temperature.

No entropy accompanies work as it crosses the system boundary. But entropy may be generated within the system as work is dissipated into a less useful form of energy.

So, S_{heat} for a constant temperature is simply Q/T that is due to the heat entropy transfer by the heat, if the temperatures are changing across the boundary you can also make use of summation of heat at different part of the boundary and this will be your $\sum Q_k/T_k$ divided by T_k summation of that. Entropy transfer due to the work which is ordered form of energy is not; is it going to be 0 anything which is associated; while for example, considering the shaft the entropy is being generated only due to the friction associated with this.

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Mechanisms of entropy transfer, S_{in} and S_{out}

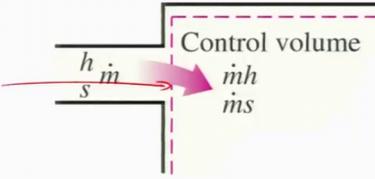
2 Mass Flow

Entropy transfer by mass:

$$S_{mass} = ms$$

When the properties of the mass change during the process

$$\dot{S}_{mass} = \int s \rho V_n dA_c$$

$$S_{mass} = \int s \delta m = \int_{\Delta t} \dot{S}_{mass} dt$$


Mass contains entropy as well as energy, and thus mass flow into or out of system is always accompanied by energy and entropy transfer.

So, in addition to the heat transfer you have also due to the entropic transfer due to the mass ok. So, of the fluid is flowing it also bring in entropy into the control volume and that is can be written as simply S mass is equal to m times the specific entropy. And if it if the property of the mass changes during time you can make use of these expressions, which is well known it is S times density times the volumetric normal velocity multiplied by the cross sectional area or in general S mass is equal to s times the differential mass which can be written in this form.

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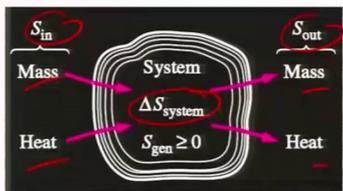
Entropy generation

$$\underbrace{S_{in} - S_{out}}_{\text{Net entropy transfer by heat and mass}} + \underbrace{S_{gen}}_{\text{Entropy generation}} = \underbrace{\Delta S_{system}}_{\text{Change in entropy}} \quad (\text{kJ/K})$$

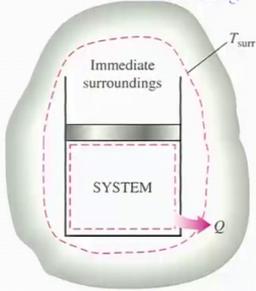
$$\underbrace{\dot{S}_{in} - \dot{S}_{out}}_{\text{Rate of net entropy transfer by heat and mass}} + \underbrace{\dot{S}_{gen}}_{\text{Rate of entropy generation}} = \underbrace{dS_{system}/dt}_{\text{Rate of change in entropy}} \quad (\text{kW/K})$$

$$\underline{(s_{in} - s_{out}) + s_{gen} = \Delta s_{system}} \quad (\text{kJ/kg} \cdot \text{K})$$

Entropy generation outside system boundaries can be accounted for by writing an entropy balance on an extended system that includes the system and its immediate surroundings.



Mechanisms of entropy transfer for a general system



So let me get back to the again the entropy balance here as I said is S in minus S out plus S generation is equal to ΔS system, S in minus S out is due to the entropy transfer by heat and mass ok.

This can be written in to rate form and this is what we have written also earlier. So, in summary S in is due to mass and heat S out is due to mass again heat and ΔS system the change is due to the changes in the s m S out plus the S generation.

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Closed system

The entropy change of a closed system during a process is equal to the sum of the net entropy transferred through the system boundary by heat transfer and the entropy generated within the system boundaries.

Closed system:
$$\sum \frac{Q_k}{T_k} + S_{\text{gen}} = \Delta S_{\text{system}} = S_2 - S_1 \quad (\text{kJ/K})$$

Adiabatic closed system:
$$S_{\text{gen}} = \Delta S_{\text{adiabatic system}}$$

Any closed system + surrounding can be considered as adiabatic

System + Surroundings:
$$S_{\text{gen}} = \sum \Delta S = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$

$$\Delta S_{\text{system}} = m(s_2 - s_1)$$

Entropy change of the surrounding
$$\Delta S_{\text{surr}} = Q_{\text{surr}}/T_{\text{surr}}$$

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For a closed system we can write down S_{in} minus S_{out} , simply as due to the heat transfer there is no mass entropy due to the mass transfer and thus this can be written as summation of Q_k/T_k plus $S_{\text{generation}}$ is equal to ΔS_{system} ok.

So, for adiabatic closed system when the heat is also 0, supply then $S_{\text{generation}}$ is nothing, but ΔS of system which is adiabatic. For any closed system plus surrounding we can consider that to be an adiabatic in other word $S_{\text{generation}}$ is basically nothing, but summation of ΔS_{system} plus surrounding. If we consider system plus surrounding as a combined system which can be considered as adiabatic, then this expression holds and $\Delta S_{\text{surrounding}}$ would be nothing, but $Q_{\text{surrounding}}$ divided by $T_{\text{surrounding}}$.

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Control volume

$$\sum \frac{\dot{Q}_i}{T_i} + \sum \dot{m}_i s_i - \sum \dot{m}_e s_e + \dot{S}_{\text{gen}} = (S_2 - S_1)_{\text{CV}} \quad (\text{kJ/K})$$

$$\sum \frac{\dot{Q}_k}{T_k} + \sum \dot{m}_i s_i - \sum \dot{m}_e s_e + \dot{S}_{\text{gen}} = dS_{\text{CV}}/dt \quad (\text{kW/K})$$

$\Delta S_{\text{CV}} = \frac{Q}{T} + \underbrace{m_i s_i - m_e s_e}_{\text{Entropy transfer by mass}} + \underbrace{S_{\text{gen}}}_{\text{Entropy transfer by heat}}$

The entropy of a control volume changes as a result of mass flow as well as heat transfer.

For the case of control volume beside the heat you have to consider the mass element here and the rest of the terms are straight forward; whereas, of course S_2 minus S_1 would be of the control systems you can write this in terms of rate expression as well ok.

So, this is something which I expect that you have already gone through earlier it is just recap. So, let me just try to finish this particular lecture by working on this example.

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Examples

A frictionless piston–cylinder device contains a saturated liquid–vapor mixture of water at 100°C. During a constant-pressure process, 600 kJ of heat is transferred to the surrounding air at 25°C. As a result, part of the water vapor contained in the cylinder condenses. Determine (a) the entropy change of the water and (b) the total entropy generation during this heat transfer process.

$$\Delta S_{\text{system}} = \frac{Q}{T_{\text{system}}} = \frac{-600 \text{ kJ}}{(100 + 273 \text{ K})} = \underline{-1.61 \text{ kJ/K}}$$

The entropy balance for this extended system (system + immediate surroundings) yields

$$\underbrace{S_{\text{in}} - S_{\text{out}}}_{\text{Net entropy transfer by heat and mass}} + \underbrace{S_{\text{gen}}}_{\text{Entropy generation}} = \underbrace{\Delta S_{\text{system}}}_{\text{Change in entropy}}$$

$$-\frac{Q_{\text{out}}}{T_b} + S_{\text{gen}} = \Delta S_{\text{system}}$$

$$S_{\text{gen}} = \frac{Q_{\text{out}}}{T_b} + \Delta S_{\text{system}} = \frac{600 \text{ kJ}}{(25 + 273) \text{ K}} + (-1.61 \text{ kJ/K}) = \underline{0.40 \text{ kJ/K}}$$

So, here we have a frictionless piston cylinder device which contains a saturated liquid vapor mixture of water at 100 degree Celsius, during a constant pressure process 600 kilo joules of heat is transferred to the surrounding at 25 degree Celsius as a result part of the

way water vapor contains in the cylinder condenses ok. So, some part of the vapor condensed to the liquid and what we have to find out the entropy change of the water and the total entropy generation during this heat transfer process.

So, for the case of a delta S system, we will simply consider the Q which we know and the T system because it is a saturated liquid vapor mixture the temperature remains constant, so this is 100 plus 273 Kelvin and the Q is minus 600 which turns out to be this.

Now, for the case of total entropy generation, we have to also find out entropy generation outside or particularly the surrounding as well. So, the way we are going to do is we are going to consider a combined extended system where system plus surrounding is extended system.

So, this is extended system, such that here T b or the boundary is 25 degree Celsius. So, in that case if you consider the total energy total entropy balance, you have S in minus S out there is no S in only the heat is being transferred. Now at the boundary of extended system this is Q out divided by T b which is 25 degree Celsius plus S generation is equal to delta S system, S generation is a total entropy generation. So, you can rewrite you can write in this way S generation is Q out plus T b plus delta S system. Now delta S system we know and this entropy generation or the entropy due to the heat is can be written as in this way.

So, this plus delta S system which we have already calculated will give us the total entropy generation during this heat transfer process. So, the idea is basically to make use of extender system in order to calculate this. So, I hope that this quick exercise and as well as quick recap of second law of thermodynamics and beside the earlier contents which we have covered the basic definition of the system ah; then the first law of thermodynamics, open system close systems and how to make use of the balances energy and then the introduction of the entropy and finally a very quick example.

With this I hope that you are now well warmed up in order to take more fundamental aspect of the thermodynamics which we will be starting from next lecture onward with the basic thermodynamics or calculus related to thermodynamics.

So, with this I will stop here and we will see you in the next lecture.