Pressure and Temperature of One Atom

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Abstract-The relation between pressure, volume and temperature of an ideal gas is PV=CT. Based on this relation the pressure and temperature of one atom can be calculated, leading to interesting physical considerations at atomic level regarding the conversion of radiation to heat energy.

1. Introduction

This theoretical investigation started at the moment the author picked up a hot piece of metal that had lain in the sun during a few hours, by asking himself the question: how can electro-magnetic radiation, fundamentally considered, cause raising the temperature of matter?
It turned out that asking that same question in case of a gas, held together in a constant volume, leads to a beginning of understanding the phenomenon.

2. The ideal gas law

The relation PV=CT, well known as the ideal gas law, expresses the energy of such a gas, held together in the volume V under pressure P and absolute temperature T.
The constant C equals nN_Ak_B, with:

n	amount of substance of gas	[mol]	
N_A	Avogadro's *constant*	[mol^{-1}]	(Avogadro's *number* is dimensionless.)
k_B	Boltzmann constant	[J/K]	

From now on only the gas constant $R=N_Ak_B = 6.0*10^{23}*1.38*10^{-23} = 8.3$ [J/Kmol] will be used.
So, the ideal gas law expresses the energy of gas, in the volume V, in two ways: E=PV and E=nRT.

Starting with the arbitrary volume of 1 m^3 and the arbitrary pressure of 1 bar, being 10^5 N/m^2, the energy of that gas is 10^5 Joule. For T=300 K, n=40 [mol].

In this article only atoms are considered, given the title of the article.

The amount n of substance of gas, expressed in mol, equals N/N_A, with N the total amount of atoms. In the chosen example $N=2.4*10^{25}$.

Taking N=1 and P and T the same as in the example, $n=1.7*10^{-24}$ and $V=4*10^{-26}$ m^3.
This has to be compared to the volume of the atom, because one of the conditions of ideal gas is: "The average distance between molecules is much larger than the size of the molecules." So in case of one atom the volume V has to be much larger than the volume of one atom.
Reference [1] shows what the minimum volume of an H-atom is: $(4/3)*\pi*a_0^3$, with a_0 the so-called Bohr's radius ($5.3*10^{-11}$).
Higher atom numbers Z have linear proportional smaller radii. (a_0/Z)
The related volume is $6.2*10^{-31}$ m^3, being 66000 times less than V.

Intermediate conclusion:
An atom enclosed in a volume of $4*10^{-26}$ m^3 causes a pressure of 1 bar at a temperature of 300 K.
The atom itself does not have a temperature, because the space between nucleus and orbiting electrons is vacuum. It is the surrounding of this volume that determines the temperature.
And this temperature determines the pressure inside the volume.

3. Theory behind the phenomenon 'temperature'

The generally accepted theory behind the phenomenon 'temperature' is that atoms / molecules make random movements and random elastic collisions with each other and with the boundary of the volume that holds them together. The higher the mean velocity of these particles is, the higher the pressure of the gas is, but, as has been concluded in the previous chapter, the temperature of the gas will not increase if the temperature of the surrounding does not "allow" it to do so.
As a result the phenomenon described in the Introduction: a piece of metal that had lain in the sun during a few hours and got hot, has to be interpreted as: and got hot, just like its surroundings got hot. In this example without increasing pressure in a closed volume.
So the original question now concentrates on the question how EM-radiation can cause atoms / molecules in whatever circumstances moving faster?

There is no possibility that EM-radiation *directly* influences this *linear* velocity of the particles. The only possibility is that EM-radiation increases the orbital velocity of the electron orbiting the nucleus of the atom: opposite of the fact that EM-radiation is created, by means of a photon, when such an electron is forced by external influences to jump from an inner to an outer orbit. See [1]. This reference also shows that the smaller the radius of such an orbit is, the higher the orbital velocity has to be, in order to fulfil the requirement that centripetal and centrifugal force, applied to the electron, are in balance. Reference [2] shows that this higher orbital velocity represents a higher energy state of the atom, in combat with the generally accepted opinion that the atomic energy decreases with smaller orbit radius.
That reference also shows why this opinion is fundamentally wrong.

Suppose, for the moment being, that the external EM-radiation indeed causes orbiting electrons to jump to a lower orbit, thus to a higher orbital velocity. Then first of all the question: how can this higher orbital velocity cause higher linear velocities of the atom, has to be answered.

To explain what might happen, a comparison with the behaviour of a spinning billiard ball on a billiard table, colliding the inner edge of this table, might help.
In such a situation the ball reflects with more energy in its straightforward direction than it would do without spinning.
An atom with an orbiting electron looks, physically seen, like a spinning billiard ball. Assuming the same kind of conversion of energy, atoms with higher orbiting electrons will, as a result of collisions with each other and/or with the boundary of the volume holding them together, develop higher linear velocities.

To gain confidence in such a model it has at least to fulfil the criterion that the linear velocity of the considered H-atom has to be much smaller than the orbital velocity of its electron.
The kinetic energy $\frac{1}{2}mv^2$ of one H-atom, with m the mass of the atom and v its linear velocity, must be equal to PV. With $V = 4*10^{-26}$ m^3 and $P=10^5$ N/m^2, $PV = 4*10^{-21}$ J.
N.B. The intrinsic energy of the atom, due to its orbiting electron, must not be added to this kinetic energy.
The mass of an $^1_1$H-atom is the sum of the mass of a proton and an electron. The last one is negligible w.r.t. the first one, so $m=1.7*10^{-27}$ kg and $v= 2200$ m/s.
For comparison: the orbital velocity of the electron at radius a_0 is $2*10^6$ m/s!

In case a $^2_1$H-atom would be considered, the mass of the atom would be twice as large and thus its linear velocity $\sqrt{2}$ times as small, not having any influence on the principle working of the chosen model.

So it is assumed that this approach explains sufficiently the increasing linear velocity of atoms with increasing orbital velocities of the electrons of the atom.

4. From EM-radiation to orbital velocity

In chapter 3 it has been mentioned that a photon is generated in an atom when an external force compels an orbiting electron to jump from an inner to an outer orbit. Reference [1] describes this in detail and also shows that actually not the kinetic but the magnetic energy of the atom is converted into the energy of the emitted photon. The orbiting electron creates this magnetic energy, due to the fact that such an electron represents a circular shaped electric current.
So such a model describes the phenomenon: from orbital velocity to EM-radiation, leaving yet unanswered the question what kind of external force compels the electron to jump from an inner to an outer orbit and thus how this in more detail happens.

In this article the opposite situation is under consideration, not leaving unanswered the question what kind of external force causes the electron to jump from an outer to an inner orbit: the external EM-radiation is the only present one. It has been argued that the temperature of the surroundings of the matter under consideration is as important as well. So one might argue that the temperature of the surroundings is the external force. Agreed, but the same question has then to be asked from the point of view of the matter of the surroundings. In fact from both.

A photon, representing EM-radiation, entering an atom has an electric and a magnetic field.
Both fields can, in principle, directly and/or indirectly influence the trajectory of the electron.
A curious phenomenon, from this point of view, is that a *perfect* black object will be heated by means of *all* EM energy received by this object, while a 'perfect' white object will not be heated 'at all' in such a situation. In fact a white object does not receive this EM radiation. Or it does, but transforms it immediately again to photons, thus to EM radiation. Of the same frequency!
The phenomenon resembles rather much EM-radiation entering for example a radio-receiver.
If the receiver is not tuned to the frequency of the radiation it doesn't absorb it.
Infrared radiation, for example, is much more 'tuned' to heat matter than ultraviolet radiation is.
Anyway, this part of the model cannot be explained in more detail, at least not by the author.

Remark about the photoelectric effect:
The photoelectric effect is a phenomenon that creates free electrons when photons enter atoms.
Indeed, fundamentally different from heating by EM-radiation and besides that only applicable to specific matter. Quote from Wikipedia: "Instead, electrons are dislodged only by the impingement of photons when those photons reach or exceed a threshold frequency (energy)."
Is the energy of the photon critical, or its frequency? Formulated in an other way: is the (specific) matter tuned to EM-energy or to EM-frequency? Given the fact that its energy equals h*frequency the distinction cannot be made. The author expects that it is eventually tuned to frequency. So however great the photon's energy might be, it will not dislodge valence electrons.

Conclusion

Although it has not been successful to explain in deep detail the reason that EM-radiation heats matter, it has been explained that such a heating will be caused by forcing orbiting electrons around the nuclei in the atoms from an outer to an inner orbit. The resulting higher orbital velocity causes, during collisions, higher random linear velocities of the atoms. It is a generally accepted that such higher velocities of atoms represent higher temperatures.

References

[1] Why a Photon is not a Particle http://vixra.org/abs/1505.0225

[2] Conventional Definition of Potential Energy is Controversial http://vixra.org/abs/1709.0440