Time and entropy: the two sides of the same medal in ideal open systems

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Abstract: The second thermodynamic law implies a continuous increase of entropy with time and a formal relation of both characteristics. Based on observations in ideal biophysical diffusion processes the letter presents a model that substantiates an exponential relationship between time and entropy.

***Keywords**: entropy, time*

1. Introduction

The arrow of time and the second thermodynamic law are connected in some mystical physical relation.[1] Although we admit that entropy may be reversed in isolated systems, e.g. in the living organism, it is clear that in cosmology or open systems, in general, it moves to one direction as time does.[2] One might therefore postulate a clear correlation or relation between time and entropy and the subsequent letter presents a theoretical approach to the problem.

2. Theoretical

We start with thought experiment of concerning particle diffusion according the Fick´s law in liquid, for illustration just only in one direction. The velocity V of diffusion at X_0 along the x-direction is given by the general equation $V_x = \Delta x \div \Delta t$.[3] During the time interval Δt 50% of the molecules of a volume Δvol pass the transverse section area A towards the x-direction and vice versa. With regard to velocity we only concentrate on the x-direction. We can admit that $\Delta Vol = A \times \Delta x$ which is equivalent to

$$\Delta Vol = A \times V_x \times \Delta t \tag{1}$$

With regard to t_1 and t_2 ($\Delta t_1 = t_1 - t_0$ or $\Delta t_2 = t_2 - t_0$, respectively) for $t_0 = 0$ we can define the corresponding volumes of fluid filled with the diffusing particles at times t_1 and t_2.

$$Vol_1 = A \times V_x \times t_1 \tag{2}$$

$$Vol_2 = A \times V_x \times t_2 \tag{3}$$

Note that $Vol_2 > Vol_1$. We now introduce the entropy characteristic using the Boltzmann equation of entropy including the initial entropy S_0 at $t = t_0$ (k = Boltzmann constant) and the initial volume $V_{\min}$, which represents the minimum volume of the pure (undiluted) particles that will diffuse[4], which is given by the equation

$$S = S_o + k * \ln \frac{Vol_2 + V_{\min}}{Vol_1 + V_{\min}} \tag{4}$$

$V_{\min}$ is the constant minimum volume of the diffusing particles. Now we replace the volumes filled by the diffusion particles into the Boltzmann equation and get for the two states at times t_2 and t_1.

$$S = S_o + k * \ln\left(A * V_x * t_2\right) + V_{\min} / \left(\left(A * V_x * t_1\right) + V_{\min}\right) \tag{5}$$

As $V_{\min}$ is constant and t_1 is set to 0, i. e we focus on the difference between time intervals t_1 and t_2, we can re-arrange the equation

$$\ln \frac{(A * V_x * t_2) + V_{\min}}{V_{\min}} = S - S_o = \Delta S / k \tag{6}$$

As the product of the transverse section and velocity $A * V_x$ is constant (K), we get

$$\ln\left(K * t_2 + V_{\min}\right) / V_{\min} = \Delta S / k \tag{7}$$

which can be re-arranged and leads to

$$K * t_2 = V_{\min} * e^{\Delta S / k} - V_{\min} \tag{8}$$

which is equivalent to

$$t_2 = \frac{V_{\min}}{K} * e^{\Delta S / k} - \frac{V_{\min}}{K} \tag{9}$$

i.e.

$$t_2 = \frac{V_{\min}}{K} * (e^{\frac{\Delta S}{k}} - 1) \tag{10}$$

Now we generalize the relation between entropy and get the final equation

$$t = \frac{V_{\min}}{K} * (e^{\frac{\Delta S}{k}} - 1) \tag{11}$$

If $\Delta S = 0$ time would become 0 $\left(e_0 = 1\right)$, which is quite reasonable. There is a beginning of time. On the other hand time increases exponentially according to the increase of entropy. Time is not constant but increases and gets "faster" with increasing entropy. Obviously, in cosmological terms, one may speculated that the end of the universe is characterized by acceleration of time. Obviously, we living on a stable "island of time" form moment, but this will change.

3. Conclusion

Time and entropy in open ideal systems – diffusion may be considered to correspond to such a system – are closely related and time will increase with increasing entropy.

References

1 Maccone L, Physical Review Letters **103** 0804011-4 (2009).

2 Lemons DS, “A students's guide to entropy,”Cambridge University Press. Cambridge (UK) (2013).

3 Dörr F, "*Methoden zur Untersuchung struktureller und funktioneller Eigenschaften einzelner Biomoleküle und ganzer biologischer Systeme – Äußere Struktur,"*, Methoden zur Untersuchung struktureller und funktioneller Eigenschaften einzelner Biomoleküle und ganzer biologischer Systeme – Äußere Struktur (1982).

4 Meschede D, “*Gerthsen Physik (24.Aufl.) – Kap. 6 – Wärme,*” Springer Verlag Heidelberg, 252-308 (2010).