

Figure 1.5 – Comparison between the mechanical work obtained from two identical thermal motors functioning according to the Carnot cycle for two different exhaust temperatures ( $T_0''$  in case A and  $T_0'$  in case B).

The point of view seen above and resumed in equation 2) seems favorable to the presence of high values of entropy tout court: to avoid erroneous generalizations it needs remember that Gibbs says that the maximum energetic gain in thermal transformations, that is to obtain the maximum “free energy”  $G$ , is to exploit the total energy (enthalpy)  $H$  of the active mass minimizing the entropy at discharge. In fact, the Gibbs equation states that

$$G = H - T \cdot \Delta S$$

where  $H$  represents the enthalpy of the mass transformed.

We stress that it is necessary to compare two cases with identical initial temperature (as in Figure 4.1) and to consider that it is the factor  $\Delta T$  which determines the efficiency of the transformation<sup>5</sup>.

Sea water contains an enormous amount of thermal energy, but at a temperature  $T$  (of the source) very near to  $T_0$  (that of the coolant): in other words rendering unusable the heat it contains; we can state that sea water contains a “large” amount of thermal energy, but no practical possibility of making a thermal motor work (the thermal difference available is “practically nil”).

Exactly for this reason a boiler which burns a combustible fossil material capable of achieving “high” temperatures enabling it to provide water at  $90\text{ }^\circ\text{C}$ , is to be considered the perpetrator of a grave “thermodynamic crime”. That combustible could be used with more results, for example, in a cogeneration plant where water at low temperature is a “waste” product.

<sup>5</sup> Sources at high temperature are necessary to produce thermodynamic cycles with acceptable results. Our car, be it Otto or Diesel, develops a temperature of around  $1500\text{ }^\circ\text{C}$  in the combustion chamber and give us a mechanical efficiency at the wheels of about 35% (approx, 30% remains “internal energy” and is expelled to the exhaust. The coolant temperature is that of the atmosphere; the remainder is transformed into heat by thermal loss and passive resistances and is dispersed mainly by the radiator).



## 1.4 ENTROPY AND LIFE

Livio Gratton (Italian cosmologist from Trieste, died in 1991 and considered the father of Italian Astrophysics) observed that the phenomenon “life” contains something singular which does not fit in with the mechanism described up to this point. The appearance of life, in an electromagnetically structured universe, constitutes a singular moment which cannot be explained technically.

In fact, *an organism is alive when, within itself, it produces transformations of negative entropy (that is with  $\Delta S < 0$ ) which contradicts the second principle.*

Let us observe a plant seed: if it is alive, in conditions expected in nature, it germinates *spontaneously* and grows, capturing carbon from the atmosphere, giving body to the plant, and releasing oxygen through chlorophyll synthesis.

A small wheat seedling, recently sprouted amongst the snow, germinates and grows, warming itself up at the expense of the ground (who has not observed the molten snow round the seedling? The seedlings, under a thin blanket of snow, poke out and are clearly visible, green seedlings on a white blanket, in the middle of a dark patch of earth, free from that which surrounds them?!).

Naturally, if we were to also consider the interaction of the plant with the quanta of solar energy and the surrounding minerals, we would find that the sum of transformations has generated positive entropy (the affirmation that the entropy of the universe tends to increase without limits is correct).

A living animal organism, should it be injured, is capable of healing itself: the *vis vitalis*, as our ancestors called it, produces such an effect, while a dead animal organism remains injured and decomposes with the passing of time (increase of disorder).

One could consider the possibility of turning to entropy to define the state of life or death about which we periodically debate, even in practical cases (Terry Schiavo, Eluana Englaro...): if the organism produces negative entropy it is alive, in the opposite case it is not...

One could also suggest a crude experimental procedure, of a slightly Hitlerian nature..., which would settle the matter once and for all, consisting of injuring an organism that has a dubious state of life *to verify its reactions in one entropic direction or the other...*

The *vis vitalis* departs even if all the mechanical organs would be perfectly functional: we can think of the so called cardiac arrest (a phrase that could be a savior for the corner of the art of medicine). One could certainly object that the arrest is the cause, while the departure of the *vis vitalis* is the effect: who knows!? The only certainty is that with death an irreversible process starts, with the production of positive entropy... and we fall back into line with the second principle!

In conclusion, it can be said that the property of entropy is that of an increase in every transformation that can be performed practically (like saying, in every irreversible transformation), ***except in the case of living organisms.***

How to produce heating of the plant at the expense of the surrounding masses and to increase the order of the molecules to the point of “forcing” the carbon, taken from the most formless state in existence (that of gaseous  $CO_2$ ), to take on the shape of a trunk giving rise to transformations of decreasing entropy?

Also an ordinary refrigerator can produce a local decrease of entropy, expending some energy; in the following figure we represent the energy transformations occurring in it: at the end of the transformation we have the temperatures marked with an asterisk, after the energy  $Q^*$  leaves the cool body to join the warmest body with the energy  $Q_3$  that is needed for the refrigerator to run<sup>6</sup>.

---

<sup>6</sup> The ratio  $(Q_2 + Q^* + Q_3)/Q_3$  is the widely known COP (Coefficient Of Performance) of the heat pumps

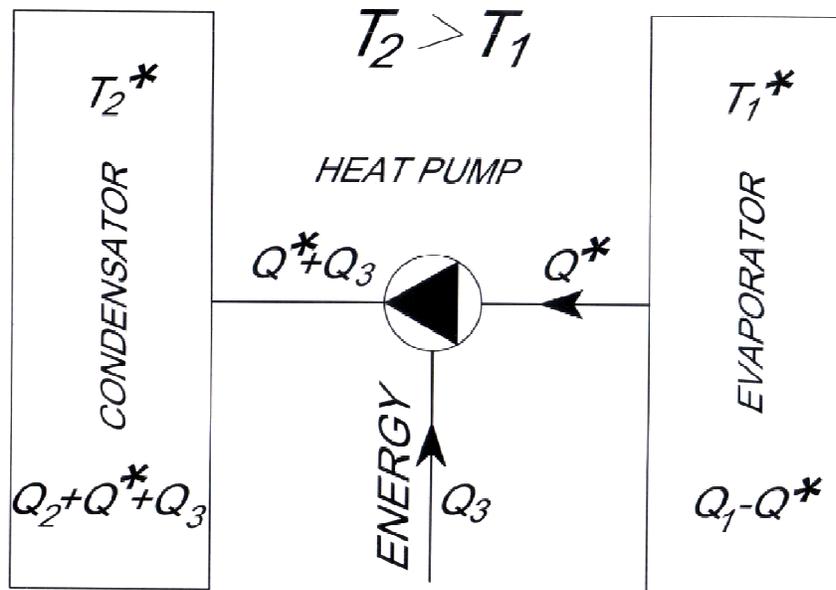


Figure 1.6 – Heat pumping in a refrigerator

In this sketch the external energy  $Q_3$  appears essential and the system is open: the energy  $Q^*$  increase its entropy, gaining the temperature  $T_2^*$  entering the condenser.

Restarting the numerical example of the Clausius calorimeter we reconfirm  $Q^*=50 J$  as the heat exchanged; in this condition it is easy to verify that the water temperature decreases by  $10 K$  while the copper increases by  $90 K$ .

Assuming  $COP=3$  we have

$$\begin{array}{ll} \text{final temperature of water} & T_1^* = 290 \quad K \\ \text{and for the copper} & T_2^* = 490 + 90 : 3 = 520 \quad K, \end{array}$$

proceeding as above it follows that  
for the copper:

$$\Delta S_{Cu} = C_{Cu} \ln \frac{520}{400} = 0,5 \cdot 0,04 = 0,02 \quad \frac{J}{K}$$

for the water

$$\Delta S_W = C_W \ln \frac{290}{300} = 5 \cdot (-0,034) = -0,170 \quad \frac{J}{K}$$

Therefore the quantity of transformed heat,  $Q^*$ , is subject to the variation

$$\Delta S = \Delta S_{Cu} + \Delta S_W = 0,02 - (-0,170) = -0,15 < 0 \quad \frac{J}{K} :$$

thanks to the contribution of the external energy  $Q_3$  the exchanged heat decreases its entropy!

Now we will see in what way nature does the heat pumping.



## Part 2 (of 4): Boltzmann's Distribution

### 2.1 THE BOLTZMANN'S DISTRIBUTION

We will reply to the question after having examined the second pillar on which we base this paper: *Boltzmann's Distribution* (Ludwig Boltzmann: Austria, 1844-1906).

As can also be seen in excellent web pages, the disorganized vibrational velocity of the molecules of a gas (but also those of liquids and solids), at a given temperature, take on values which are continuously and randomly variable *following a particular distribution* represented graphically in *Figure 2.1*.

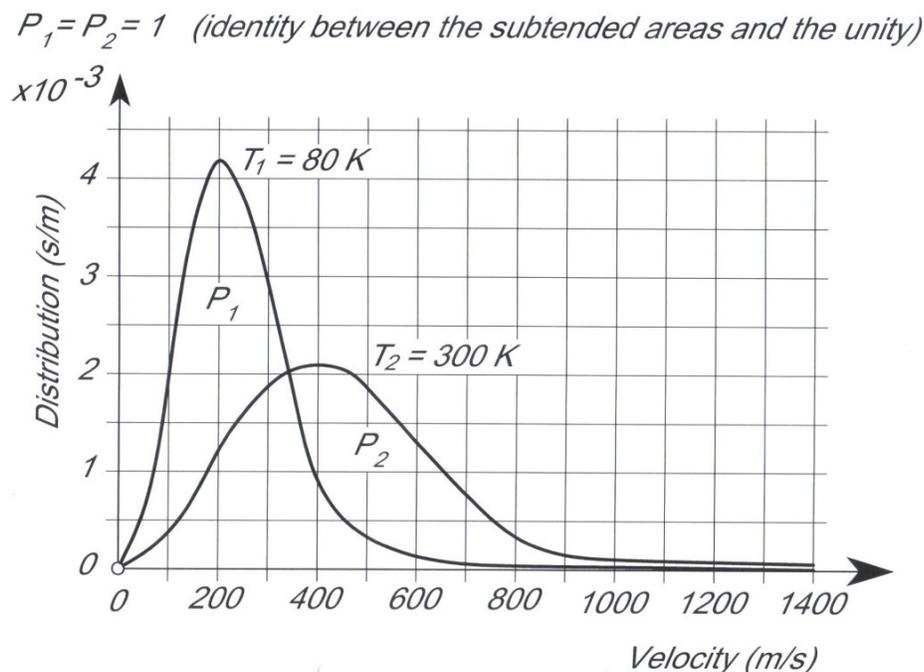


Figure 2.1 – Probability distribution of the velocity of molecules of a gas as a function of the velocity itself, according to Boltzmann's Statistic

***It is thanks to this distribution, discovered by Boltzmann, that living nature, vegetable and animal, can perform local transformations with decreasing entropy:*** the great masters have thought up theoretical experiments, based on devices capable of selecting molecules of colder gas having higher velocities than what is thought to be the average velocity of the molecules of the warmer gas (Maxwell: *the demon*, Polvani: *the choosing porter*, Amerio: *the selecting valve*) to allow them to pass from a lower temperature environment to another, adjacent environment with higher temperature; in this way obtaining a transformation which locally invalidates the second principle of thermodynamics.

In *Figure 2.2* it is possible to see that at every average velocity (considered) of the “warm” molecules one can find a corresponding branch of the “cold” curve related to those particles that, should they pass to the warmer side, could cause an increase in that average velocity, and therefore of the temperature.

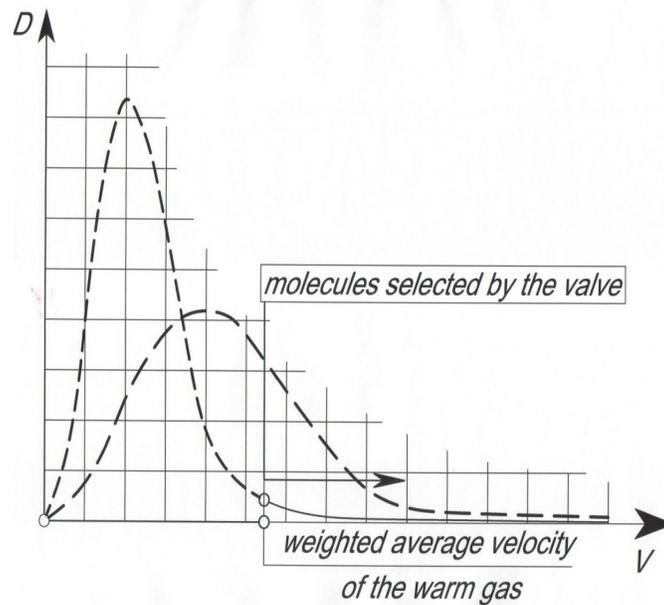


Figure 2.2 –The Maxwell demon allows the passage from the colder to the warmer environment only of the molecules which have a velocity higher than the weighted average velocity of the warmer molecules.

It is necessary to perform a sorting of the molecules, one by one, with mechanical means not available to man, while the experimental observations, of the type reported above, would suggest that nature is capable of it, operating at a molecular level in the realm of living organisms.

In Figure 2.3 is represented the device which allows the “theoretical experiment”, in the form proposed by Prof. Amerio of the Polytechnic of Milano (1955). Maxwell had proposed a “demon” as selector of the molecules (1867): the selection device has been the object of particular attention on the part of Szilard (1929) and later Bennet (1981), with the scope of correctly counting the variation of entropy in the test universe and calculate the required energy for the selection.

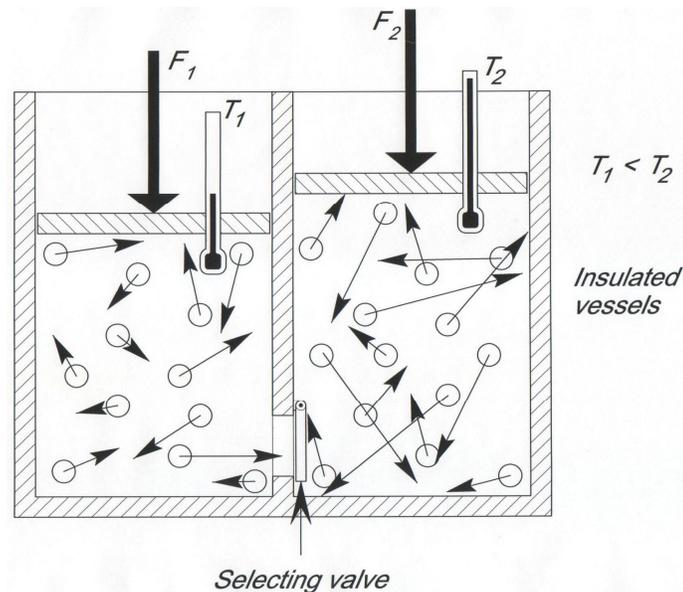


Figure 2.3 – The selective valve allows the passage from the colder to the warmer environment only of the molecules which have a velocity higher than the weighted average velocity of the warmer molecules as shown in Fig. 2.2.