How Electro Magnetic radiation raises temperature

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Abstract- 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, considered at atomic level, cause raising the temperature of matter? The answer to that question has been found. However another question popped up (again): why are the orbits of electrons in an atom quantified? Only exactly orbiting at radii proportional to the square of integers is suspicious unnatural. Indeed, unless we define such a behaviour as natural of course.

1. Introduction

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.
It turned out that asking the question, formulated in the abstract, 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}]
k_B	Boltzmann constant	[J/K]

The so-called gas constant R is defined as $N_Ak_B = 6.0{\cdot}10^{23} \cdot 1.38{\cdot}10^{-23} = 8.3$ [$JK^{-1}mol^{-1}$].
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.

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 $N=2.4{\cdot}10^{25}$.

Taking N=1 and P and T the same as in the example, $n=1.7{\cdot}10^{-24}$ mol and $V=4{\cdot}10^{-26}$ 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 ($5.3{\cdot}10^{-11}$).
Higher atom numbers Z have proportional smaller radii (a_0/Z).
The related volume of an H-atom is $6.2{\cdot}10^{-31}$ m^3, being 66000 times less than V.

Intermediate conclusion:
An atom enclosed in a volume of $4{\cdot}10^{-26}$ 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 surroundings 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 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 the atoms the higher the pressure of the gas, but, as has been concluded in chapter 2, the temperature of the gas will not increase if the temperature of the surroundings does not "allow" it to do so.
As a result the phenomenon: a piece of metal that had lain in the sun during a few hours and got hot, has to be interpreted as: ...... and got warmer, just like its surroundings got warmer.
At this point the ideal gas situation will be left in order to concentrate on the question how EM radiation can cause atoms to move faster, in whatever circumstances?

There is no possibility that EM radiation *directly* influences the velocity of the atoms. 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 radii.
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 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 forward direction than it would do without spinning. On the opposite: if in the same situation the spinning of the ball is reversed, the reflection will cause a loss of kinetic energy in its forward direction. In both cases the spinning energy of the ball will decrease.
The same happens in case the reflection is w.r.t. another ball, in stead of the edge of the table.

An atom with its orbiting electrons looks, physically seen, like a spinning billiard ball.
Assuming the same kind of conversion of energy during a collision, atoms with faster orbiting electrons will thus on the average develop higher velocities. It has to be concluded too that mutual interactions will also lead to atoms with lower velocity, because electrons can also jump to higher orbits during a collision.

Such a model has at least to fulfil the criterion that the velocity of the atom has to be much smaller than the orbital velocity of its electron.
The kinetic energy $\frac{1}{2}mv^2$ of one, for example, H-atom, with m the mass of the atom and v its velocity, must be equal to PV. With $V = 4\cdot10^{-26}$ m^3 and $P=10^5$ N/m^2, $PV = 4\cdot10^{-21}$ J.
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 $m=1.7\cdot10^{-27}$ kg and v= 2200 m/s. The orbital velocity of the electron at radius a_0 is $2.2\cdot10^6$ m/s! Such a kind of difference is also found in case of a $^2_1$H-atom.

It is therefore assumed that this model satisfactorily explains the increasing velocity of atoms, when orbital velocities of the electrons increase, *still assuming that the external EM radiation causes orbiting electrons to jump to a lower orbit with a higher orbital velocity.*

4. From EM radiation to orbital velocity

In chapter 3 it has been mentioned that a photon is generated in an atom when external forces compel 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.

Remark:

> Based on the spinning billiard ball model, it is likely that a neighbour atom can, during collision, function as an external force too. Not only to compel an electron from an inner to an outer orbit, but also contrariwise.

The situation to be investigated here is EM radiation as external force.
A curious phenomenon, from this point of view, is that a perfect black object will be heated by means of external EM radiation, of whatever frequency, received by this object.
A perfect white object, on the opposite, will not be heated at all by EM radiation. In fact a perfect white object does not receive external EM radiation. It just reflects it!
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.

EM radiation is called as such because it has an electric and a magnetic field.
Orbiting electrons create a magnetic field. This field changes when the related electron jumps to another orbit, whether it is to a more inner or more outer orbit.
Logically arguing one can state that thus an external magnetic field, entering an atom, must be able to change the radius of the orbiting electron.
It is like the internal magnetic field in a coil, created by the electric current through this coil, that is disturbed by an external magnetic field, causing a change in the electric current.

Chapter 2 closes with the intermediate conclusion that the temperature of the surroundings of the matter under consideration is as important as well. The here proposed model is not in combat with this conclusion: it is generally accepted that faster moving atoms in the surroundings *directly* activate the atoms of the matter to higher velocities.

5. Bohr's radii and the phenomenon 'temperature'

Bohr's atomic model prescribes that electrons orbit the atomic nucleus at discrete distances, mathematically presented by $r_n = n^2 a_0/Z$, with n an integer and Z the atomic number. The radius a_0 is the so-called Bohr's radius, the smallest in the hydrogen atom. Orbit number n is supposed to be able to contain a maximum of $2(n^2)$ electrons.
The idea behind the quantitative presentation of the discrete radii is based on the assumption, <u>for whatever reason</u>, that the angular momentum of the electron mvr_n is quantized as $nh/2\pi$.

In chapter 4 the following statement has been written:

"Logically arguing one can state that thus an external magnetic field, entering an atom, must be able to change the radius of the orbiting electron and as a result its orbiting velocity."

Given this argumentation and obeying Bohr's discrete radii strictly, the consequence in first instance is that the temperature of matter cannot change with arbitrarily small increments. The example shown in chapter 3 with one atom emphasizes this conclusion. This example shows that the orbital velocity of the electron is 1000 times larger than the velocity of the atom.

In Bohr's atomic model the electron can only jump from one orbit to another orbit in the range $r_n=n^2\ a_0/Z$. It is seductive to argue now that the velocity of the atom can also only change abruptly and thus the temperature. But that conclusion is only correct in case of one or a few atoms/elements in a very small volume under consideration.

In a real ideal gas the number of elements in a normal volume is enormous. And such a gas contains another property, shown in reference [3]: the Maxwell-Boltzmann distribution of atomic velocities (v), expressed by: $f(v) = 4\pi v^2(m/2\pi k_BT)^{3/2}\exp(-½mv^2/k_BT)$.

Graphs of f(v) are shown in the appendix.

Three possible kind-of-mean values can be calculated from this distribution: the most probable: $v_p = \sqrt{2k_BT/m}$, the mean: $v_{mean} = \sqrt{8k_BT/\pi m}$ and the root-mean-square: $v_{rms} = \sqrt{3k_BT/m}$. The total kinetic energy of the gas its N elements are respectively: $N\cdot½mv_p^2 = Nk_BT$, $N\cdot½mv_{mean}^2 \sim 1.3Nk_BT$ and $N\cdot½mv_{rms}^2 = 1.5Nk_BT$. The ideal gas law shows: $E = Nk_BT$, so the most probable velocity is the most fitting too.

Figure 1 in the appendix shows that the heavy element Xe has a low v_p (with a high probability) opposite to the v_p of the light element He. In the electron configuration of Xe the outer electrons orbit at a higher orbit than in the one of He, both considered at the same temperature of the gas. So the outer electrons of Xe orbit wit a lower orbital velocity than the outer electrons of He. As shown in chapter 3 the atomic speed v_p of Xe will thus be lower than of He. So the theory presented in chapter 4 is supported by the theory behind the Maxwell-Boltzmann distribution.

But the most important conclusion is that the temperature of a large gathering of elements in an ideal gas can, thanks to the Maxwell-Boltzmann distribution of the velocities of the elements, be changed gradually, notwithstanding the quantized character of Bohr's atomic model.

However the pressing question, why are orbits quantified, lingers. Especially due to this extremely unnatural behaviour. Indeed, unless we define such a behaviour as natural of course.

Conclusion

1 Just like an orbiting electron in an atom, jumping to an outer orbit, creates EM radiation, external EM radiation will, by means of its magnetic field, be able to force electrons to smaller respectively larger orbits, resulting in higher resp. lower orbital velocities.

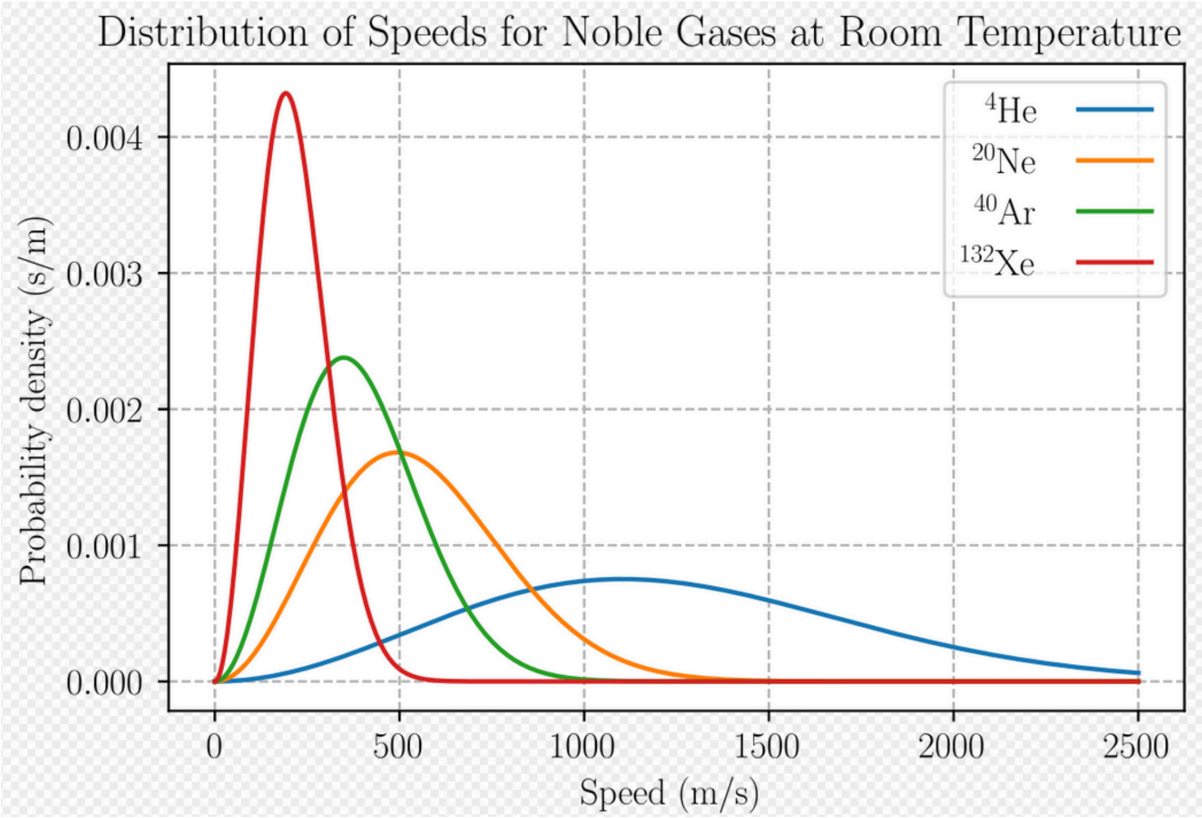
2 The intrinsic energy level of an atom increases, resp. decreases, as a result of an increasing, respectively decreasing orbital velocity of the electron.
N.B. The mainstream opinion is the opposite, due to a fundamental misconception of the phenomenon 'potential energy', especially in orbiting configurations. See [2].

3 Higher orbital velocities cause higher velocities of the atoms, due to mutual collisions and 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
[3] https://en.wikipedia.org/wiki/Maxwell-Boltzmann_distribution

Appendix



$$f_v = (m/2\pi k_B T)^{3/2} 4\pi v^2 / \exp(½ m v^2 / k_B T)$$

Figure 1 *Maxwell-Boltzmann distribution*