CHEMICAL POTENTIAL – A QUANTITY IN SEARCH OF RECOGNITION

What is Light? Light is a Substance, Too!

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To oppose the contemporary decline of scientific education, many people have advocated better integration of the basic disciplines. We propose to address the border zone between chemistry and physics teaching. The general idea is to identify and exploit some general structural analogies, without giving up the essential specificity of the disciplines. The main feature of our proposal lies in the generalization of the concepts of substance and reaction[1].

For many years a group of researchers from many countries have united around the pioneering work done at the Institute for the Didactic of Physics of the University of Karlsruhe[2], and at the Institute for Physical Chemistry of the University of Hamburg[3]. This approach promotes teaching that pays particular attention to a class of extensive physical quantities that are easily "balanced" during natural processes. Examples include entropy, electric charge, and the amount of matter, and their corresponding intensive quantities including temperature, electric potential, and chemical potential[4]. In this picture, the paradigm of "substance and reaction" acquires more generality and capability to describe phenomena not normally thought of as reactions. We'll show that many processes of the physical system light can be easily interpreted as reactions.

The first teaching difficulty is the widespread opinion that takes the "physicality" away from light, the so-called immaterial nature of light. The idea originated when both the mass and the amount of matter of light were not well established scientific facts. Together with the ambiguous pair "energy & matter", light is frequently described as pure energy in books and articles of the big market of science popularization.

The correct way to answer the legitimate question "What is light?" is the unimaginative answer of the physicist: light *is* a physical system. Like any other physical system light *has* energy, light *has* momentum and angular momentum, light *has* entropy. Would you ever say a table *is* length?

The second difficulty is related to, but not caused by, the official treatment of optics in manuals and textbooks. Light as a classical electromagnetic field, summarized by Maxwell's equations, is of course a correct physical description. But Maxwell's equations do not help to explain the phenomenology of light in everyday life, especially to an audience unfamiliar with those equations.

It is also a fact that in high schools and undergraduate education light is taught with the general wave model, paying little attention to its electric and magnetic aspects. Of course the wave model is successful, but it needs a huge investment of teaching energies to master the mathematics of the model. It is justified if it will be used to deal with other subjects, and this can be done at a level of physics education higher than the target of our proposal, which is meant for low secondary schools.

We propose, for the physical system light, the model of a substance[5]. The common language is almost "ready" to use this model of light as a kind of stuff, based on the many ways we already have to speak about light, as we can see in the following examples:

.. filtering light
.. source of light
.. receives light from
.. the analysis of the light of the sun
.. the synthesis of colours
.. white light is a mixture
.. pure red light
.. full of light

The experimental support of the model comes from well-known photochemical reactions. All that is needed is a symbol for light, and objections cannot arise to the Greek letter γ:

ozone production in the atmosphere $\mathbf{2O_2 + \gamma_{150-200\ nm} \rightarrow O + O}$

photosynthesis $\mathbf{6CO_2 + 6H_2O + 48\gamma \rightarrow C_6H_{12}O_6 + 6O}$

photographic film $\mathbf{Ag\ Br + \gamma \rightarrow Ag + Br}$

The new feature is the absence of light from the products of the reaction: the property of being created and annihilated. This is a most extraordinary property for a substance, and it took a long time to be acknowledged. It is interesting to observe that it has been possible since the experimental evidence of the creation and annihilation reactions between elementary particles.

Here we are, to the core of any contemporary substance model, with the notion of the smallest portion of it that maintains the same so-called qualities of the substance. It seems that the concept of photon is at hand to answer this expectation, but a little care is needed[6].

Once the wall of the non-material nature of light has been broken, the properties of this physical system show it is very simple, maybe the simplest substance of them all![7]

velocity: only one possible value
rest energy: zero
energy and momentum: proportional to each other
chemical potential: absolute zero (black body radiation)
angular momentum: one unit

In conclusion, we have the elements to revive the ancient geometrical model for light, the ray of the optics. We can dress it physically at the microscopic level: the photon is completely described with one vector and one scalar. But we can also introduce the "Ray Density", a vector field describing the behavior of light at the macroscopic level.

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[1] C.Agnes The Idea of Substance in Physics Education
[2] http://www.physikdidaktik.uni-karlsruhe.de
[3] http://www.job-stiftung.de
[4] F.Herrmann, G.Job. "The Chemical Potential – a quantity in search of recognition". Eur.J.Phys. 27 (2006) 353-371
[5] Unfortunately in English,French, Spanish and Italian, the equivalent of the German word Stoff is unavailable in this meaning.
[6] P.Würfel. Die Menge von Licht Konzepte eines zeitgemässen Physik – Unterricht, Heft 2, Schroedel 1978
[7] "..as simple as possibile, but not simpler" attributed to A. Einstein