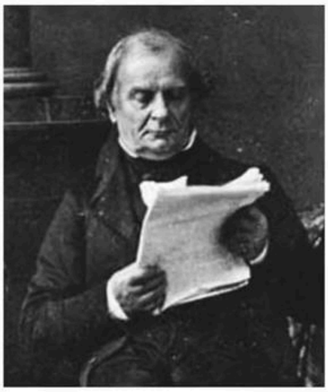
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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

Thermodynamique

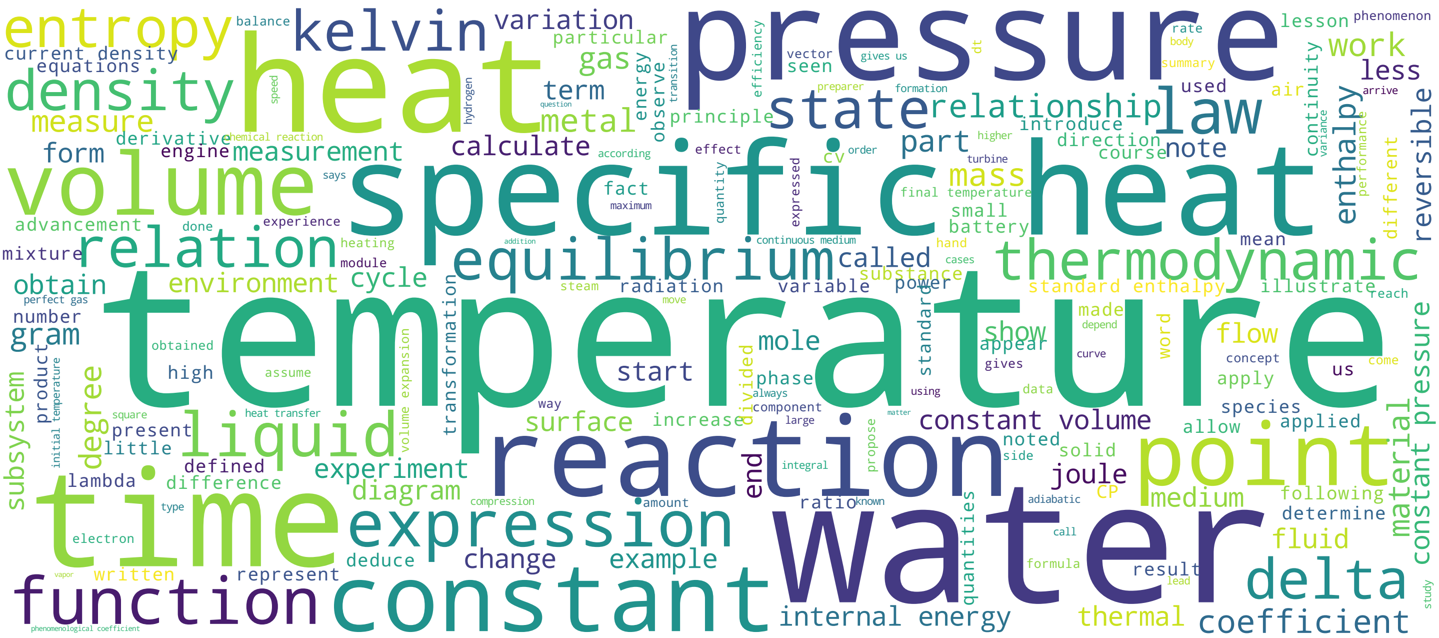
Expériences : Coefficients calorimétriques



Emile Clapeyron, 1799-1864

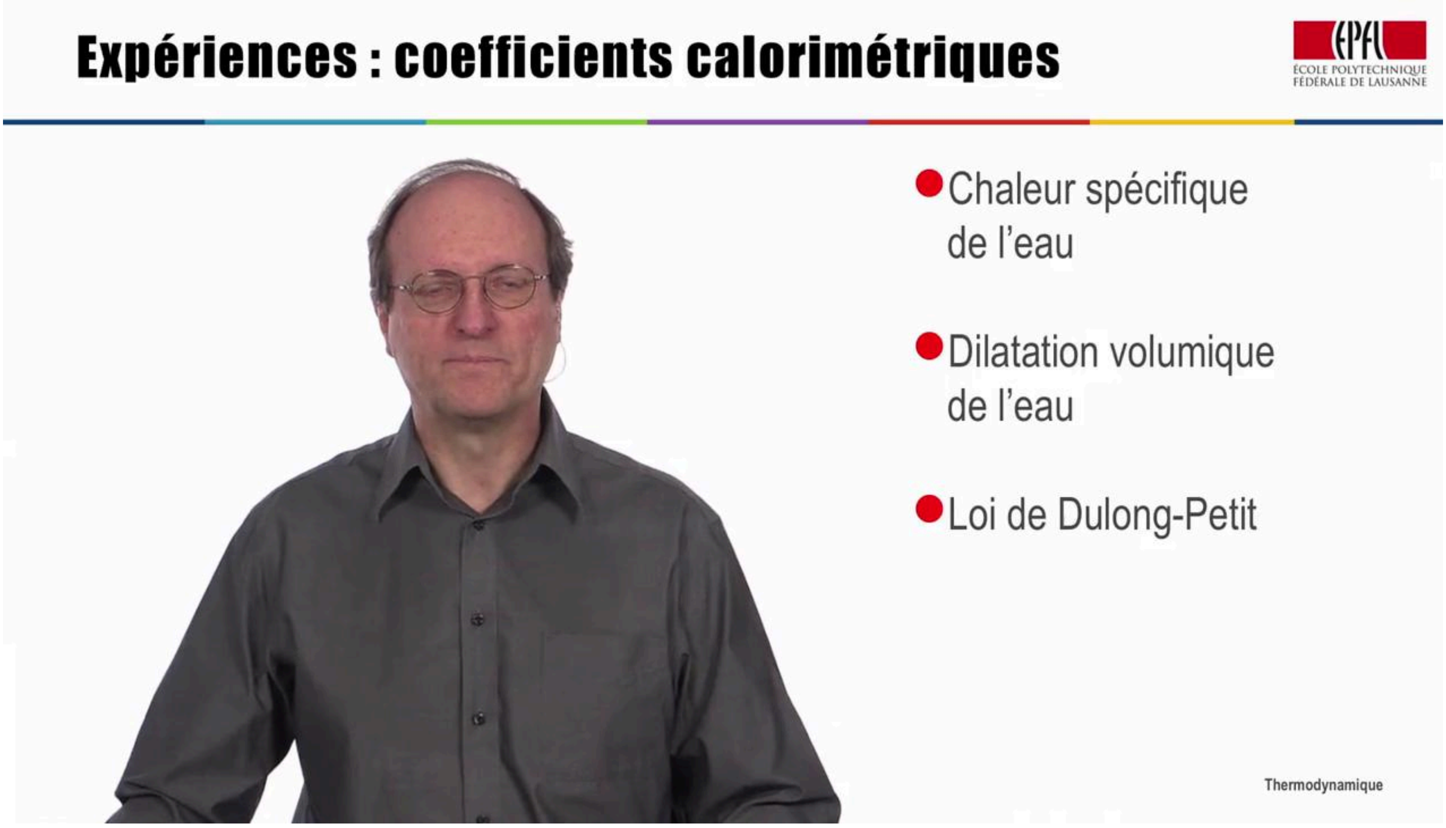
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Prof. Jean-Philippe Ansermet



Video

EPFL

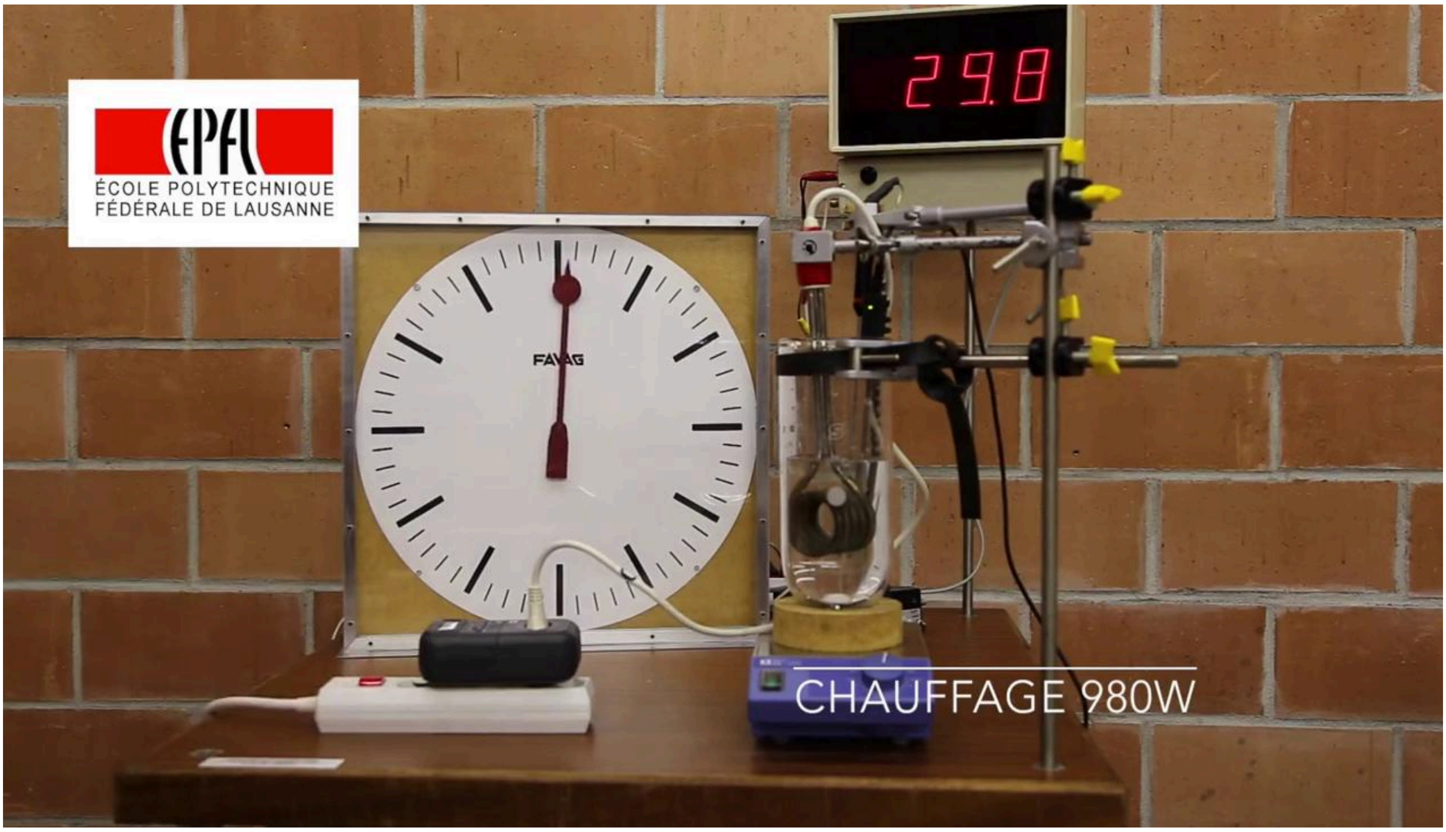


Here I am again to present you some experiences in this lesson. For the ECAM you defined the colorimetric coefficients. In particular, he talked about sensible heat. Personally, I use the term specific heat. So in this module experience, I would like to make sure that everyone has a good understanding of the concept of specific heat. Also, I will show you an approximate measure of the specific heat of water. In relation to the question of if a specific heat is measured at constant volume or constant pressure, we will look at the volume expansion of water as a function of temperature. Finally, I will mention the law of empathy. And I'll do an experiment to illustrate this law.

Notes

Summary

0m 04s



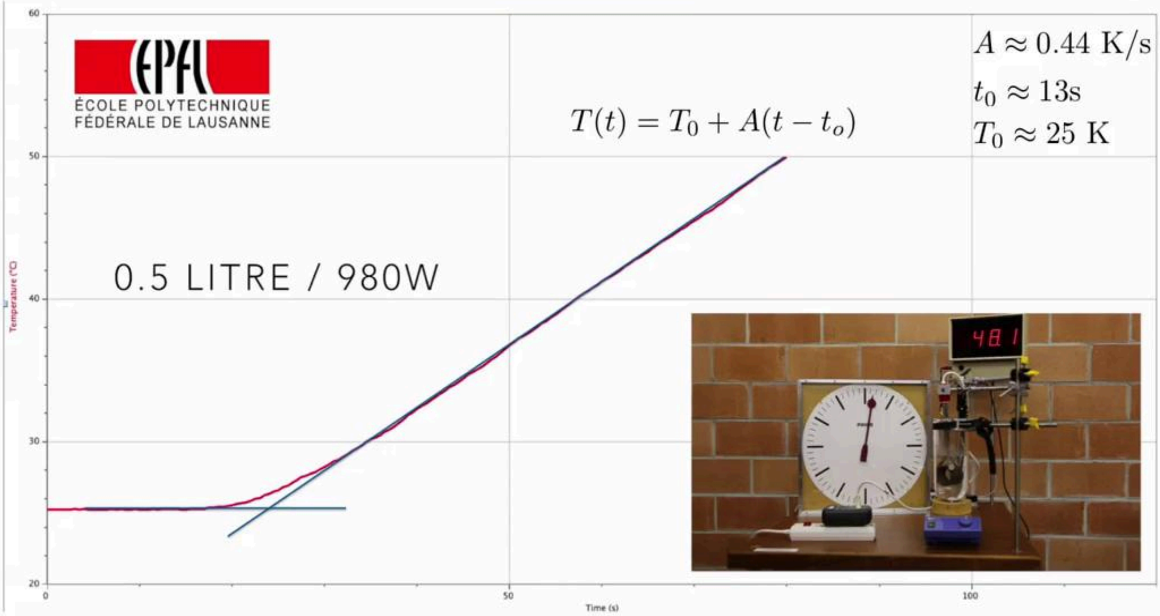
Let's start with the specific heat of water. We have here. One. Electric heating. That's about one kilowatt that will heat a given amount of water in a calorimeter and we will measure the temperature of water as a function of time at constant power. By observing the experiment. The preparer puts half a liter of water in the calorimeter. And. At a specific moment, it turns on the heating.

Notes

Summary

1m 06s

Chaleur spécifique de l'eau



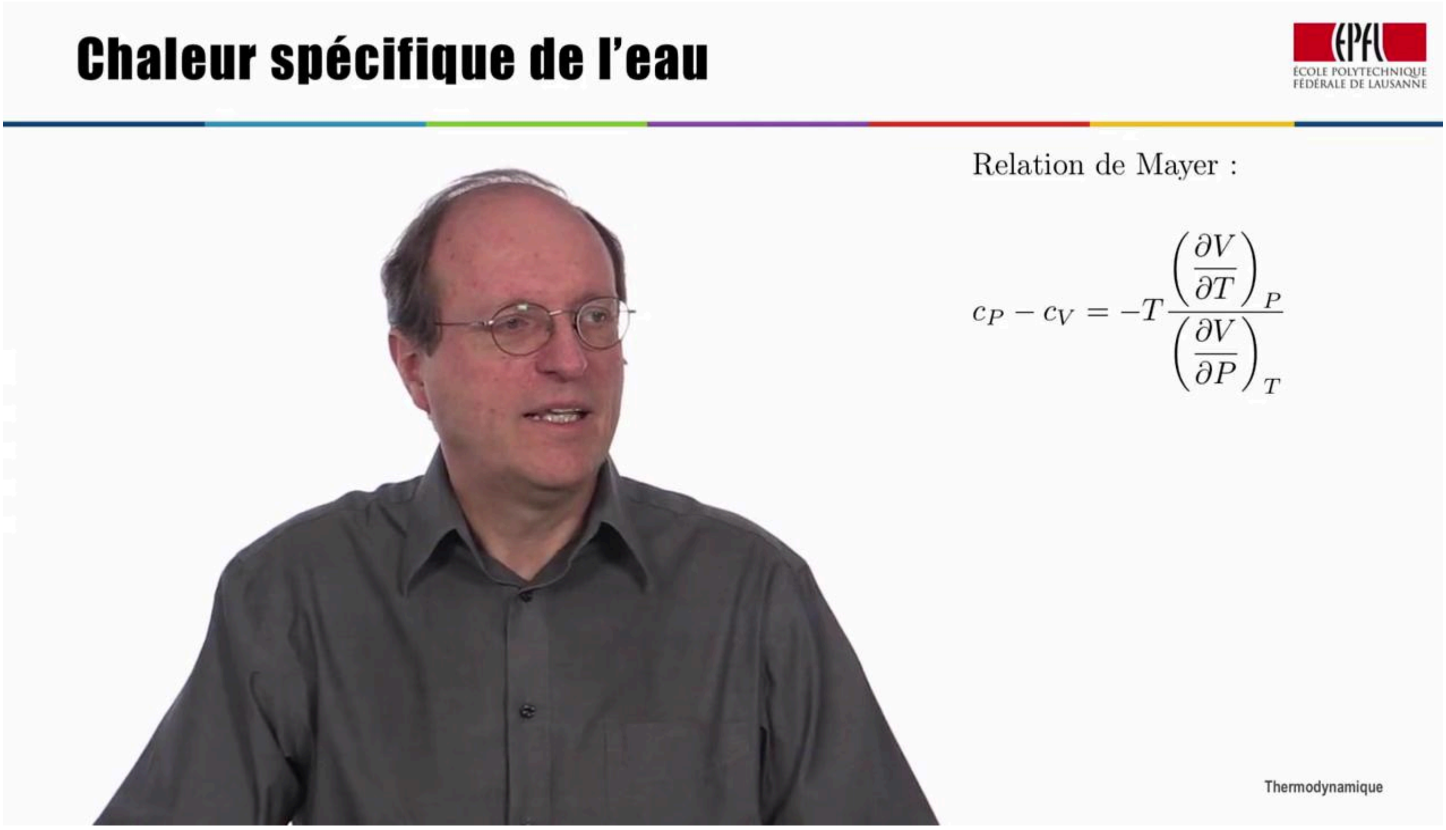
Thermodynamique

And now you see a recording? Data of temperature versus time. The heating power of 900 eighty watts. Here is the graph of the measurement thus obtained. It is now a question of to take these data and deduce the specific heat of water. So the first thing I propose is to do is to make an approximation, to suppose that we have a linear growth of the temperature. Like this, so we have a linear law in time. With the most important parameter here is the slope which is 0.44 kelvin per second.

Notes

Summary

1m 54s

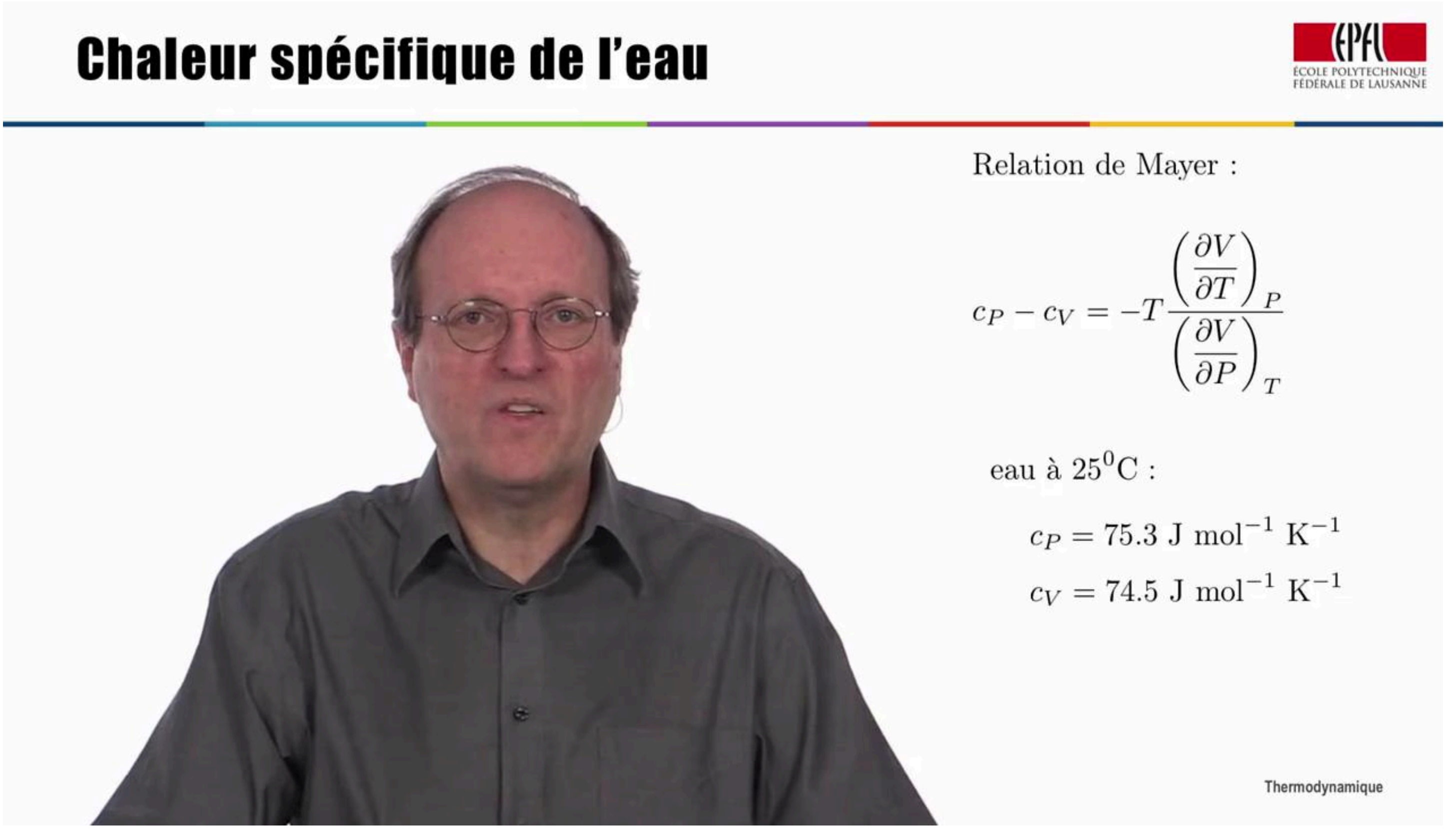


I recall here the data and now with these data there, I propose to calculate the specific heat of water. I invite you to pause and try to do the math for yourself. Then we will assume that the power electrical power is the thermal power supplied to the water. I will use a formula which is very similar to the one of ECAM or I introduce the specific heat here. I rated it CP with a star to indicate that it is a specific heat per unit of mass. And I multiply by the mass of water I have that I have noted M here. Now. From this formula, I deduce the specific heat. I give the index P because my measurement is made with a given pressure. With the numerical values, I get 4.4 joules per gram per kelvin. Then you probably already know that the specific heat of water is rather 4.18 joule per gram and per kelvin, i.e. one calorie per gram and per kelvin. We made a quick and approximate measurement is not surprising that our value is not the tabular value. Now you might ask yourself. What is, what would be the specific heat at constant volume? For the given you the formula called mother formula that reads cp and cv. In this formula, the denominator appears. The iso-compressibility. Term and in the numerator.

Notes

Summary

2m 57s

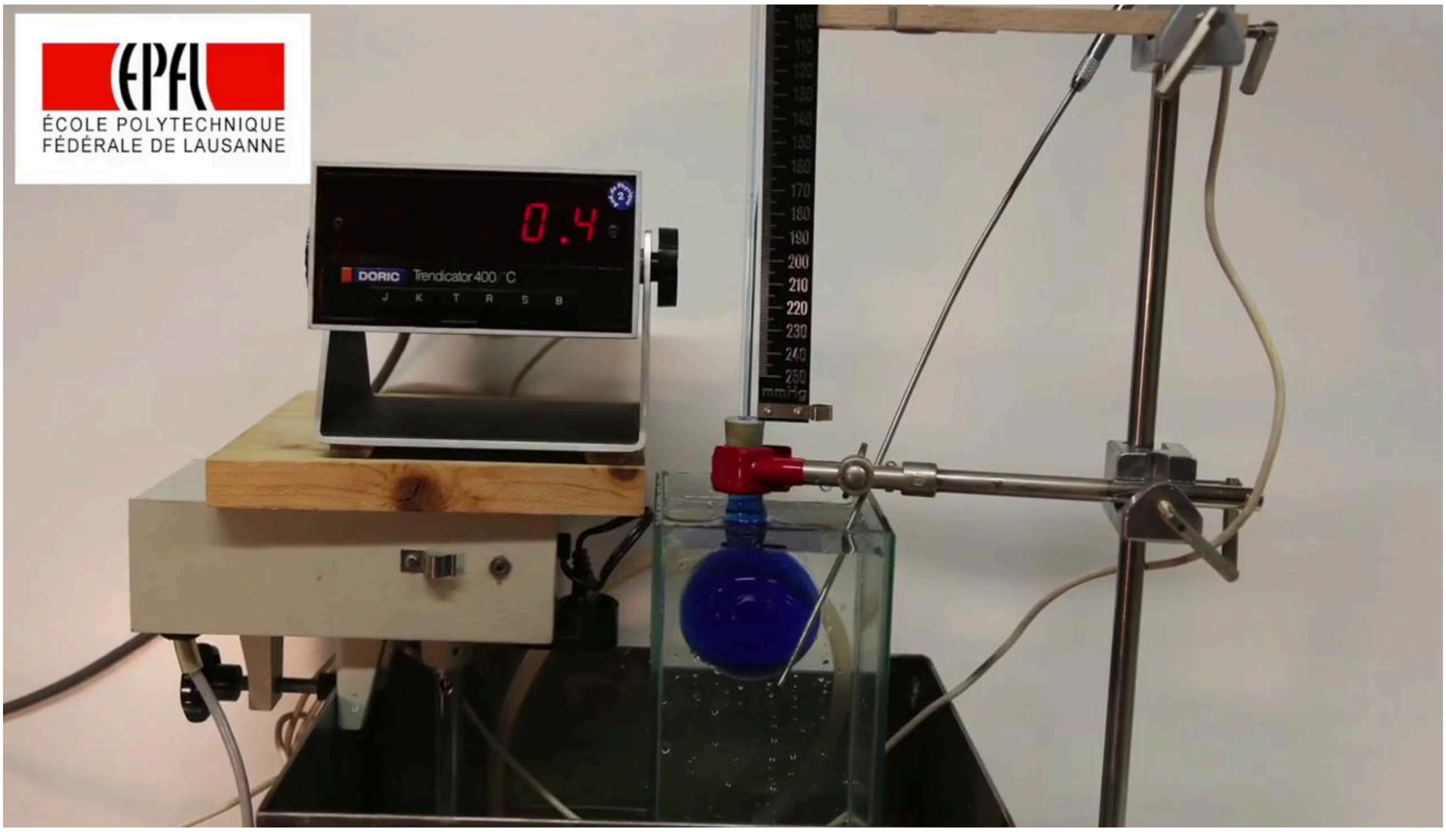


Volume expansion at constant pressure. In the next sequence, we will make a measurement that allows to calculate or measure this volume expansion here. To conclude, I would just like to point out that for water at 20 degrees, it is thick that I give here in joule per word. The loving to floor. So it was in joule per gram and per kelvin in words, in joules, in moles per kelvin. We have about seventy five joules per word. The floor, vine and cv would be about 64.

Notes

Summary

4m 53s

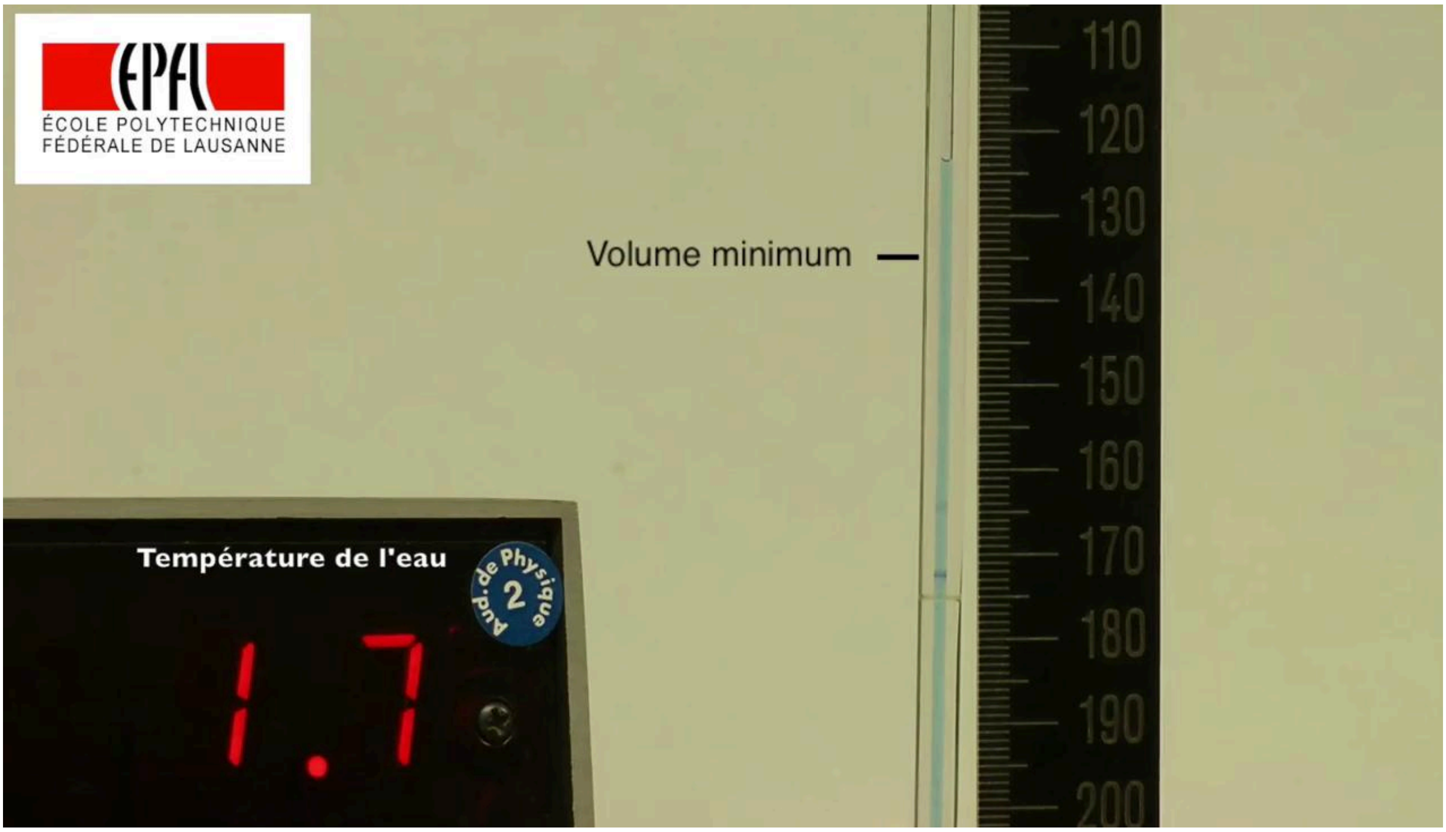


So there is a small difference. So now I propose to do a measurement of the volume of water as a function of temperature at constant pressure. It means that I want to measure this partial derivative. To do this, I have at my disposal. A balloon filled with colored water was dipped into a basin which was controlled by a the temperature and measures this temperature. The flask is closed by a capillary tube open at the end, so that the pressure is constant and we will observe the variation of the liquid level in the capillary.

Notes

Summary

5m 32s



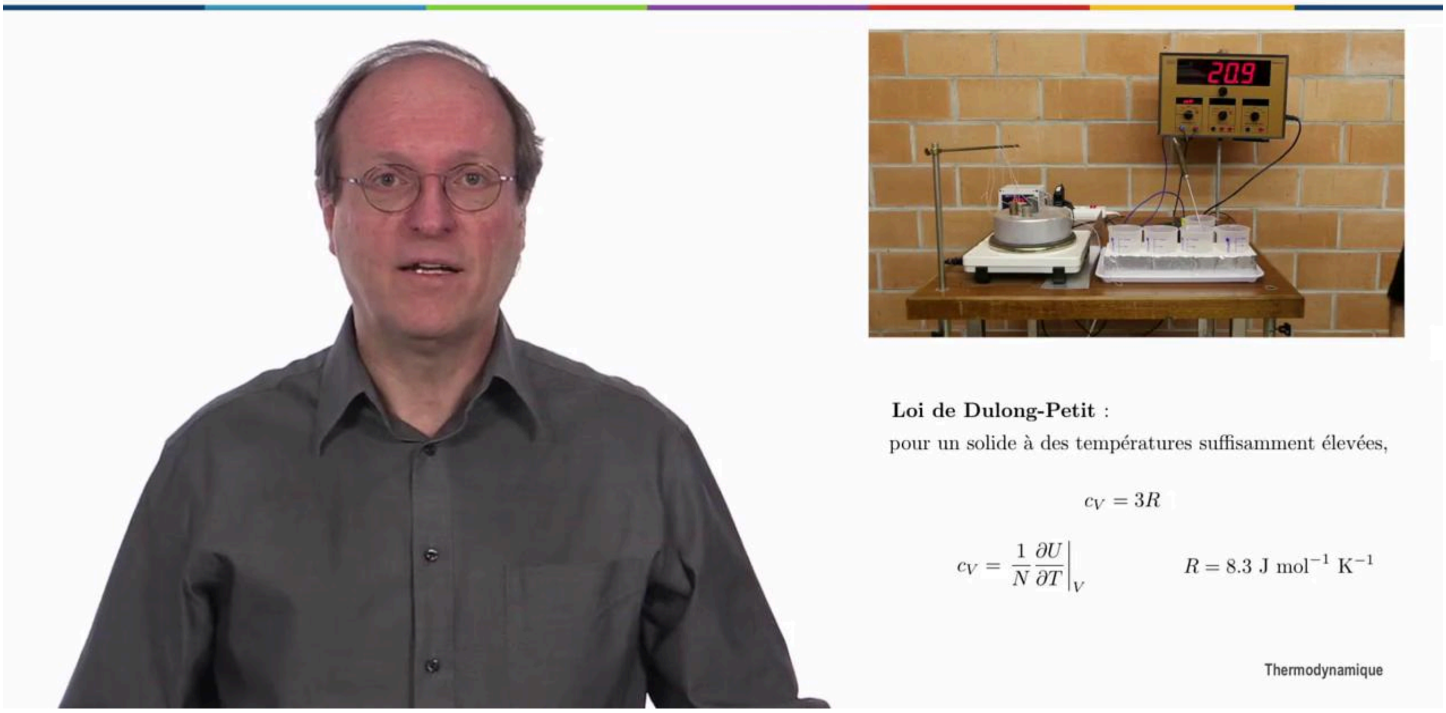
You can see here that we have an indication of the temperature. Let's get started. A. About eight. Degrees centigrade. And you can see on the picture the slightly bluish water level in the capillary. Do you have a ruler in cm next to the tube? And you see that, as one might expect, the more the liquid is cooled, the more its volume decreases. But. You'll see. There are about four degrees. Volume reaches a minimum and as the temperature continues to drop, the volume increases. This is called abnormal water behavior.

Notes

Summary

6m 17s

Loi de Dulong-Petit

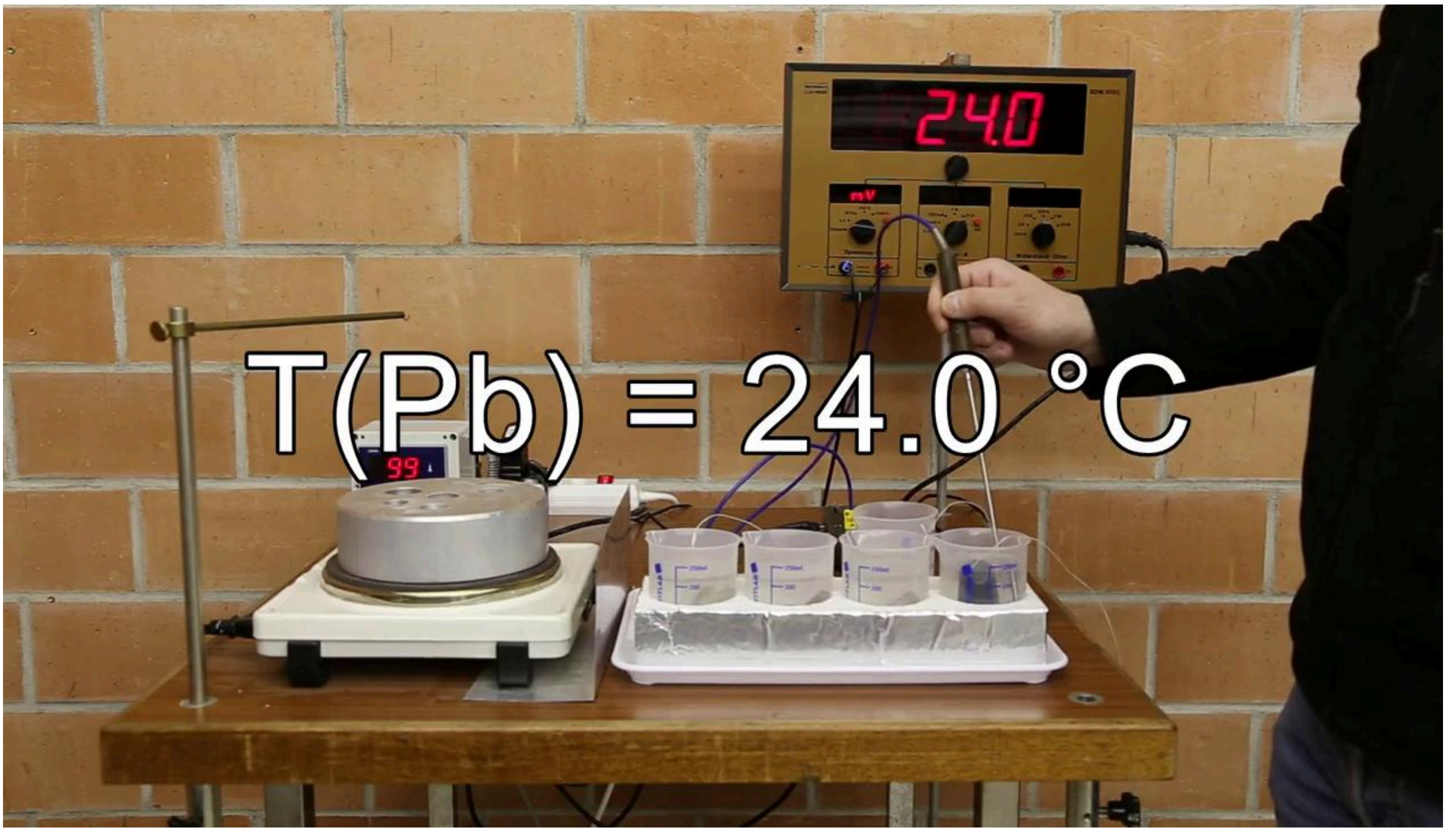


I would like to show you now an experiment on the specific heat of solids. There is a law called the law of the long small which says that the specific heat at volume constant of solids is about three R or R and the constant of perfect gases. This is therefore a molar specific heat. To illustrate this law. We will do an experiment where we heats up to about 100 degrees, four different metals and then we dive in. We will have exactly two moles of each of these metals and we will immerse these metals in water at 20 degrees.

Notes

Summary

7m 19s

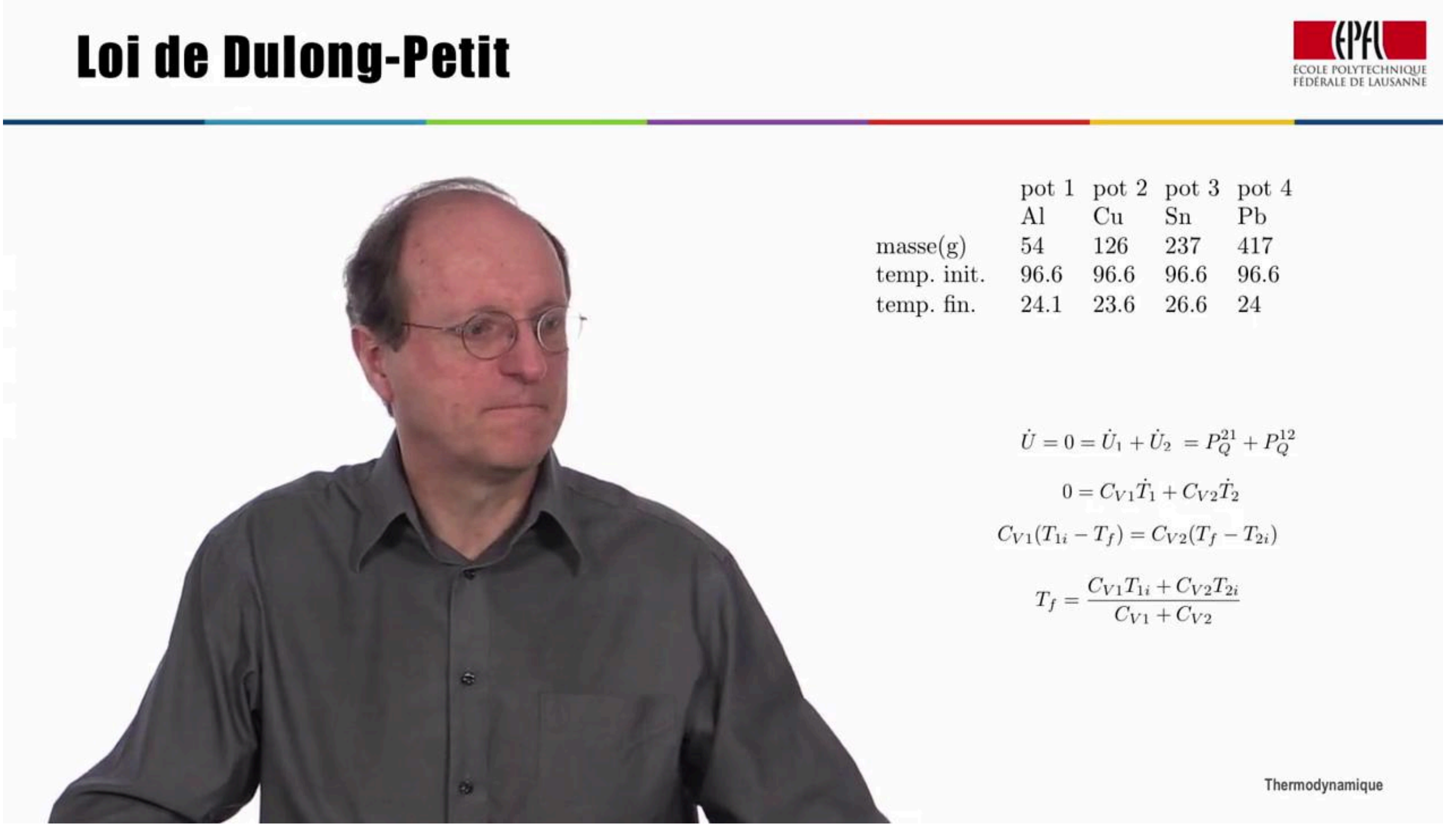


And we will observe for each metal the temperature increase of the water. Let's look at the measurement. The preparer puts 200 milliliters of water, at about 20 degrees in each of the four small pots you see on the front of the table. On the left, we have a metal block in which our samples are heated. We have lead. Aluminum. Copper. And the last head of state. We note that the temperature of each metal was about six degrees. We wait a moment. We brew a bit. We have, we let the system reach each system, reach an equilibrium. The water initially was about 20.3 degrees Celsius. And now the preparer tries to measure the temperature of the water in each pot.

Notes

Summary

8m 08s

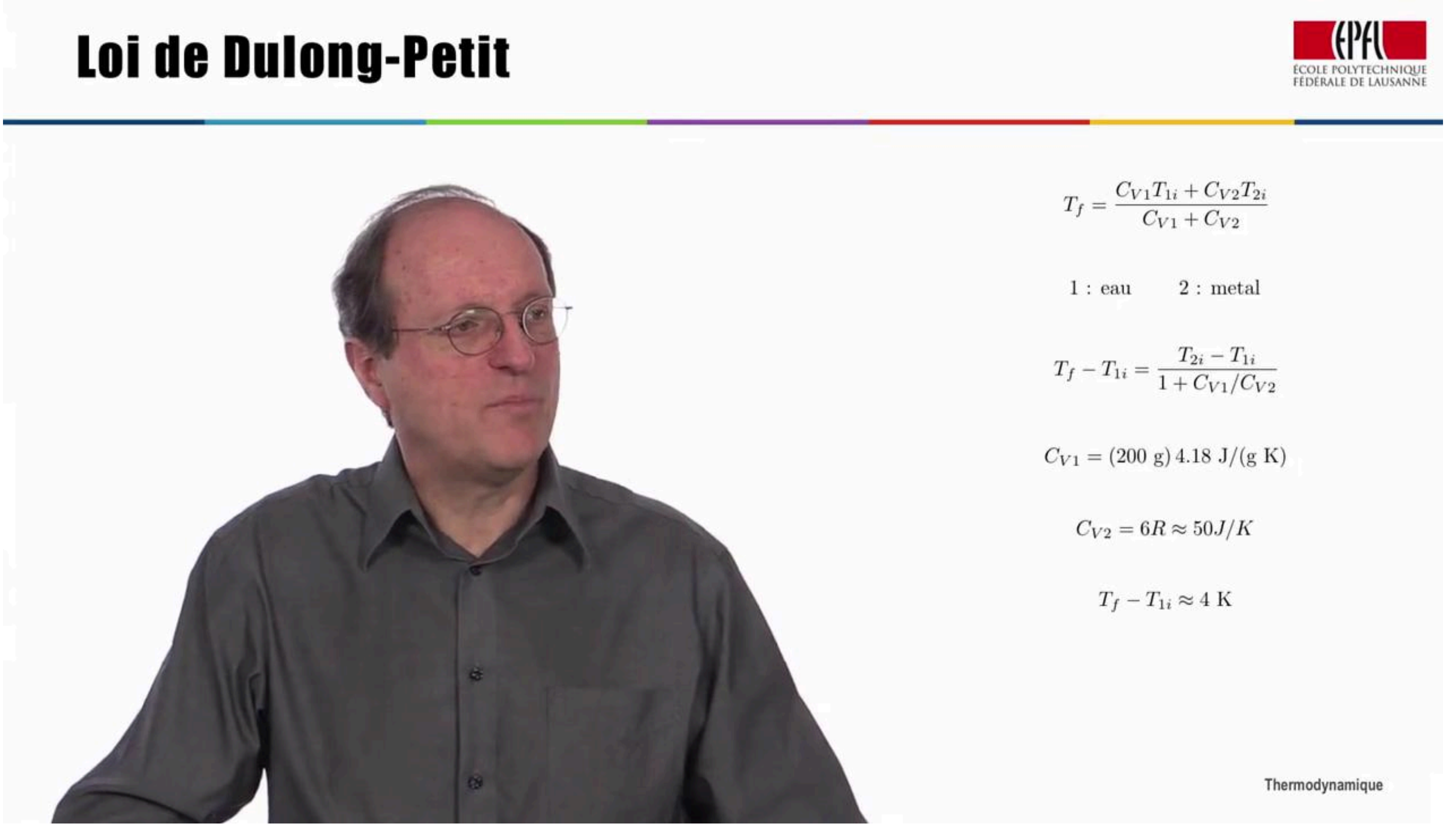


Here is a summary of the temperatures obtained. The final temperature of the water for the port, pots containing aluminum, copper, tin, plan. You will note in passing that the masses we had two moles of each, but in mass we go from 54 grams to 417 grams. So we have samples from the mass point of view that are very different. However, the warm-ups are more or less the same. Now, how do we analyze this experience? Well, we'll make the assumption. That each pot is a system composed of of water and the piece of metal and that this system is isolated. So the internal energy does not change. Each subsystem has an internal energy which changes because there is a thermal process. So I write that I have a thermal power of two of subsystem two sub-system one and from this system a sub-system two. Now I apply the chicken formulas as to express the PQ power in each case and I introduce specific heats for subsystem one for subsystem two. I integrate this equation in time. I introduce the initial temperature of the subsystem. One. The final temperature, so the equilibrium temperature of the water plus the metal is the initial temperature of the subsystem of this network for the final temperature. This is what I get. Just do a little algebra.

Notes

Summary

9m 29s

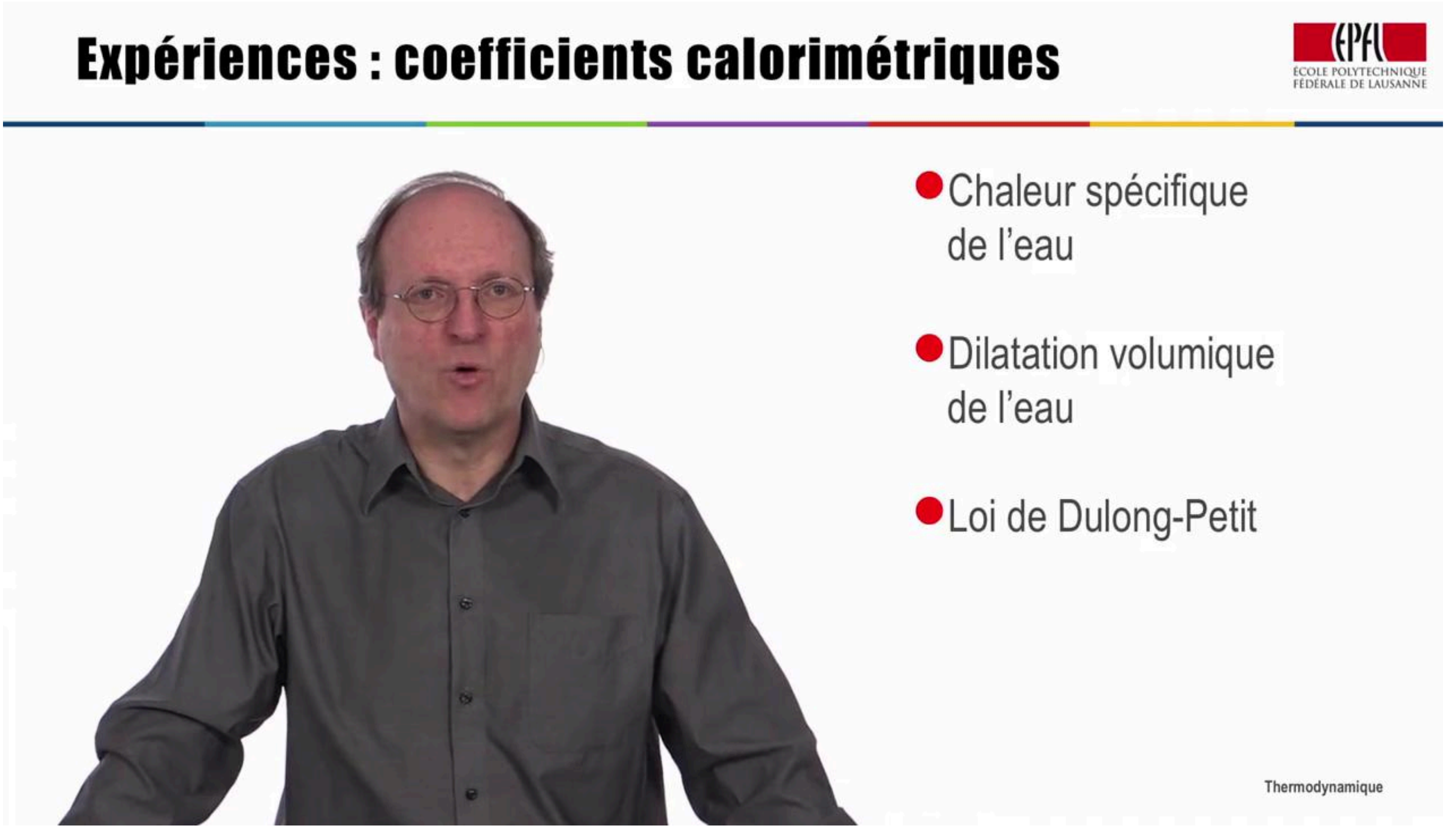


From there, I will calculate the heating of the water. I will agree that. Sub-system one is water and the sub-system. Two is metal. So I will calculate the final temperature minus the initial temperature of the water. Do a little algebra and you come up with the following formula. For this increase in water temperature. The specific heat of water is known. That's 4.18 joules per gram per kelvin and we had 200 grams of water. For the specific heat of the metal. I apply the law of the long small. Since I have two calves, that's 6 hours. And the numerical application gives me a temperature increase of four Kelvin. So the preparers did a pretty good job.

Notes

Summary

11m 19s



In summary, to illustrate the concepts introduced in this lesson we made a measurement of the specific heat, of the water simply. We looked at the abnormal behavior the volume expansion of water around four kelvins and I illustrated the law of the small white which says that for a solid, the specific heat is about three r per mole.

Notes

Summary

12m 12s