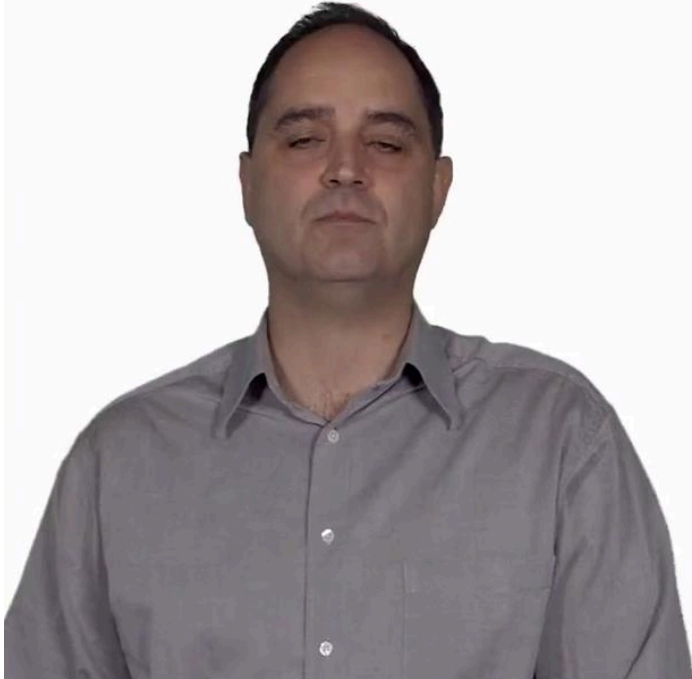


Bilan énergétique – courant et source d'entropie



- bilan énergétique local
- équation thermostatique locale (Euler)
- équation pour la densité de courant d'entropie
- équation pour la densité de source d'entropie

Thermodynamique

Hello and welcome to the thermodynamics classes. In the previous precipitation, we obtained the equations continuity for continuous media state variables as well as for other detailed extensive observables. In this part of the courses. We will use some of these equations that we have derived to realize the local energy balance of continuous media. Using the local energy balance of the continuous environment, we can obtain the local thermostatic equation, in other words the local student equation, and an equation for the entropy current density of the continuous medium and an equation for the density of entropy sources of a continuous medium.

Notes

Summary



0m 04s

Bilan énergétique – courant et source d'entropie

- Hypothèse d'équilibre local : la relation de Gibbs est valable au niveau local.

$$T ds = du - \sum_{A=1}^r \mu_A dn_A - \varphi dq. \quad (29)$$

- T : température, $T \equiv \frac{\partial u}{\partial s}$,
- μ_A : potentiel chimique de la substance A , $\mu_A \equiv \frac{\partial u}{\partial n_A}$,
- φ : potentiel électrostatique externe, $\varphi \equiv \frac{\partial u}{\partial q}$.
- Si nous divisons la relation de Gibbs par dt , nous arrivons à

$$T \dot{s} = \dot{u} - \sum_{A=1}^r \mu_A \dot{n}_A - \varphi \dot{q}. \quad (30)$$

Thermodynamique

The local energy balance of environments is based on the assumption of local equilibrium. According to this hypothesis, a local thermodynamic system, i.e. a material point which belongs to the continuous medium, is in a state of equilibrium. Then the reversion of the applicable guides for the local system, which means that the version of the guides is valid at the local level, can be written in terms of differential of thermodynamic fields. This is the relationship of the local guides. This exemption allows us to express the total differential of the density of entropy of a continuous medium in terms of total differential other fields of thermodynamic states according to the structure of this relation. The time temperature field is defined as the partial derivative of the density of internal energy compared to the density of entropy and more. Miwa. The chemical potential of the substance chemical A is defined as the partial derivative of the internal energy density of the medium in relation to the density of chemical substance A. Finally, the external prostatic potential is defined as the partial derivative of the internal energy density compared to the electric charge density. If we divide the Guise relationship by DT, we arrive at this relationship. This is a relation for the material derivative of the entropy density.

Notes

Summary



Bilan énergétique – courant et source d'entropie

- Objectif : exprimer les densités de courant et de source d'entropie en fonction des densités des courants et des sources des autres champs d'état.
- A cette fin, nous introduisons les équations de continuité pour
 - i. l'énergie interne,

$$\dot{u} + u \nabla \cdot \mathbf{v} = -\nabla \cdot \mathbf{j}_u + \boldsymbol{\tau} : \tilde{\nabla} \mathbf{v} \quad (23)$$

- ii. les substances chimiques,

$$\dot{n}_A + n_A \nabla \cdot \mathbf{v} = -\nabla \cdot \mathbf{j}_A + \sum_{a=1}^n \omega_a \nu_{aA}. \quad (11)$$

- iii. la charge électrique,

$$\dot{q} + q \nabla \cdot \mathbf{v} = -\nabla \cdot \mathbf{j}_q. \quad (24)$$

à l'équation précédente. Ceci donne :

Thermodynamique

Is this also the objective of the assessment and to express the current densities of the sources entropy as a function of current and state source densities. To this end, we will produce there. In the previous relationship, some of the equations of the continuous doubted that we have quotation marks in the previous part of the course. That is, for this purpose. Here we translate the continuity equations for the internal energy. For chemical substances and for the electric charge to the previous equation.

Notes

Summary



$$\begin{aligned} \dot{s} = & -\frac{1}{T} \left(u - \sum_{A=1}^r \mu_A n_A - q \varphi \right) \nabla \cdot \mathbf{v} - \\ & \nabla \cdot \left(\frac{1}{T} \left(\mathbf{j}_u - \sum_{A=1}^r \mu_A \mathbf{j}_A - \varphi \mathbf{j}_q \right) \right) - \frac{1}{T} \sum_{A=1}^r \mu_A \left(\sum_{a=1}^n \omega_a \nu_{aA} \right) + \\ & \frac{1}{T} \left\{ \frac{1}{T} \left(\mathbf{j}_u - \sum_{A=1}^r \mu_A \mathbf{j}_A - \varphi \mathbf{j}_q \right) \cdot \nabla T - \sum_{A=1}^r \mathbf{j}_A \cdot \nabla \mu_A - \mathbf{j}_q \cdot \nabla \varphi + \tau : \tilde{\nabla} \mathbf{v} \right\}. \end{aligned} \quad (31)$$

Rappel : $\mathbf{j}_q = \sum_{A=1}^r q_A \mathbf{j}_A$

Thermodynamique

After a series of manipulations, Cecile begins or in this expression for the material derivative of the entropy density is without. Yes, it is, it is a fairly long relationship, but there are still some terms and some quantities that we can handle. For example, the inductive electric current density \mathbf{j}_q is given by this relation that we derived in the previous section of the course. Moreover, we can manipulate this air by the green box which represents the double scalar product between the training times and the constraints, as well as that air which involves the rate of chemical reactions. We start with the terms framed by the green box.

Notes

Summary



2m 55s

Bilan énergétique – courant et source d'entropie

- Le tenseur des contraintes τ est constitué d'une partie *réversible* et d'une partie *irréversible* (frottements): $\tau = \tau^{\text{rev}} + \tau^{\text{fr}}$.
- τ^{rev} : pour les fluides, il est défini par la pression hydrostatique : $\tau^{\text{rev}} = -p \mathbb{I}$.
- τ^{fr} : il peut être décomposé en un tenseur diagonal et un tenseur déviatorique :
$$\tau^{\text{fr}} = \tau^{\text{fr}} \mathbb{I} + \tau_{\text{d}}^{\text{fr}},$$

Thermodynamique

We notice that the tensor of the constraints consists of a reversible part and a irreversible part. The reversible part is associated with the contact forces that provide work to the target, while the irreversible part is associated with the contact forces whose work is dissipated. We then have the following decomposition. Here, your dream represents, the reversible part being that of stress, while this greenhouse represents the irreversible part, it is called that of friction. Concerning the transfer on, the reversible part for fluids is defined by the hydrostatic pressure. This means that for fluids, the only contact force that provides of the irreversible work is the hydrostatic pressure. Then your dream is given as the opposite of the product between the hydrostatic pressure P and the identity matrix. Regarding frictional trends, it can be broken down into seven diagonals and a diatonic set. This composition is quite general and can be applied to an arbitrary tensor. We then have the following decomposition. The first term on the right side of this equation represents a diagonal tensor. This set is given as. The product of a scalar quantity is. Making is the identity matrix.

Notes

Summary



3m 37s

Bilan énergétique – courant et source d'entropie

- Le tenseur des contraintes τ est constitué d'une partie *réversible* et d'une partie *irréversible* (frottements): $\tau = \tau^{\text{rev}} + \tau^{\text{fr}}$.
- τ^{rev} : pour les fluides, il est défini par la pression hydrostatique : $\tau^{\text{rev}} = -p \mathbb{I}$.
- τ^{fr} : il peut être décomposé en un tenseur diagonal et un tenseur déviatorique :

$$\tau^{\text{fr}} = \tau^{\text{fr}} \mathbb{I} + \tau_{\text{d}}^{\text{fr}}, \quad \tau^{\text{fr}} = \frac{1}{3} \text{tr}(\tau^{\text{fr}}).$$

- Alors : $\tau = (\tau^{\text{fr}} - p) \mathbb{I} + \tau_{\text{d}}^{\text{fr}}$.

- Egalement, $\tilde{\nabla} \mathbf{v} = \frac{1}{3} \text{tr}(\tilde{\nabla} \mathbf{v}) \mathbb{I} + \hat{\tilde{\nabla}} \mathbf{v}$, $\text{tr}(\tilde{\nabla} \mathbf{v}) = \nabla \cdot \mathbf{v}$.

$$\tau : \tilde{\nabla} \mathbf{v} = (\tau^{\text{fr}} - p) \nabla \cdot \mathbf{v} + \tau_{\text{d}}^{\text{fr}} : \hat{\tilde{\nabla}} \mathbf{v}.$$

(32)

Thermodynamique

The scalar quantity time fr is given as the inside of the so-called chief trace of the rubbing. It is called viscous pressure. This quantity represents time. It becomes theoretical and is defined as the difference between the friction tensor and this diagonal tensor. Then with the help of compositional tests. The stress tensor is written in the following form. Now we can apply the decomposition into an intense diagonal tensor, say the theory as well as that of deformation. We then have the following decomposition. Here, these terms represent a diagonal tensor which is given as the product between the interest of the deformation tensor trace and the identity matrix. The trace of the deformation tensor is equal to the velocity divergence. This spark here represents the atomic life part of time, that of the deformations, and it is defined as the difference between the deformation tensor and this diagonal ancestor. Using this representation, the stress tensor of the deformation tensor. The double scalar product between thoughts is given by this expression. This perceived expression is introduced to the relation for the material derivative of the entropy density. We continue with the terms entered by the blue box.

Notes

Summary



5m 07s

- Nous introduisons la définition d'affinité \mathcal{A}_a d'une réaction chimique a :

$$\mathcal{A}_a = - \sum_{A=1}^r \mu_A \nu_{aA} \quad \Rightarrow \quad \sum_{A=1}^r \mu_A \left(\sum_{a=1}^n \omega_a \nu_{aA} \right) = - \sum_{a=1}^n \omega_a \mathcal{A}_a . \quad (33)$$

- A l'aide des deux derniers résultats, l'équation pour \dot{s} s'écrit sous la forme :

$$\begin{aligned} \dot{s} = & -\frac{1}{T} \left(u + p - \sum_{A=1}^r (\mu_A + q_A \varphi) n_A \right) \nabla \cdot \mathbf{v} - \\ & \nabla \cdot \left(\frac{1}{T} \left(\mathbf{j}_u - \sum_{A=1}^r (\mu_A + q_A \varphi) \mathbf{j}_A \right) \right) + \\ & \frac{1}{T} \left\{ \sum_{a=1}^n \omega_a \mathcal{A}_a + \tau^{\text{fr}} \nabla \cdot \mathbf{v} - \frac{1}{T} \left(\mathbf{j}_u - \sum_{A=1}^r (\mu_A + q_A \varphi) \mathbf{j}_A \right) \cdot \nabla T - \sum_{A=1}^r \mathbf{j}_A \cdot (\nabla \mu_A + q_A \nabla \varphi) + \tau_d^{\text{fr}} : \hat{\nabla} \mathbf{v} \right\} \quad (34) \end{aligned}$$

Thermodynamique

First, we define affinity, i.e. a chemical reaction at the definition of the affinity of chemical reactions. The affinity of chemical reactions is given as the opposite of the comet officer's room, related to this reaction weighted by the molar masses of the substances chemicals that participate in this reaction. Using this definition, the terms encountered by the green box can be written in this form. Now using the latest results. The equation could in the derivative of the entropy density is written in this form. We note that s of others is the sum of the three contributions. The first contribution is expressed by this rule which is the product of the velocity divergence and this quantity which is combinations of thermodynamic state fields. The second contribution is expressed in these terms that attest to the differences. And finally, the third contribution is expressed by this R which is a sum of products.

Notes

Summary



6m 43s

Bilan énergétique – courant et source d'entropie

- Rappelons l'équation de continuité pour l'entropie :

$$\dot{s} = -s \nabla \cdot \mathbf{v} - \nabla \cdot \mathbf{j}_s + \pi_s. \quad (28)$$

- Par identification de deux dernières relations, nous arrivons à

$$u = T s - p + \sum_{A=1}^r (\mu_A + q_A \varphi) n_A, \quad \longrightarrow \text{(équation thermostatique locale)!} \quad (35)$$

$$\mathbf{j}_s = \frac{1}{T} \left(\mathbf{j}_u - \sum_{A=1}^r (\mu_A + q_A \varphi) \mathbf{j}_A \right), \quad (36)$$

$$\pi_s = \frac{1}{T} \left\{ \sum_{a=1}^n \omega_a \mathcal{A}_a + \tau^{\text{fr}} \nabla \cdot \mathbf{v} + \mathbf{j}_s (-\nabla T) - \sum_{A=1}^r \mathbf{j}_A \cdot (\nabla \mu_A + q_A \nabla \varphi) + \boldsymbol{\tau}_d^{\text{fr}} : \hat{\nabla} \mathbf{v} \right\}. \quad (37)$$

Thermodynamique

Now we recall the continuity equation for entropy that we described in the previous presentation. This is the continuity equation for entropy. We observe that this equation is exactly the same structure as the previous equation. Then, by identifying the last two relations, we arrive at to this expression which is the local static equation. In other words, the equation we raise local. This equation allows us to express the entropy density as a function of our thermodynamic center of state. Moreover, we arrive at this expression for the entropy current density. So, who has this expression for the density of entropy sources? We observe that the density of sources entropy is expressed as a sum of products.

Notes

Summary



Note

- Nous considérons la différentielle de l'équation thermostatique locale,

$$du = d(Ts) - dp + d\left(\sum_{A=1}^r (\mu_A + q_A \varphi) n_A\right).$$

- La combinaison de cette équation avec la relation de Gibbs locale résulte en la forme locale de l'équation de *Gibbs-Duhem* :

$$s dT + dp + \sum_{A=1}^r (n_A d\mu_A + n_A q_A d\varphi) = 0. \quad (38)$$

Thermodynamique

We will conclude this presentation with silt. We consider the differential of the local thermostatic equation. This is the differential. The combination of this equation with the relation of the local guides results in the local form of the equation of M. This is the relationship of Duhem group which is a useful relationship for the study of the equilibrium process.

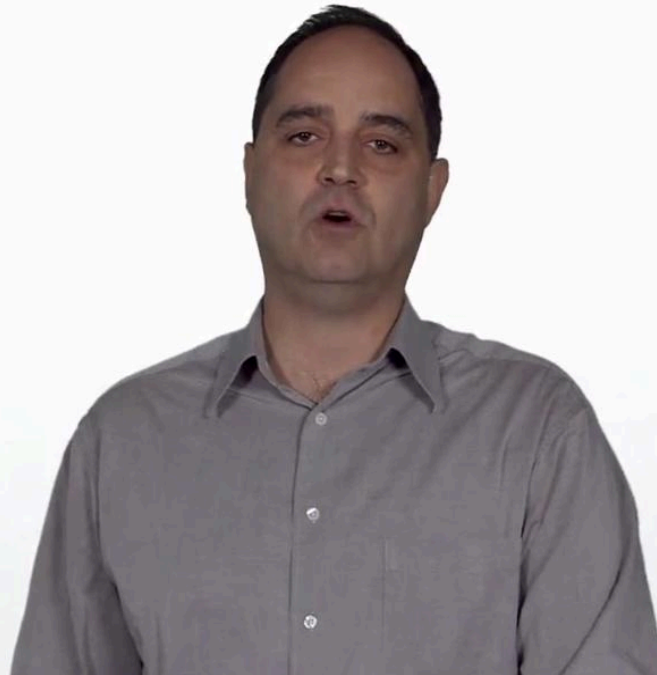
Notes

Summary



8m 47s

Bilan énergétique – courant et source d'entropie



Thermodynamique

We have also reached the end of this part of the thermodynamics course. In the next presentation, we elaborate more on the expression of the entropy sulfur density and furthermore, using this expression, we will establish a formalism thermodynamics for the study of non-equilibrium processes.

Notes

Summary



9m 12s