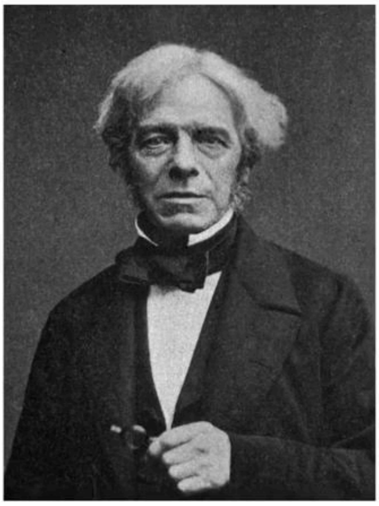
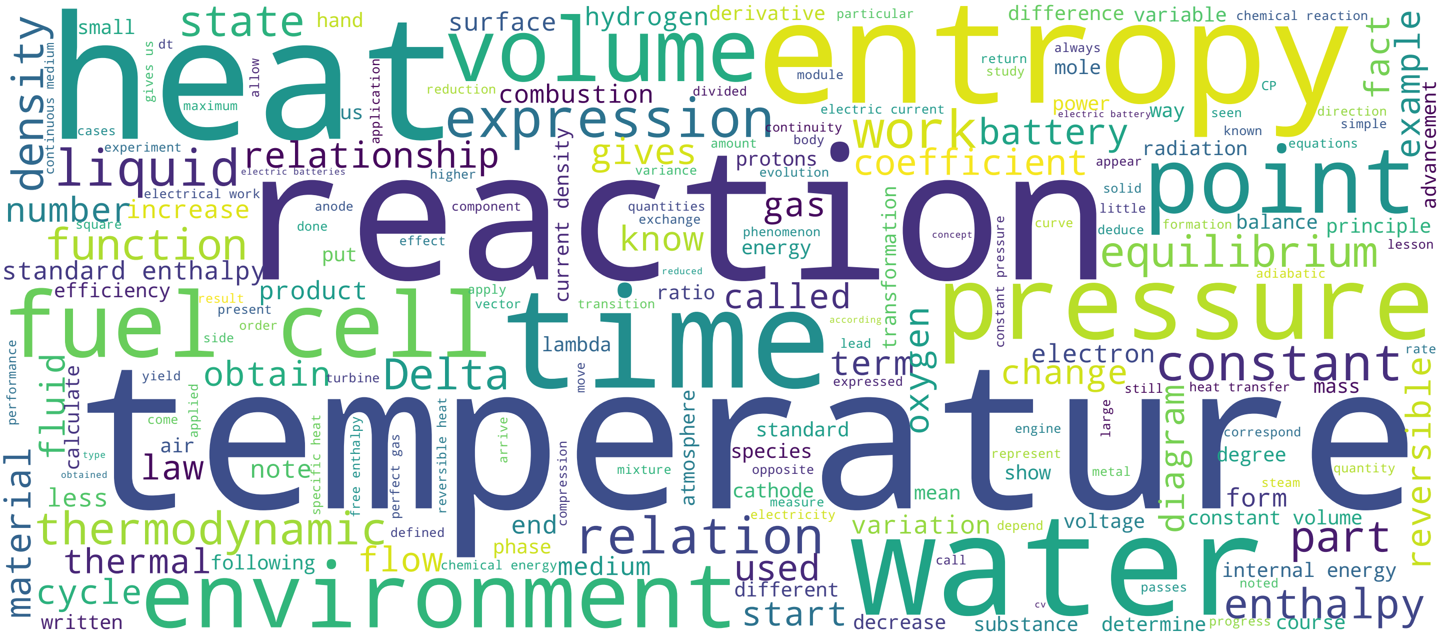
Thermodynamique

La pile à combustible

Prof. Michael Grätzel

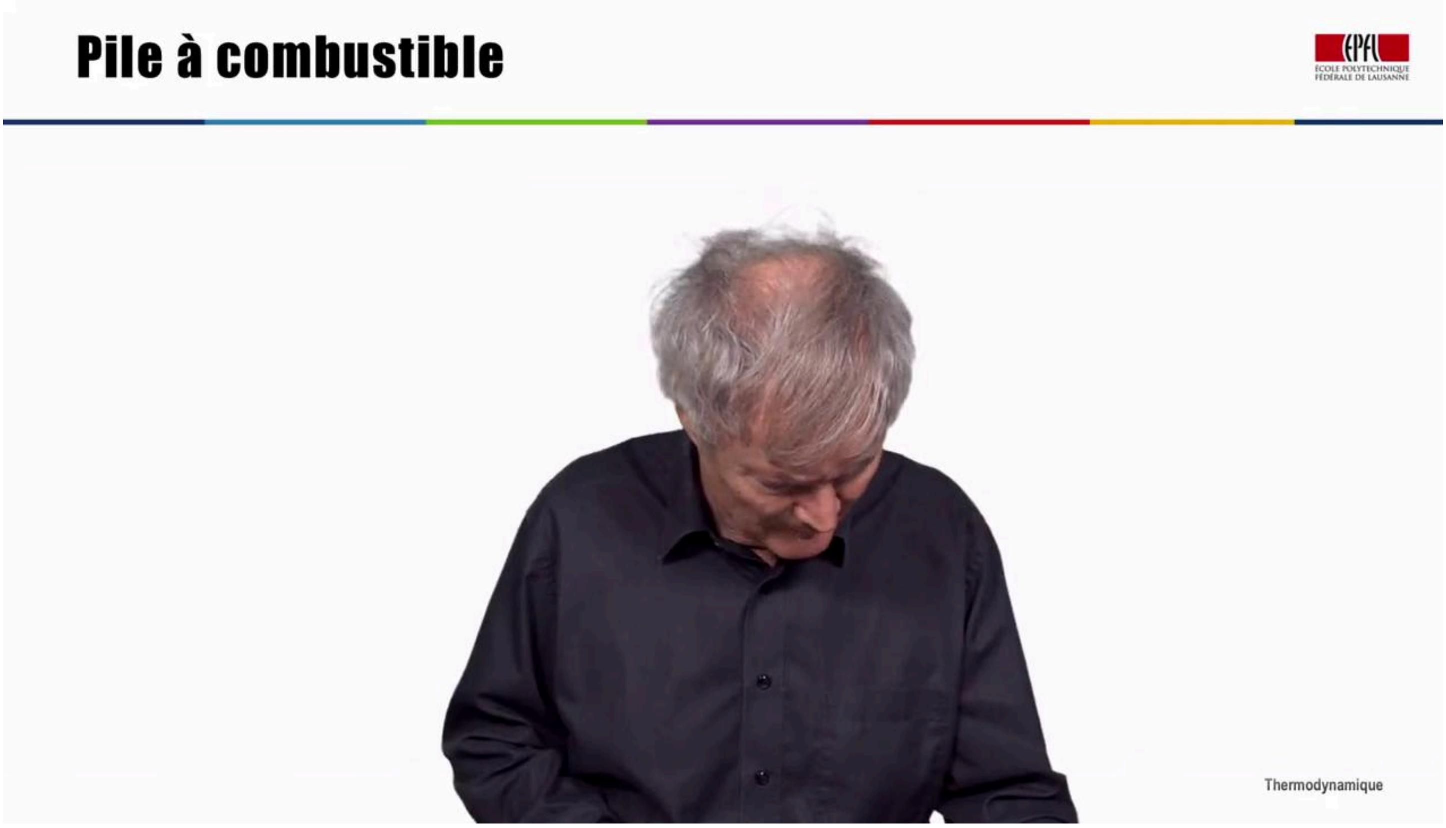


Michael Faraday



Video

EPFL



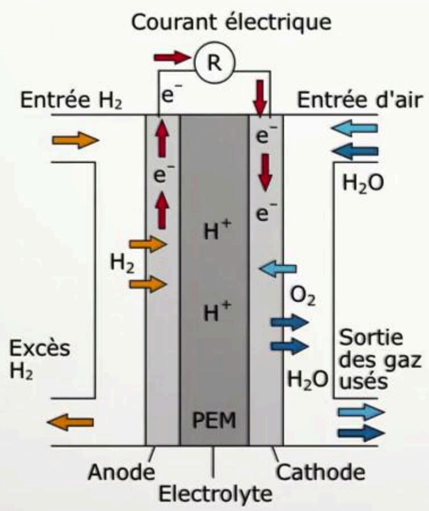
This is the last chapter of our leaving on the subject of the conversion of chemical energy into electricity or in electrical work that concerns fuel cells. Fuel cells are systems electrochemicals that use a fuel, for example methanol or hydrogen and oxidizes it to CO2. And from this reaction, we can draw an electrical energy which can then be used for example in a car to be able to run the electric car. So today we're going to look at how these fuel cells work. The first thing is that the principle changes with respect to the battery, because we have a chemical reaction which intervenes and thus generates an electric current.

Notes

Summary

0m 04s

Pile à combustible



R :Résistance externe

PEM :Polymère électrolytique (membrane qui conduit les protons)

Pour la pile à hydrogène:

Réaction à l'anode: $H_2 \rightarrow 2H^+ + 2e^-$

Réaction à la cathode: $2H^+ + 2e^- + \frac{1}{2}O_2 \rightarrow H_2O$

Réaction globale: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

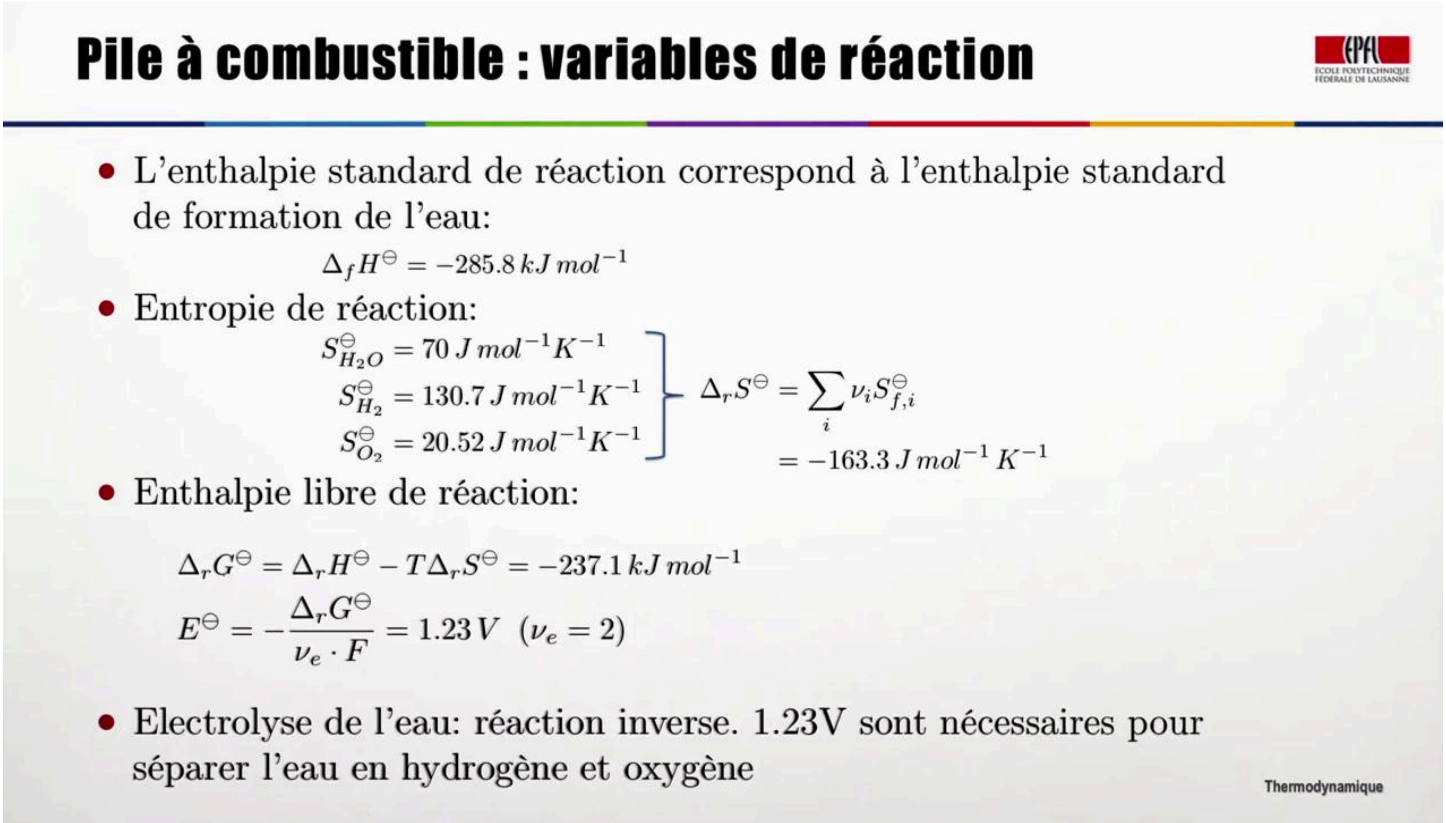
Thermodynamique

This is the principle of the battery. So I note there is the anode and the cathode and at the anode there is always oxidation. So we create electrons in the West, in this case hydrogen and the product of hydrogen oxidation is protons. So we make from the young effort two protons and two electrons. The electrons leave the system and thus produce the electric current while the protons are conducted to the other electrode, the cathode, or it is used for the reduction of oxygen, thus for the reduction of oxygen in water. So the product of the reduction is water. I need two protons and two electrons that give the liquid water. So if I look at these two reactions, oxidation at the anode and reduction at the cathode. And then it gives a global reaction. The combustion of hydrogen with oxygen. Aura, so that's what we call these fuel cells. So there is always a combustion and at the cathode, it is the oxygen that is reduced to gold. So the diagram of the fuel cell is very simple there is no liquid to the electrolyte which is in fact a polymer. It is called nation that leads the protons through. So the separation between the anode and the cathode.

Notes

Summary

1m 13s

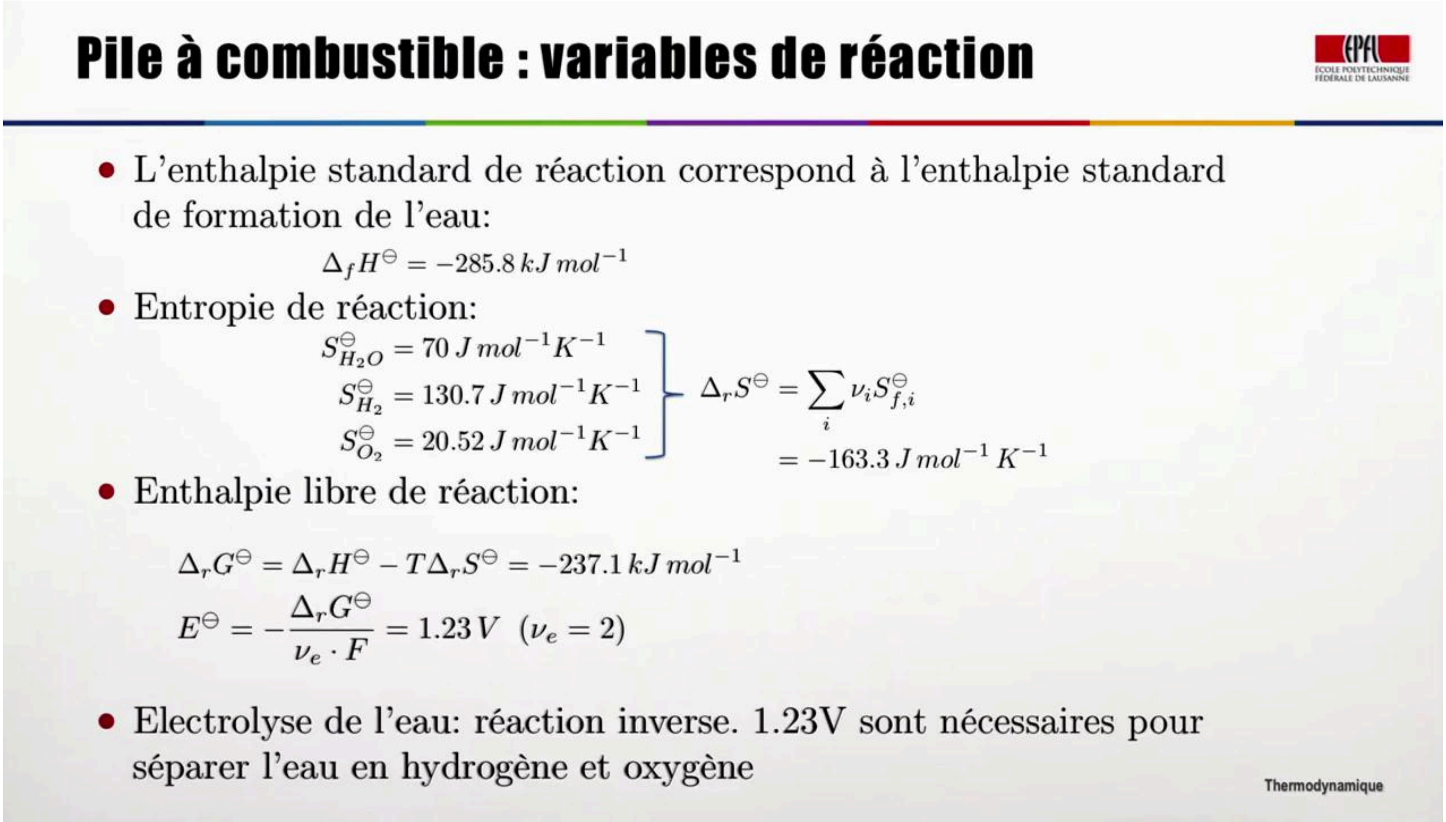


Let's see now at the thermodynamic level, what does it give ? So first we'll look at the plants, then enthalpy, reactions, reaction variables. And then we start with the standard enthalpy. So it's worth -235 for the vehicle to play well. So the heat of combustion of water is worth as much as hot water. Therefore, I can calculate the entropy of the reaction from the entropies for the individual compounds that participate in the reaction. So I have the entropy of water GN time and oxygen entropy which are known in absolute value. So I can simply do the math with the stack metric coefficients, it gives me 163.3 days per month. So the reaction is accompanied by a decrease in entropy. And that comes from the fact that the reaction consumes molecules, so there is less mess at the end than at the beginning. So we now know the entropy, the reaction. We know the enthalpy of the reaction and a little using the equation. In short, I can deduce the free enthalpy of the reaction. When the value 237 kilos, I don't tell you me and it's still a free carpet maybe converted into voltage as it was done for the case of electric batteries. So I used 237.1 which doesn't play badly, not the number of electrons, thus the metallic quotient of electrons which is two.

Notes

Summary

2m 51s

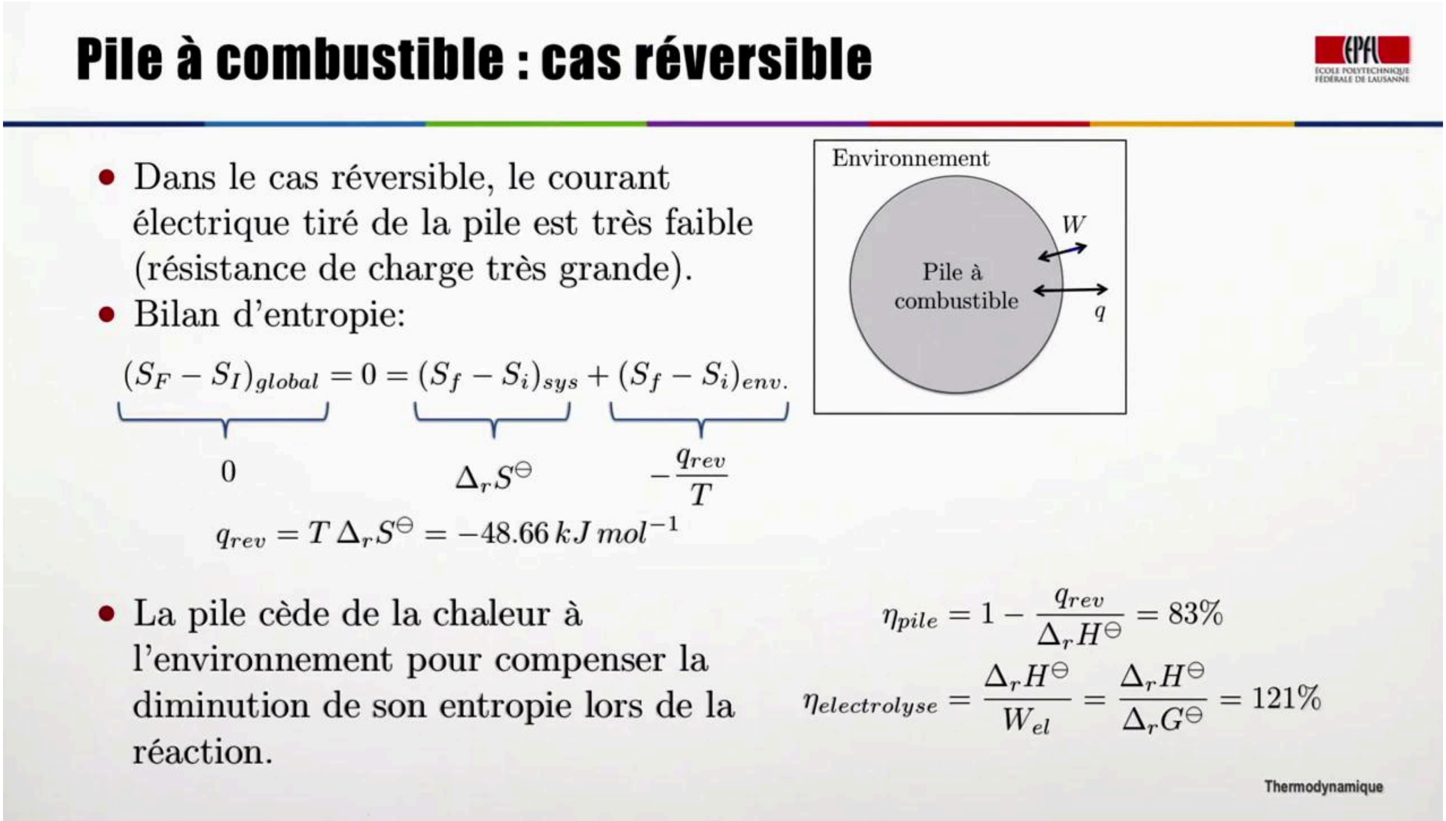


And then the total number and that gives me 1.23. So if I look at the voltage at the terminals of the fuel cell, I measure wait for an open circuit never high enough, a voltage of 23 volts, the opposite. So I can also think about doing the opposite reaction. So I want to dissociate the electrolytic water nitrogen, oxygen. So here I should apply a voltage of au -1.23. Veil to separate water into two gases, hydrogen and oxygen.

Notes

Summary

4m 44s



So let's look at the case of a reversible reaction, it gives us the maximum of work that I can get from the fuel cell operation. So the balance sheet we've already done for electric batteries and repeats, it is the same balance. We consider the global entropy of the pile which is thus surrounded by an atmosphere and the exchange of work and heat between the battery and the atmosphere. The purchase now makes a balance on this global system which is composed of two. So the environment and the fuel cell for what. Fuel, I. I know the change in its entropy, the progress of the reaction or by a mode of progress. I will therefore change its name, taken over by the amount of the reaction company. And then for the tank, it is the reversible heat which is depleted by the tank, divided by the temperature. And it is a put so and less because what counts for the system versus negative for the environment with a very elegant approach, can now remove the condition of reversibility, i.e. under reversible conditions. The change of the Ballesteros and I obtain a very simple relation that allows me to calculate the heat which is changed between the fuel cell and its environment.

Notes

Summary

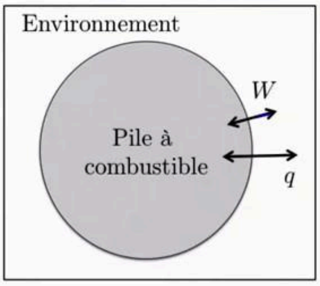
5m 22s

Pile à combustible : cas réversible

- Dans le cas réversible, le courant électrique tiré de la pile est très faible (résistance de charge très grande).
- Bilan d'entropie:

$$\underbrace{(S_F - S_I)_{global}}_{0} = 0 = \underbrace{(S_f - S_i)_{sys}}_{\Delta_r S^\ominus} + \underbrace{(S_f - S_i)_{env.}}_{-\frac{q_{rev}}{T}}$$

$$q_{rev} = T\,\Delta_r S^\ominus = -48.66\,kJ\,mol^{-1}$$



- La pile cède de la chaleur à l'environnement pour compenser la diminution de son entropie lors de la réaction.

$$\eta_{pile} = 1 - \frac{q_{rev}}{\Delta_r H^\ominus} = 83\%$$

$$\eta_{electrolyse} = \frac{\Delta_r H^\ominus}{W_{el}} = \frac{\Delta_r H^\ominus}{\Delta_r G^\ominus} = 121\%$$

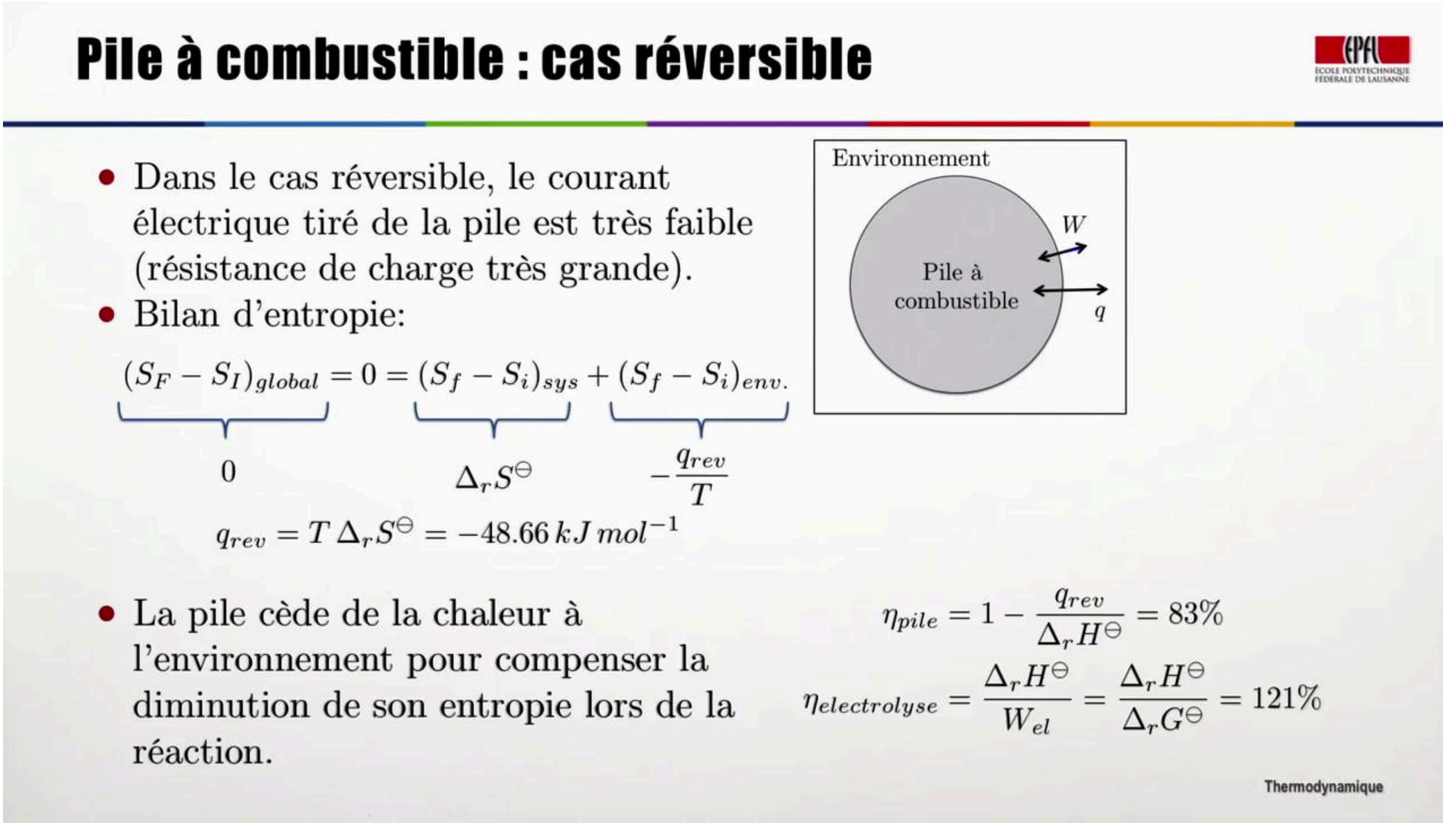
Thermodynamique

If the transformation is irreversible, then you have to put a resistance between the two terminals which is very big. So there is a very small current which passes and which maintains this relation during the reaction which is made electrochemical process that takes place in the fuel cell. So with this I get the relation between Curve and Delta RS which gives me 48 or 70 kilos. Not a bad thing. So it's a negative value. What does that mean? The system returns this heat to the environment. I can't avoid it, it's the minimum amount of heat that needs to be returned. And then, knowing the reversible heat, I can now access the efficiency of the battery as it was already done for the electric batteries. And so, if I run the fuel cell, I make therefore the combustion of hydrogen with oxygen which gives water. This I take each one the yield from the formula that it gives. And there, it is the report of the energy electrical energy that is derived from the reaction and the heat of combustion. I invested in chemical energy, This ratio is therefore the efficiency of the battery. And so by looking at the numbers for QF I obtain eighty 3 % therefore there are ten 7 % that we lose.

Notes

Summary

7m 13s

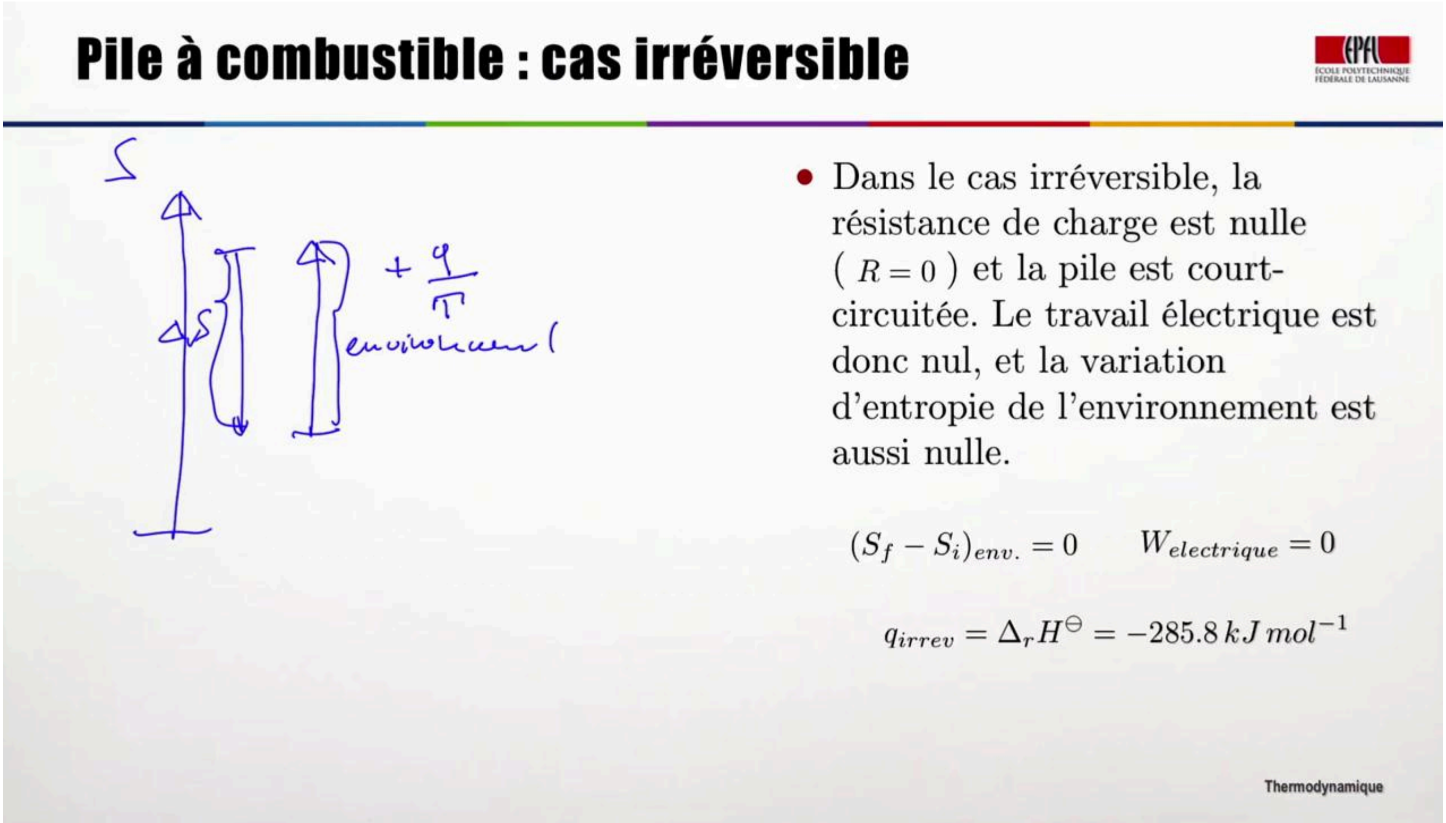


It is the reversible heat that is returned to the punk atmosphere. When I make it work The fuel cell also heats the environment, we can not prevent it. On the other hand, if I do the opposite of the reaction, so I carry out an electrolysis on the way of the electric energy and I get hydrogen and oxygen from glycolysis and water. This is different. Heat is given by the environment and used to be transformed into chemical energy. So the yield in this case is defined as the ratio to what we invest in what we want to obtain. We want to get the young state. So who has this reaction? This combustion heat from the start. And I have an electrical job for the most part. And now I see that I have a return above 100% because if I make the electricity in a reversible way, it uses the heat of the atmosphere to make the rates hinders for the most part the water and therefore the atmosphere will cool down by doing this electrolysis.

Notes

Summary

8m 55s



So if I draw this balance sheet now graphically, so I have it for the reversible case. I have. I have the. The situation is clear the entropy of the environment. Increases therefore and entropy of the system. His first arrow is the system going down. And then we have the environment. So this ass-kissing? One more. Safety. And it is the one, it is the decrease of the entropy by the chemical reaction of the system in the fuel cell. These two arrows have the same length, therefore the increase of the entropy of the environment by the fact than the heat that passes from the battery to the environment. This increase is offset by entirely by the decrease of the entropy of the system. Because there is the entropy of reaction which is negative, whereas for a reversible reaction this equilibrium is no longer present. Therefore, and we have. As we have already seen for the electric battery, we. In the extreme case, there is no electrical work that is provided? An irreversible heat will be released which corresponds to the heat of the reaction. This is 258 kilos provided by Mole.

Notes

Summary

10m 12s

So to summarize the case that we treat the case of the fuel cell. So the transformations are the transformation chemical to which the power generation key is supplied. So you have to know when you are oxidizing and you have to know the reactions and the variables of the reaction. But the thermodynamic treatment is very similar to the case of the electric battery, because finally there is a reaction that generates electricity. And these are the same principles we saw for the electric battery.

Notes

Summary

12m 02s