

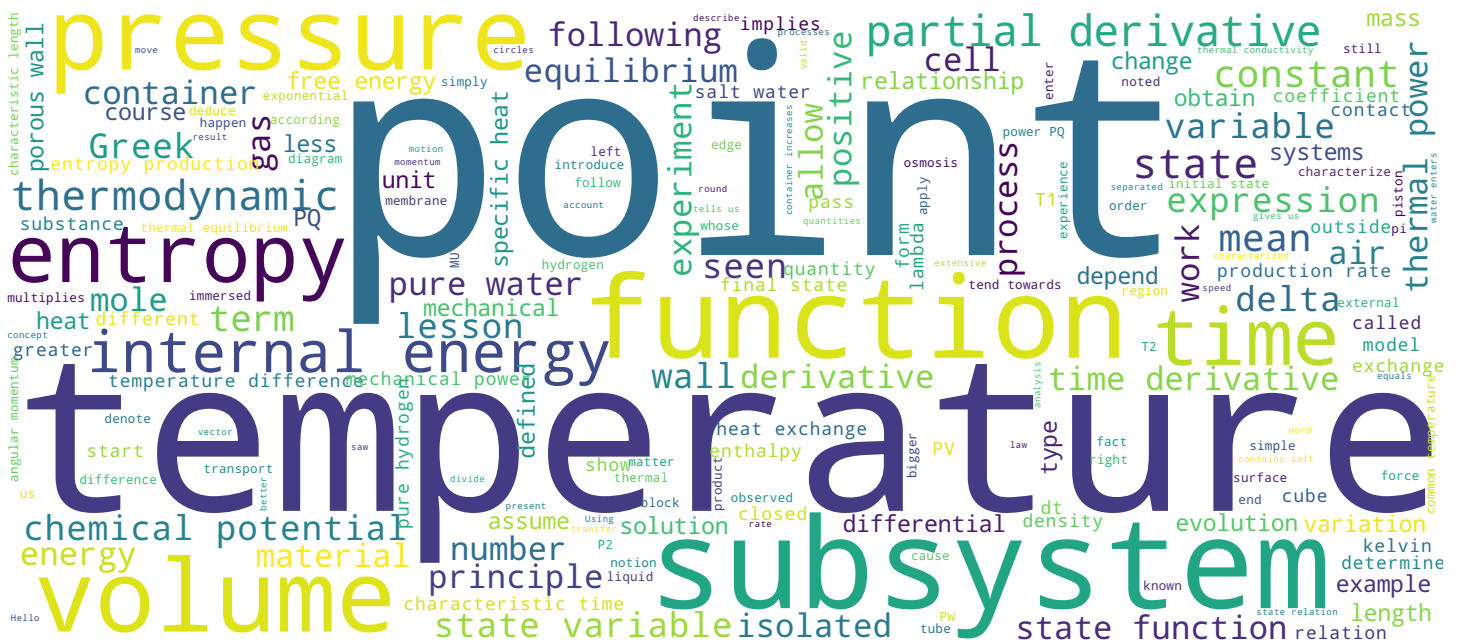
# Thermodynamique

## Expériences : Sous-systèmes simples

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Stückelberg





- Paroi diatherme
- Paroi poreuse :
  - Gaz
  - Liquide

Thermodynamique

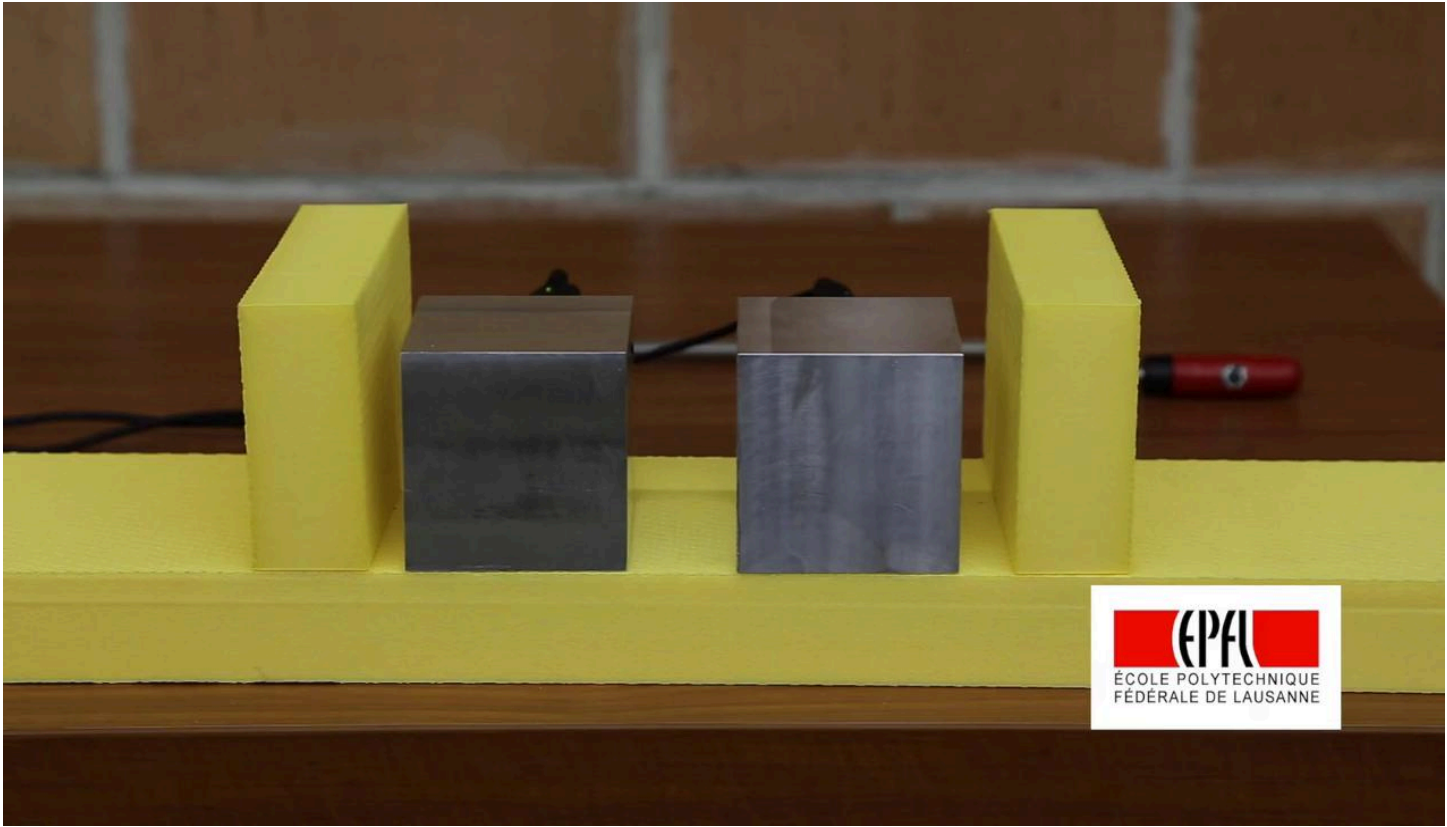
Here I am again to present you some experiences in this lesson. You have seen heat exchange between sub-systems separated by a wall due to time ? Here I will show you a system that can be interpreted with this model. In this same lesson. Have you seen the material transports? Here, we will look at a transport of materials between two subsystems separated by a wall that allows only one of the substances to pass.

Notes

Summary



0m 05s



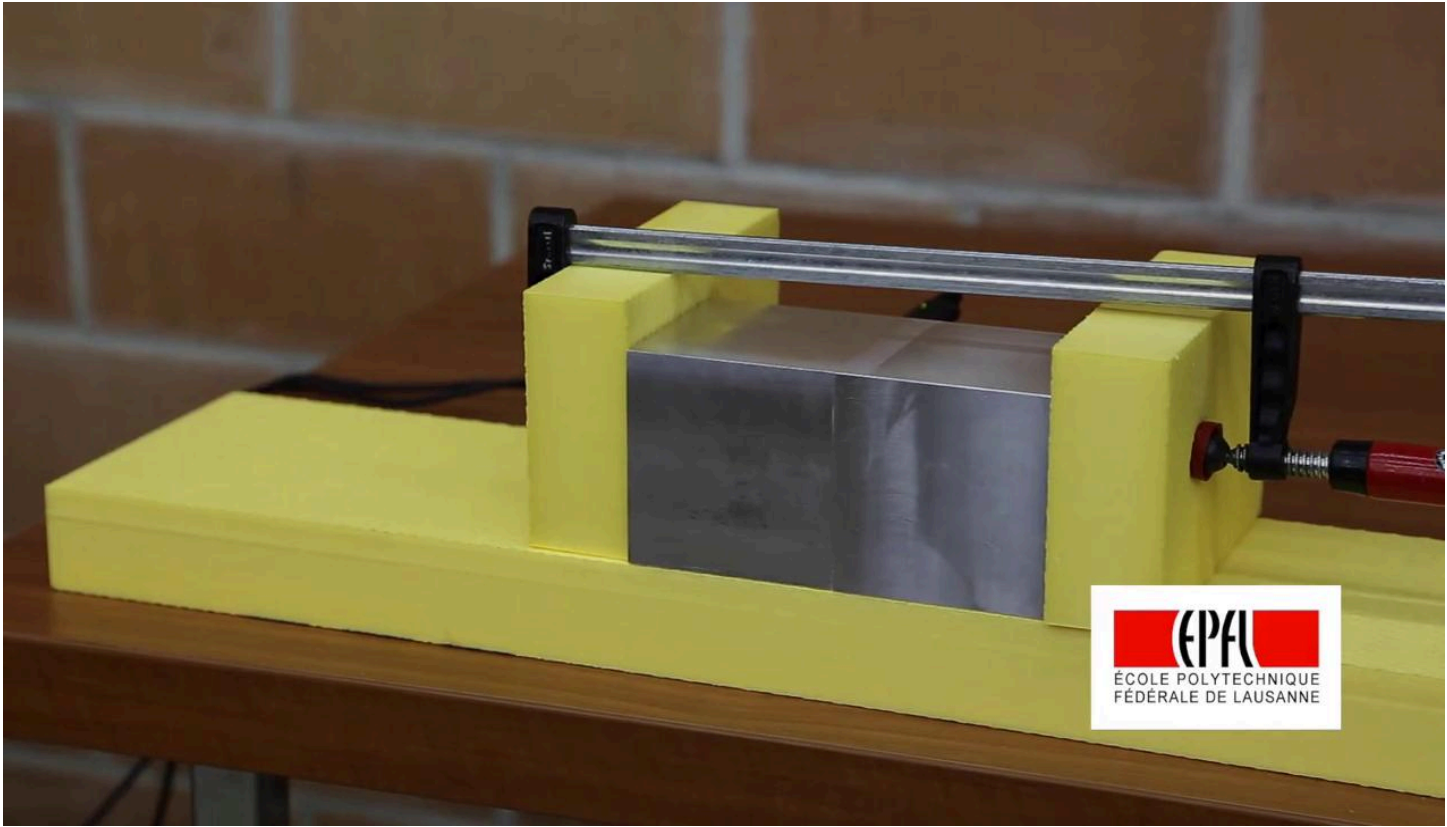
We start with. Two sub-systems which are in thermal contact and which tend towards a thermal equilibrium. Here we have two identical aluminum blocks. Each is equipped with a thermometer located at the back of the block, on the time scale of the measurement.

Notes

Summary

0m 41s





The blocks do not change temperature when separated. Let's put the two blocks together.

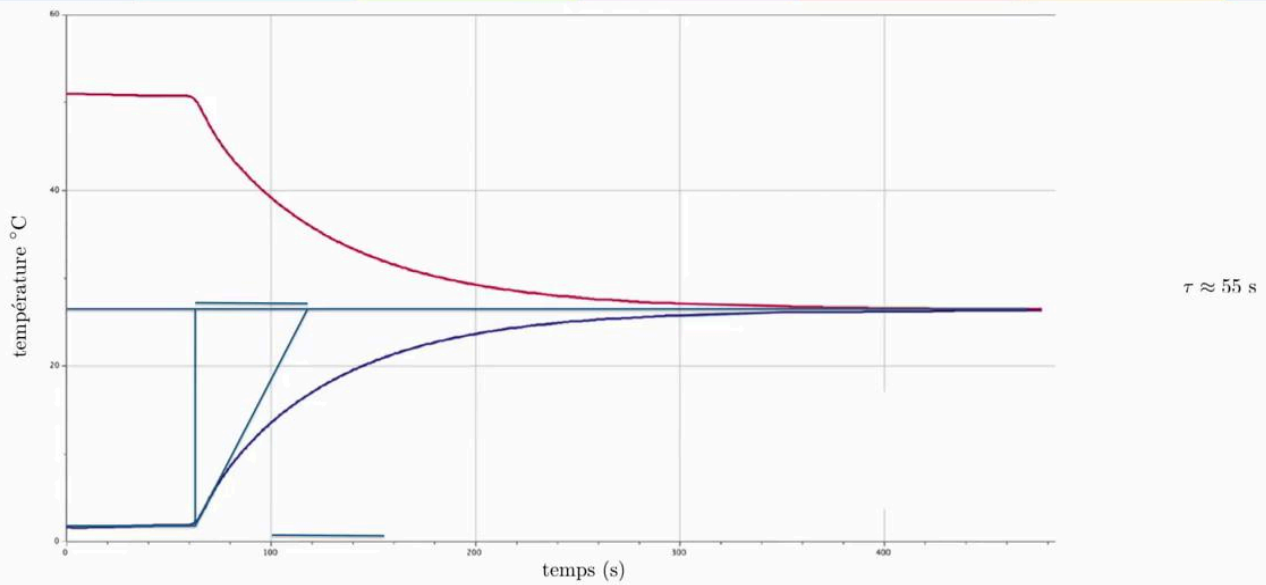
Notes

Summary

1m 02s



# Contact thermique



Thermodynamique

The two temperatures are now moving towards a common temperature. Here is the result. We will admit that we have an exponential decrease. We then use the slope at the origin to determine the time constant of the exponential. I find a time that will be noted too 55 seconds.

Notes

Summary



1m 14s



$$U = U_1 + U_2 \quad \dot{U} = 0$$

$$\dot{U}_1 = P_Q^{(21)} = \frac{\kappa A}{\ell} (T_2 - T_1)$$

$$\dot{U}_2 = P_Q^{(12)} = \frac{\kappa A}{\ell} (T_1 - T_2)$$

Equation d'état pour chaque bloc (voir leçon 5)

$$\dot{U}_1 = C_V \dot{T}_1 \quad \dot{U}_2 = C_V \dot{T}_2$$

$$\dot{T}_1 = \frac{\kappa A}{\ell C_V} (T_2 - T_1)$$

$$\dot{T}_2 = \frac{\kappa A}{\ell C_V} (T_1 - T_2)$$

$$\dot{T}_1 - \dot{T}_2 = -\frac{2\kappa A}{\ell C_V} (T_1 - T_2)$$

Thermodynamique

Resuming the analysis, as you have seen in this lesson. We will assume that the total internal energy is constant. In doing so, we assume that each block separately has a negligible heat exchange with the environment. We have seen in this lesson this law that we apply here to the subsystem and the subsystem of which give us the thermal power as a function of the temperature difference. For reasons that will become clear. The. In the third part of the course, we noted the coefficient of proportionality with the area of contact, because obviously, the bigger the contact, the better the power. We used the thermal conductivity which is a tabular property of the material, and the dimensional analysis tells us that we still have to divide by a certain length and we expect that this length is a characteristic length of the system. To continue the analysis, we still need. A state relation that links internal energy to temperature. I give you this relationship here. This is it. Or  $c_v$  is called the specific heat. This is a concept you will see in detail in 105. With these two state relations and the phenomenological relations. For thermal power, we can write the evolution equations for the temperature.

Notes

Summary



1m 55s



$$U = U_1 + U_2 \quad \dot{U} = 0$$

$$\dot{U}_1 = P_Q^{(21)} = \frac{\kappa A}{\ell} (T_2 - T_1)$$

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Equation d'état pour chaque bloc (voir leçon 5)

$$\dot{U}_1 = C_V \dot{T}_1 \quad \dot{U}_2 = C_V \dot{T}_2$$

$$\dot{T}_1 = \frac{\kappa A}{\ell C_V} (T_2 - T_1)$$

$$\dot{T}_2 = \frac{\kappa A}{\ell C_V} (T_1 - T_2)$$

$$\dot{T}_1 - \dot{T}_2 = -\frac{2\kappa A}{\ell C_V} (T_1 - T_2) \quad \tau = \frac{\ell C_V}{2\kappa A}$$

$$\Delta T(t) = \Delta T(o) \exp(-t/\tau)$$

Thermodynamique

We deduce a very simple evolution equation for the temperature difference. The coefficient that appears here has units of one on one time, so we'll define our characteristic time like this. And the solution of this equation differential for the temperature difference is simply an exponential in the characteristic time. And precisely the tao time.

Notes

Summary



3m 40s





$$\tau = \frac{\ell C_V}{2\kappa A} \quad \tau \approx 55 \text{ s}$$

dimension du cube :  $d$

chaleur spécifique par unité de masse :  $c_V$

$$A = d^2 \quad m = \rho d^3 \quad C_V = mc_V$$

$$\kappa \approx 100 \text{ W / (m K)}$$

$$c_V \approx 0.9 \text{ J / (g K)}$$

$$d \approx 79 \text{ mm}$$

$$\rho \approx 2700 \text{ kg / m}^3$$

$$\ell \approx 5 \text{ cm}$$

Thermodynamique

I summarize the experiment gave us a characteristic time of 55 seconds and our model gives us this time as a function of the system parameters. If now I denote by the length of the edge of the cube. I take the specific heat per unit because that is often what is found in the tables. The air has declared itself. The mass of the cube is its density, or volume, and the big  $c_V$  is the mass times the specific heat per unit of mass. I take typical values for aluminum a thermal conductivity of 100 watts per meter per Kelvin, a specific heat of zero nine joule per gram and per kelvin. The edge was seventy-nine millimeters. And the density of aluminum is 2700 kilos per cubic meter. With these values there, I find for the characteristic length it five cm. This is of the order of magnitude of the dimensions of the system. So it's quite reasonable.

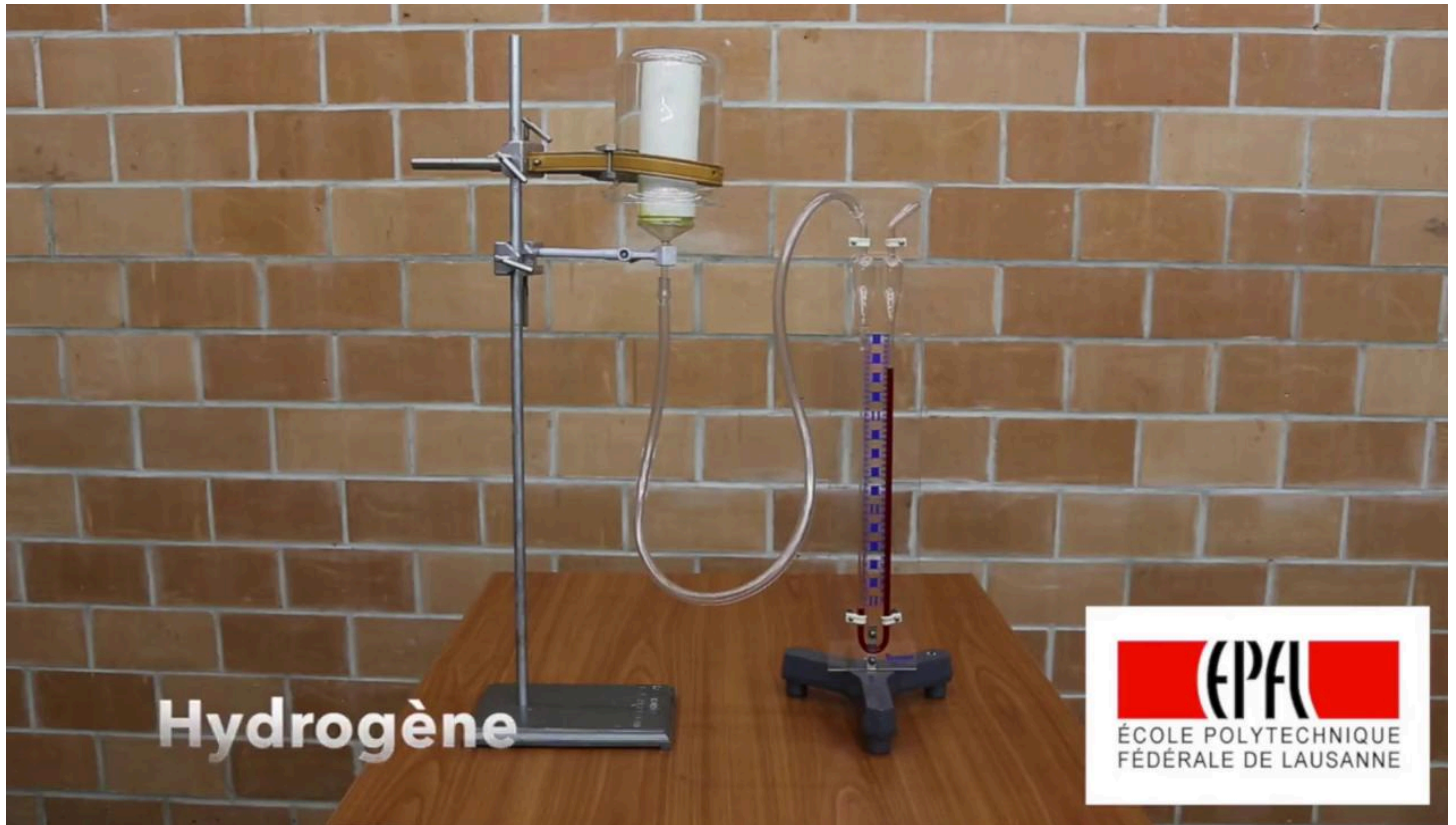
Notes

Summary



4m 08s





Hydrogène



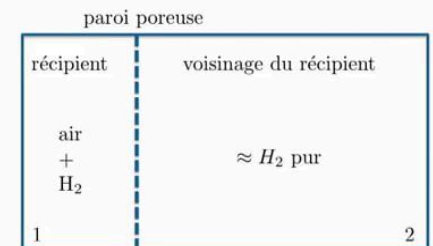
Let's move on to experiments with a transport of matter starting with a gas. We have here a container with porous walls. These walls let air through, but very slowly. On the other hand, hydrogen passes quickly through the walls. Observing what happens, the pressure in the container increases when the container is exposed to hydrogen. This means that hydrogen has entered the container.

Notes

Summary



5m 27s



Température : la même partout

Approximation :  
l'air ne diffuse pas à travers la paroi

$$\dot{N}_1 = F \frac{A}{\ell} (\mu_2 - \mu_1)$$

1 = récipient à paroi poreuse

$$p \nearrow \Rightarrow \dot{N}_1 \geq 0 \Rightarrow \mu_2 > \mu_1$$

le potentiel chimique de l'hydrogène dilué  
est plus petit que celui de l'hydrogène pur

Thermodynamique

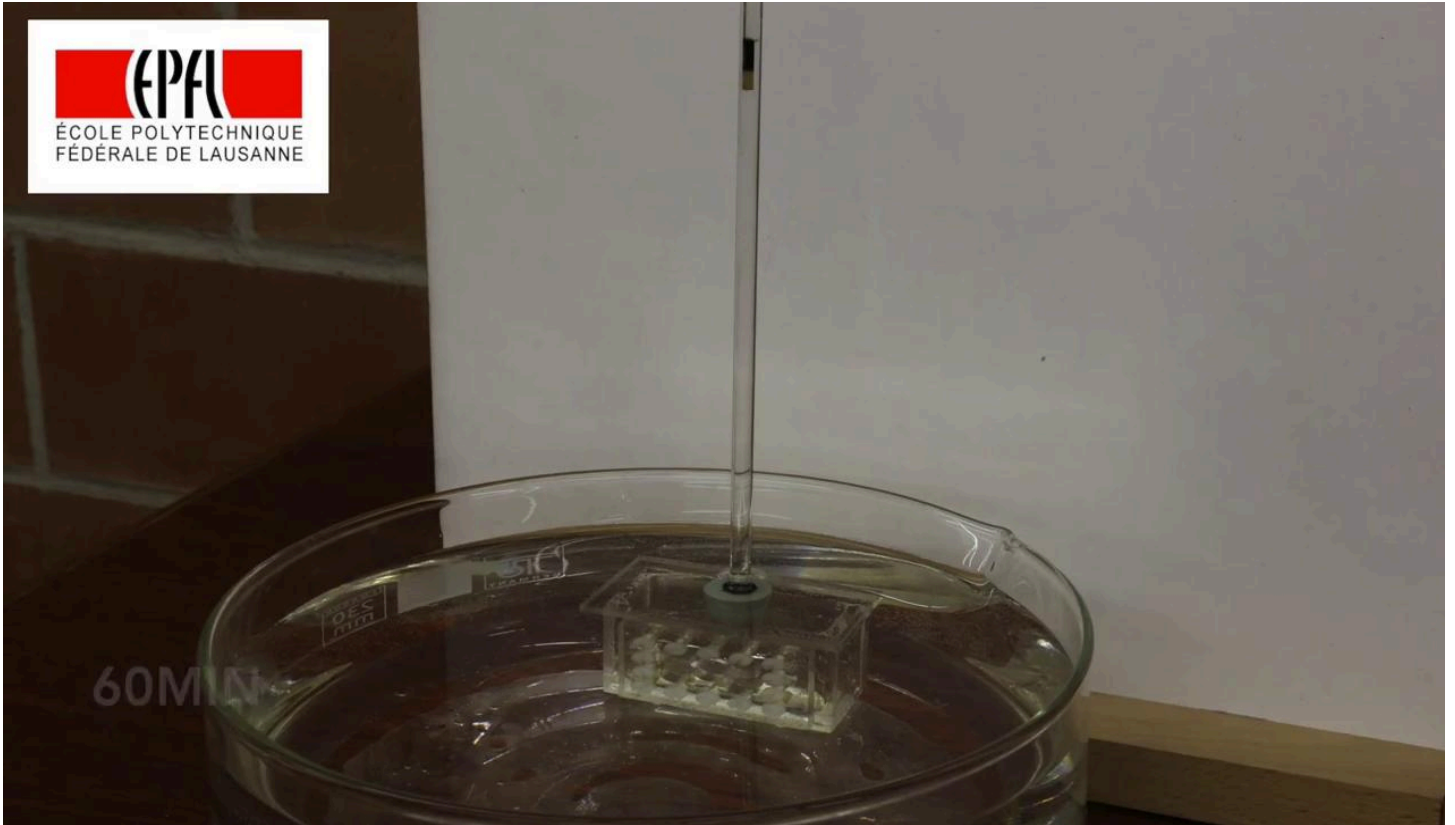
Here is how to model this system. We will consider that we have a container with a porous wall and the immediate vicinity of this porous wall. This will be our second sub-system. Outside the container, we will assume that we have pure hydrogen inside. We have the mixture. Temperature does not play a role here. We will assume that it is uniform. And we will make the approximation according to where air cannot pass through the porous wall at all. Then we can use this formula of the course for the evolution of the number of moles of hydrogen in the region. One, that is the container. You have once again a coefficient of proportionality similar to the one we saw earlier or we have. We have a length, it intervenes. It was observed that. The pressure in the container increased. This means. That the number of moles in the container increases. It means n one point is positive, this implies that two is bigger than MU one. This means that the chemical potential of pure hydrogen is greater than the chemical potential. Hydrogen in a mixture.

Notes

Summary



5m 59s



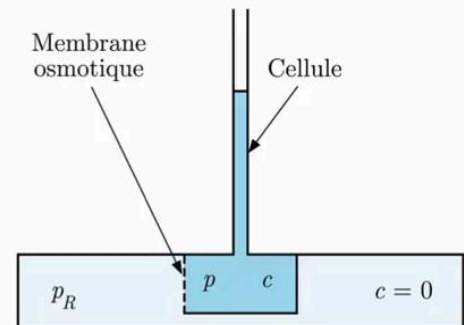
Now here is an experiment with liquids. Here, we will have a wall that does not let only one of the liquid substances present. Here we have a cell that contains salt water. One of the walls of the cell contains a membrane that lets water through, but not the salt ions in solution. We say that the membrane is osmotic and the phenomenon that we will observe is known as osmosis. Let's see what happens when this cell is immersed in pure water. Obviously pure water enters the cell.

Notes

Summary



7m 36s



Membrane osmotique :  
seulement l'eau passe à travers la membrane, pas les ions

L'eau pure a tendance à entrer  
dans la région où l'eau est salée

Le potentiel chimique de l'eau pure est plus grand  
que le potentiel chimique de l'eau salée.

Thermodynamique

Here is a schematic representation of the experiment. We have a cell that contains salt water with a tube that allows to show that the amount of liquid increases. This cell has a wall which is a wall called osmotic which allows water to pass through but not the ions in solution. This cell is immersed in pure water. It was observed that pure water tended to enter the saltwater region. This means that the chemical potential of pure water is greater than the chemical potential of water.

Notes

Summary



8m 27s



- Contact thermique
- Diffusion selective d'un gaz
- Osmose

Thermodynamique

In the solution. In summary, we have seen three experiences. In the first one, we have seen two blocks initially at different temperatures which tend towards an equilibrium of a common temperature. Then, we saw that pure hydrogen had a tendency to enter a region where hydrogen is mixed. And in a similar way, we have seen the osmosis in which pure water enters the salt water region.

Notes

Summary



9m 07s