ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

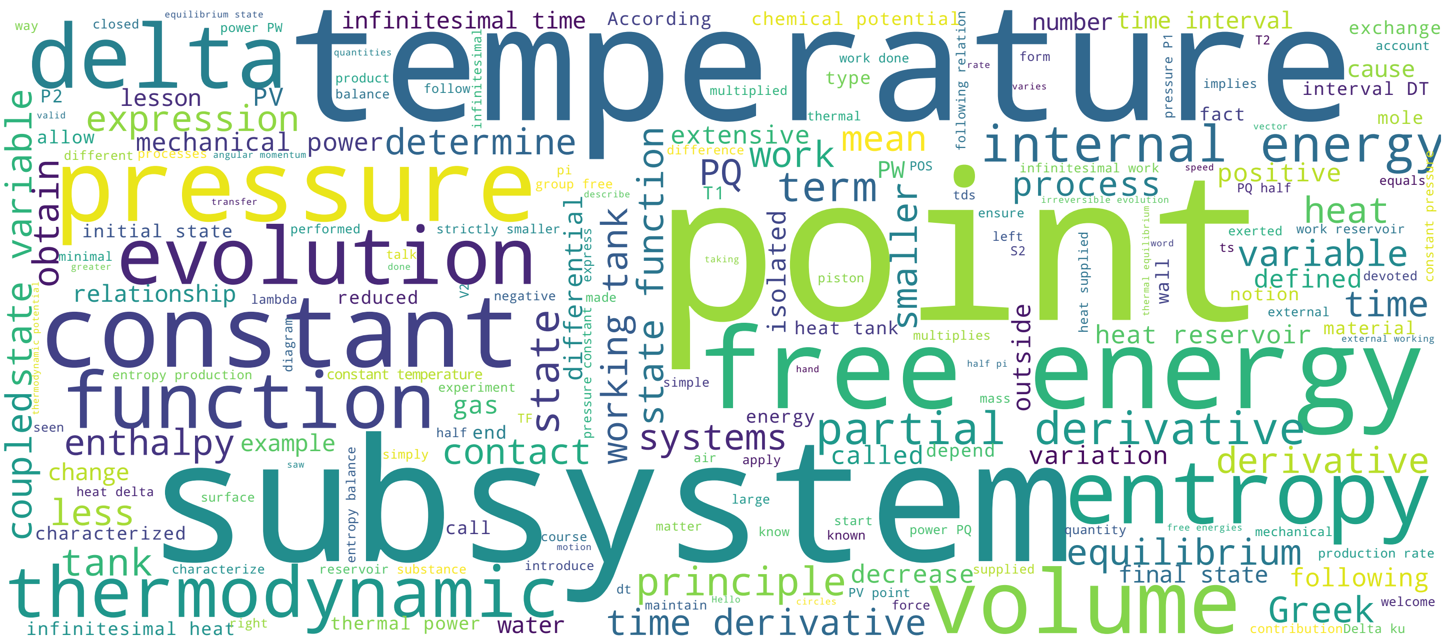
RESCIF
Réseau d'excellence des sciences de l'ingénieur de la Francophonie

Thermodynamique

Evolution d'un système couplé à un réservoir

Dr. Sylvain Bréchet

Hermann Ludwig Ferdinand von Helmoltz, 1821 - 1894



Video

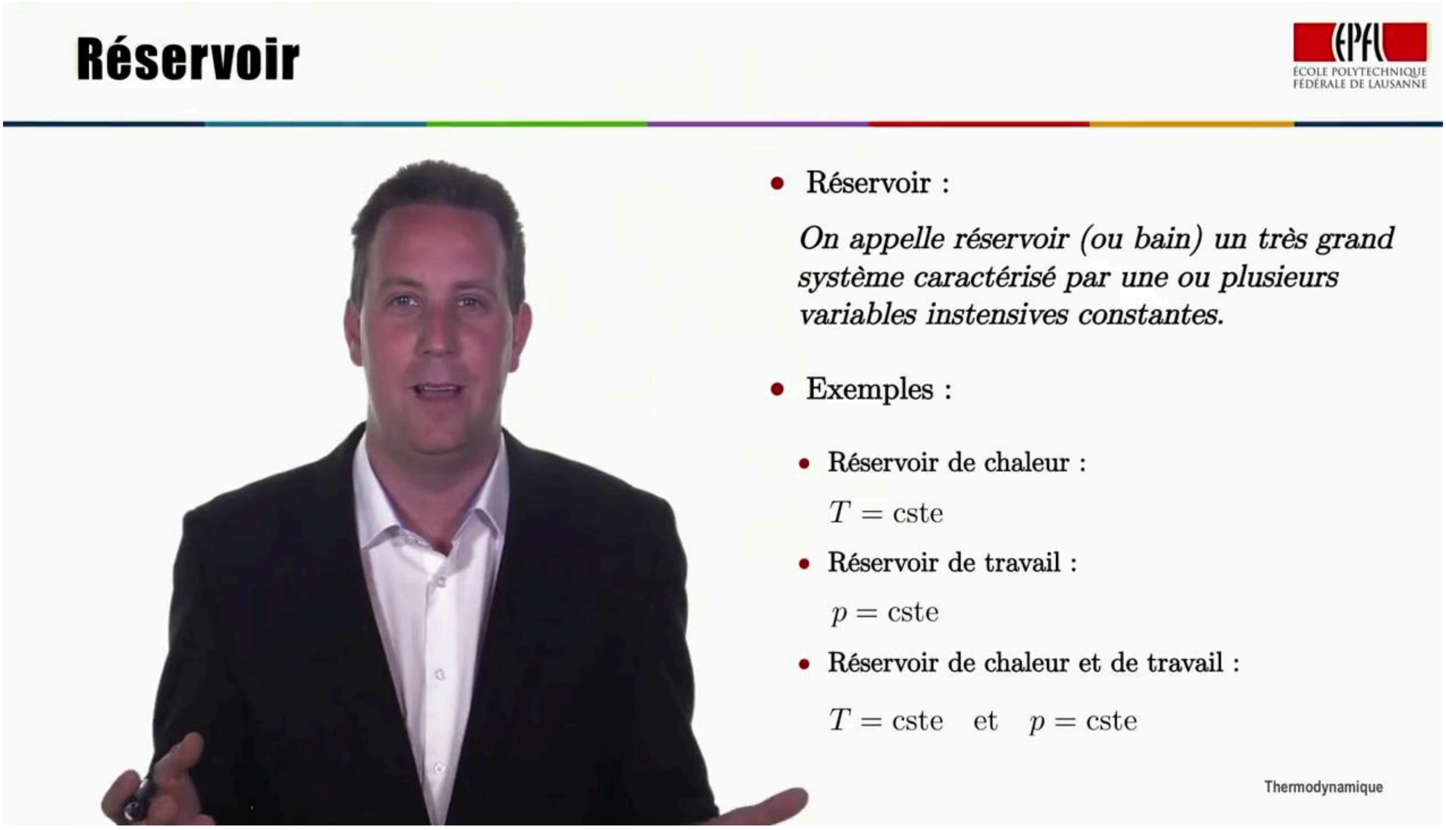
EPFL

Hello and welcome to make fun of thermodynamics. This lesson is devoted to the evolution of a system coupled to a reservoir. First, we will define the notion of reservoir. We will then consider systems that are coupled to a tank. We will first look at the evolution of free energy. Secondly, to the evolution of the enthalpy and thirdly, to the evolution of the type free energy. And then we will also determine the heat that is provided. A system that is coupled with a working tank. And the work that is done on a system that is coupled to a heat tank.

Notes

Summary

0m 05s



We call the tanks. We also talk about bath, a very large system that is characterized by the fact that one or more of these intensive variables are constant. A system with a constant temperature. Is called a heat reservoir. It is big enough. A great system whose pressure is constant to call a working tank. A large system whose temperature and pressure are constant is called a heat and work reservoir.

Notes

Summary

0m 45s

Evolution de l'énergie libre

- **Réservoir de chaleur et paroi immobile :**

  $T_{\text{ext}} = T_1 = T_2 \equiv T \qquad \text{et} \qquad V = \text{cst}$

- **Dérivée temporelle énergie libre :**

  $\dot{F} = \dot{U} - T\,\dot{S}$

- **Premier et deuxième principes :**

  $\dot{F} = P_Q - T\,\dot{S} = -T\,\Pi_S \leq 0$

- **Condition d'évolution et d'équilibre :**

$$\boxed{dF \leq 0 \qquad \text{(température et volume constants)} \qquad F \text{ est minimale à l'équilibre}}$$

Thermodynamique

We are now going to look at a system that is made up of two sub-systems under system, one in water and the sub-system two down. These subsystems are coupled to a tank. The entropy S of the system is equal to the sum of the entropy S1 and S2 of the subsystems. Since entropy is extensive, the volume is also extensive, so the volume of the system is equal to the sum of the volumes V1 and V2 of the subsystems. The thermodynamic potentials are also extensive quantities, so the internal energy U of the system is equal to the sum of the internal energy U1 and U2 of the two subsystems. the Free Energy F of the system is equal to to the sum of the free energies f one and f two. Both subsystems. The enthalpy H is equal to the sum of the enthalpy H1 and H2 of the two sub systems, and finally, the subject free energy of the system is equal to the sum of the group free energies G1 and G2 of the two subsystems. We will now determine the evolution of the free energy. We will consider a system made up of two subsystems subsystem one and subsystem two that are in contact with a heat reservoir. The temperature of the external tank is equal to the temperature T1 and the temperature T2. Of the two subsystems.

Notes

Summary

1m 23s

Evolution de l'énergie libre

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Thermodynamique

This temperature is the temperature T. And then, we consider that the wall that separates the system from the tank is immobile, which means that the volume of the system is constant. On the other hand, the volume comes from subsystem one and the volume V2 of subsystem two can vary and it varies in such a way as to ensure that V is constant. the free energy f is equal to U minus TF. The temperature T is constant. It is imposed by the heat reservoir. Therefore, the time derivative of the free energy is equal to a half point. Is this the point? We can now apply the first principle of thermodynamics. Since the volume is constant of the point is equal to PQ and therefore is this point equal to PQ? Moité is the point according to the entropy balance equation. Is this the point? Is equal to PI plus PQ safety. Which means that PQ half is this point? Is equal to half pi of s. According to the second principle, Pie de Hesse is greater than or equal to zero. The temperature is positive and therefore less. Hessian Pie is smaller than or equal to zero, which means that f point. And smaller or equal to zero. This relationship can be multiplied by the infinitesimal time interval DT and we obtain the following relation df is smaller or equal to zero.

Notes

Summary

2m 57s

Evolution de l'enthalpie

- **Réservoir de travail et entropie constante :**

  $p_{\text{ext}} = p_1 = p_2 \equiv p \qquad \text{et} \qquad S = \text{cste}$

- **Dérivée temporelle enthalpie :**

  $\dot{H} = \dot{U} + p\,\dot{V}$

- **Puissance mécanique :**

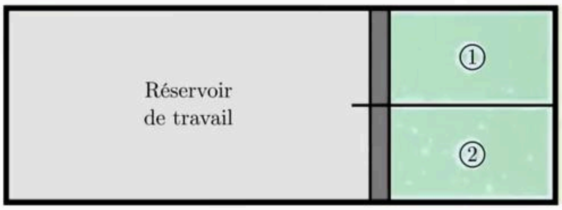
  $P_W = -\,p_{\text{ext}}\,\dot{V} = -\,p\,\dot{V}$

- **Premier principe et entropie constante :**

  $\dot{H} = P_Q + P_W + p\,\dot{V} = P_Q \leq 0$

- **Condition d'évolution et d'équilibre :**

$$\boxed{dH \leq 0 \qquad \text{(pression et entropie constantes)} \qquad H \text{ est minimale à l'équilibre}}$$



Thermodynamique

So let's first consider the evolution condition which is the following. DF strictly smaller than zero. Therefore, when the system is in contact with a heat reservoir which ensures that it has a constant temperature and that its volume is constant. The irreversible evolution of this system. Will cause the decrease of free energy since EDF is smaller than zero. This is the condition of evolution and the system will then evolve towards a steady state and at equilibrium, the CDF equilibrium condition equals zero. the free energy F will be minimal. Now we will to be interested in the evolution of the enthalpy, to consider a system formed of two sub systems, sub-system one and sub-system two that are in contact with a working tank. The pressure of the external working tank is equal to the pressure. P1 and P2, the two subsystems. And this pressure is the p-pressure. And then the system is such that its entropy is constant, so it is a constant. The enthalpy H is u plus pv or p is constant. Therefore, the time derivative of the enthalpy hPa is equal to u point p v point. The mechanical power pw that is exerted by the tank of work on the system, it is less p outside v point.

Notes

Summary

4m 41s

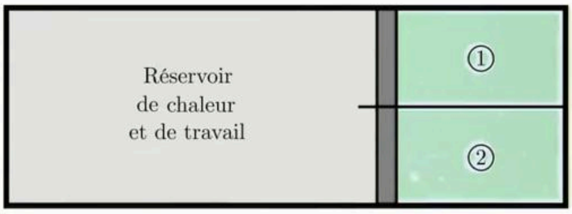
Evolution de énergie libre de Gibbs

- **Réservoir de chaleur et de travail :**

$$T_{\text{ext}} = T_1 = T_2 \equiv T \qquad \text{et} \qquad p_{\text{ext}} = p_1 = p_2 \equiv p$$

- **Dérivée temporelle énergie libre de Gibbs :**

$$\dot{G} = \dot{U} - T\,\dot{S} + p\,\dot{V}$$



- **Puissance mécanique :**

$$P_W = -\,p_{\text{ext}}\,\dot{V} = -\,p\,\dot{V}$$

- **Premier et deuxième principes :**

$$\dot{G} = P_Q + P_W - T\,\dot{S} + p\,\dot{V} = P_Q - T\,\dot{S} = -\,T\,\Pi_S \leq 0$$

- **Condition d'évolution et d'équilibre :**

$$\boxed{dG \leq 0 \qquad \text{(température et pression constantes)} \qquad G \text{ est minimale à l'équilibre}}$$

Thermodynamique

That is, taking into account because p outside is equal to p, it is minus p point. We can now rewrite the derivative enthalpy using the first principle. The point is equal to PQ plus pw, which means that h point is equal to pq plus pw plus sup v for. Only PW is equal to one PV. For this contribution. The PV point is simplified with the PV contribution and in the end H points is reduced to PQ. As we saw in a previous lesson. When entropy is constant, DQ can be zero or it can be negative. Therefore, each point is smaller than or equal to zero. This relation can be multiplied by the infinitesimal time interval dt and we obtain the following relation dh is smaller or equal to zero. Therefore, when the system is in contact with a working tank that guarantees that it has a constant pressure and that in addition the entropy remains constant, the evolution of the system is an evolution irreversible whose condition is DH strictly smaller than zero, and during this evolution, the enthalpy of the system decreases and the system will tend towards an equilibrium state which is defined by the condition DH equal to zero and at equilibrium H is minimal. We will now consider the evolution of the group free energy of the system.

Notes

Summary

6m 24s

Evolution de énergie libre de Gibbs

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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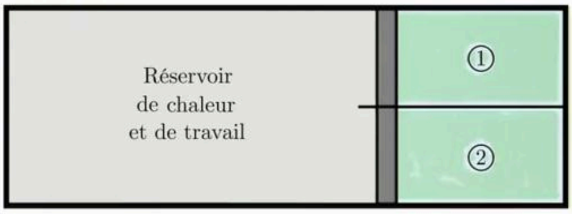
$$T_{\text{ext}} = T_1 = T_2 \equiv T \qquad \text{et} \qquad p_{\text{ext}} = p_1 = p_2 \equiv p$$

- **Dérivée temporelle énergie libre de Gibbs :**

$$\dot{G} = \dot{U} - T\,\dot{S} + p\,\dot{V}$$

- **Puissance mécanique :**

$$P_W = -\,p_{\text{ext}}\,\dot{V} = -\,p\,\dot{V}$$



- **Premier et deuxième principes :**

$$\dot{G} = P_Q + P_W - T\,\dot{S} + p\,\dot{V} = P_Q - T\,\dot{S} = -\,T\,\Pi_S \leq 0$$

- **Condition d'évolution et d'équilibre :**

$$\boxed{dG \leq 0 \qquad \text{(température et pression constantes)} \qquad G \text{ est minimale à l'équilibre}}$$

Thermodynamique

So we have a system consisting of two sub-systems one and two. This system is in contact with a heat and work reservoir. The temperature of the tank was outside. Outdoor summer is equal to T1 and T2. The temperatures of the two subsystems and this temperature is the temperature T and the external pressure of the tank is equal to the pressure. P1 and P2 the two subsystems. And this pressure is the P pressure. the Gypsum Free Energy G is equal to one TF. Plus PV or T and P are constant. Therefore, the time derivative of the group free energy G points is equal to a rise s point plus p v point. The mechanical power PW exerted by the tank on the system. It is less external p v point. That is, given the equality between external p and P. The mechanical power PW is equal to less than p. 20 point. We can now use the first principle to express the derivative time of the team's free energy in terms of power. And point is pq plus bw so g point it's pq plus pw me ts points plus pv points. It is also known that the power mechanical PW is less p v for this term will simplify with the more PV for. And so g points is reduced to PQ half hope.

Notes

Summary

8m 09s

Evolution de énergie libre de Gibbs

- **Réservoir de chaleur et de travail :**

  $T_{\text{ext}} = T_1 = T_2 \equiv T \qquad \text{et} \qquad p_{\text{ext}} = p_1 = p_2 \equiv p$

- **Dérivée temporelle énergie libre de Gibbs :**

  $\dot{G} = \dot{U} - T\,\dot{S} + p\,\dot{V}$

- **Puissance mécanique :**

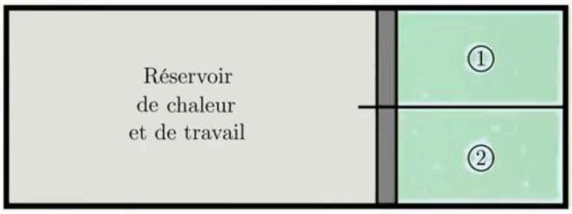
  $P_W = -\,p_{\text{ext}}\,\dot{V} = -\,p\,\dot{V}$

- **Premier et deuxième principes :**

  $\dot{G} = P_Q + P_W - T\,\dot{S} + p\,\dot{V} = P_Q - T\,\dot{S} = -\,T\,\Pi_S \leq 0$

- **Condition d'évolution et d'équilibre :**

  $dG \leq 0$ (température et pression constantes) G est minimale à l'équilibre



Thermodynamique

Given the entropy balance equation PQ half is this point is reduced to half a foot of decline based on the second principle. Pi of its largest is zero. Therefore, g for the half pi of bone and G for will be smaller than or equal to zero. By multiplying this condition by the infinitesimal time interval DT, we obtain the following relation dg. Smaller or equal to zero. Therefore, when the system is coupled to a heat and work reservoir which maintains its temperature and pressure constant, the evolution of this system, which is characterized by the condition of age, is strictly smaller than zero. This evolution will cause the decrease of the free energy. This is an irreversible evolution, so I decrease and when the system approaches the equilibrium, G will reach a minimum value at equilibrium. We have the following condition DG equals zero and thus at equilibrium, G is minimal.

Notes

Summary

10m 00s

Travail : système couplé à un réservoir de chaleur

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

- **Réservoir de chaleur :**

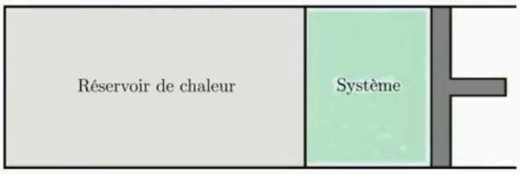
$$T_{\text{ext}} = T$$

- **Travail infinitésimal effectué :**

$$\delta W = dU - \delta Q = dU - T\,dS = d\,(U - T\,S) = dF$$

- **Travail effectué** $(i \rightarrow f)$:

$$W_{if} = \Delta F_{if} = \int_{F_i}^{F_f} dF = F_f - F_i$$



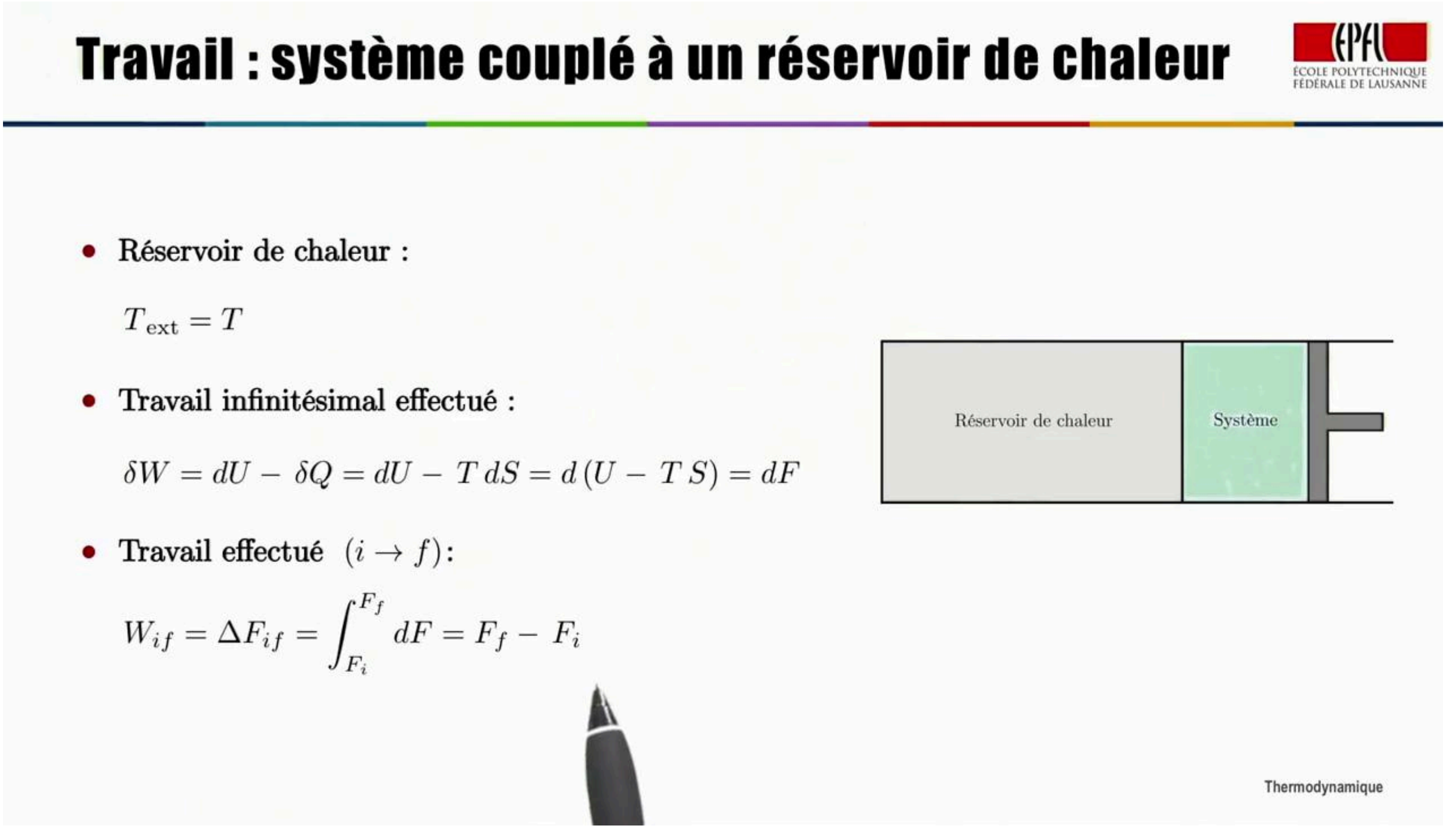
Thermodynamique

We will now determine the heat which is supplied to a system that is coupled to a working tank. The pressure of this external working tank. And then the pressure of the CP system. And then we heat this system, so we provide it with infinitesimal heat. Delta Q. From the first principle, we know that it is Delta ku plus delta w. So. Delta ku is delta W. The infinitesimal work done on the Delta W system is equal to half of the exterior. dV as p outside is equal to p delta W is equal to minus pdv, which implies that less delta W is more POS. And then there is constant pressure from POS to write it as d. In addition PV got more tickets. It is by definition. H. Therefore, the infinitesimal heat delta q which is supplied to the system when this system is in contact with a working tank that maintains its pressure constant. This infinitesimal heat delta Q is equal to the differential of the enthalpy DH. We can now determine the heat provided during a process that goes from the initial state i to the final state f. This heat supplied to the system Q and F is equal to the variation enthalpy of the system, i.e. delta h x. This enthalpy variation. More than enthalpy is a state function is equal to a head month hash.

Notes

Summary

11m 20s



Finally, we will determine the work which is performed on a system that is coupled to a heat tank. The system here is the heat tank. The temperature of the heat tank and the temperature of the CT system. So, we want to determine the work infinitesimal which is performed on this delta W system. According to the first principle, Delta W is equal to minus delta ku. Since the temperature of the tank, which is the external environment, is equal to the temperature of the system T delta Q in this case, is equal to TDS. So Delta W is equal to half DS. Since the temperature is constant, d u tds can be rewritten as d of U minus ts and u minus ts. This is the free energy f. Therefore, when doing a job infinitesimal on a system that is in contact with a heat reservoir that ensures that this system is maintained at a constant temperature, this infinitesimal work delta W is equal to the differential of the free energy DF. We can now determine the work performed on this system in the initial state i a final state f. This work w y f is equal to the variation of free energy of the system delta f. the Free Energy is a state function. Therefore, this variation is simply. The final free energy ff minus the initial free energy is EFI.

Notes

Summary

13m 12s